A Solution in the Digitalization Era and Information System Resilience to cope with Supply Chain Disruption

by

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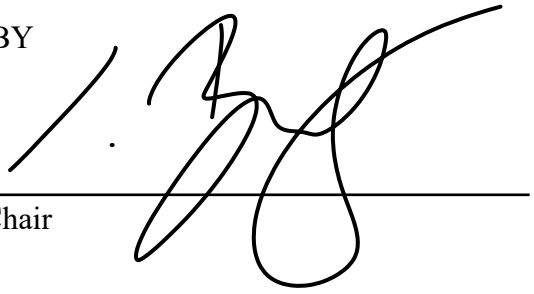

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1. Abstract

Artificial Intelligence (AI) is getting increased attention from various manufacturing industries, including fashion and textiles, due to its ability to work effectively, similar to human intelligence. This Systematic Literature Review (SLR) paper proposes potential future research directions that emphasize the impacts of AI on supply chain integration (SCI) efforts through information sharing (IS). A structured literature review of articles in the 2010-2021 period, addressing geographic location, journals, publishers, authors, research designs, and applied theories, has been used to prepare this paper. The additional discussion of AI incorporates information from the structured review to conclude the findings and suggest future research directions. The authors have used the Scopus database and prestigious peer-reviewed journals to search for relevant papers using suitable keywords. This paper concluded that the Asian region has the highest concentration of publications, and that AI adoption positively affects the IS-SCI relationship. Empirical quantitative research design and resource-based view theory are prominent among the reviewed publications. This SLR paper is limited by not having the impacts of AI discussed at the subset level.

1.1. Artificial Intelligence (AI)

The critical aspects of risk management in global supply chains, with a specific focus on vulnerabilities within shipping and logistics. The interconnected nature of today's supply chains exposes them to various risks, ranging from natural disasters and geopolitical tensions to operational challenges and cybersecurity threats. The paper outlines a comprehensive framework for risk identification, assessment, and mitigation, emphasizing the importance of proactive strategies in addressing potential disruptions. Diversification of suppliers and transportation routes, technological investments, insurance coverage, and enhanced collaboration are highlighted as key mitigation measures. Through case studies, the paper examines successful risk management practices and draws insights from failures. Additionally, it delves into emerging trends, such as technological advancements and climate change adaptation, providing a forward-looking perspective on evolving risks. The conclusion underscores the dynamic nature of global supply chain risks and advocates for continuous improvement in risk management practices to ensure resilience and sustainability.

1.2. Technology and Infrastructure

Artificial intelligence (AI) as a technology has the potential to interpret and evaluate alternatives where multidimensional data is involved in dynamic situations such as supply chain disruption. This study aims to explore the role of resilient information systems (RIS) in minimizing the risk magnitude in disruption situations in supply chain operations. The study is conducted in the qualitative mode through semi-structured interview schedule for professionals of supply chains. Thematic analysis has been used to create emerging categories. The findings of this work present critical gaps in current information systems and demonstrate how AI-oriented systems can facilitate the ecosystem of disrupted supply chains to save costs and drive efficiency on multiple parameters. The study also proposes a conceptual framework where organizational values and architectural components can be viewed jointly for quick and adequate business decisions in the complex and uncertain disruptions. The framework presents the relationships among AI, information systems and supply chain disruption. Installing appropriate AI-based data acquisition, processing and self-training capabilities along with

information system infrastructure can help organizations lessen the impact of supply chain disruption while aligning the transportation network and ensuring geographically suitable supply chains and cybersecurity. Finally, the implications for theory and practice with the limitations and scope for future research are described.

1.3. Digital and Software

Artificial intelligent (AI) is becoming a more effective digital domain promised to facilitate immediate access to information and effective decision making in ever-increasing business environments. The researchers understand the extensive use of artificial intelligence among firms as an essential and necessary tool for shaping the future of supply chain 4.0 industry. This chapter discusses the role of AI applications for the success of a supply chain in the big data era. From a holistic perspective, today, manufacturers, particularly those with global operations and presence, are under enormous pressure to keep up with the continuous growth of disruptive innovative procurement models. This has open doors for the firms to aggressively seek out big data management capabilities to improve operational efficiencies and to innovate the process. This chapter provides a better understanding related to the application of data analytics in the supply chain context. The research issues are classified into different categories, including big data management and machine learning, a business case for the supply chain and innovation in supply using data. This study also present machine learning data analysis steps.

It is wide known that the world has been moving towards a digital future over the years, and industry technologies are considered to be the way of the future. One of the most prominent of these technologies (including Block Chain, Internet of Things, Cloud Computing, Big Data, etc.) is Artificial Intelligence (AI), was introduced to develop and create “thinking machines” that are capable of mimicking, learning, and replacing human intelligence. However, its widespread acceptance as a decision-aid tool, AI has seen limited application in supply chain management (SCM). The purpose of this work is to identify the contributions of AI to SCM through a brief review of the existing literature. Besides, this paper reviews the past record of success in AI applications to SCM and identifies the most subfields of SCM in which to apply AI.

In an increasingly interconnected global economy, supply chains are vulnerable to a myriad of disruptions, including geopolitical conflicts, natural disasters, technological failures, and unforeseen crises. These disruptions can cause significant delays, increased costs, and loss of revenue. The resilience and continuity of supply chains are often determined by how effectively organizations manage these disturbances. To proactively address these challenges, this study examines the integration of Artificial Intelligence (AI) into SAP Supply Chain Management, specifically SAP Transportation Management (SAP TM). By leveraging AI’s advanced capabilities—such as predictive analytics, machine learning, and real-time data processing—SAP TM can enhance supply chain visibility, responsiveness, and decision-making processes, reducing risks and improving operational efficiency**.**

1.4. Transforming Supply Chain Management

This paper explores the emerging role of AI in transforming supply chain management, with a focus on how its integration into SAP TM can provide actionable insights for better decision-making and optimized logistics. AI-driven systems offer

significant advantages, including improved demand forecasting, reduced lead times, and enhanced on time delivery performance. According to McKinsey & Company, AI applications can reduce supply chain costs by up to 20% and improve inventory turnover by as much as 25%. These capabilities are especially critical in the face of recent global disruptions, such as natural disasters, pandemics, and geopolitical tensions, which have stressed the vulnerability of traditional supply chain models.

The use of AI to model and simulate real-world disruptions, both natural and human-made, has the potential to revolutionize supply chain management by providing organizations with more accurate and timely forecasts. In scenarios ranging from the collapse of critical infrastructure, like the Baltimore Bridge, to the impact of ongoing geopolitical conflicts in the Middle East and EU, AI's predictive power can allow companies to adapt more swiftly to changing conditions. By combining real-world data with synthetic models, AI systems can simulate a variety of disruption scenarios, offering unprecedented precision in supply chain planning and risk mitigation.

1.5. SAP in Transportation

This paper investigates how AI technologies integrated into SAP TM can not only help companies anticipate and react to disruptions but also enable them to optimize supply chain operations and move from a reactive to a proactive, precision-driven approach.

Explores the transformative impact of advanced artificial intelligence (AI) techniques on real-time inventory optimization within dynamic supply chains. The introduction highlights the significance of inventory optimization and the limitations of traditional methods, setting the stage for the integration of AI. A comprehensive literature review summarizes existing research on AI applications in supply chain management, identifying key gaps and areas for further exploration. The paper then delves into various AI techniques, including machine learning, deep learning, and reinforcement learning, detailing their application in predicting demand and supply, and the benefits and challenges of implementing these technologies in real-time inventory systems. The analysis of AI-driven inventory optimization reveals significant improvements in supply chain responsiveness, efficiency, and risk management, alongside discussions on scalability and adaptability across different industries and organizational sizes. The conclusion synthesizes key findings and provides recommendations for future research and practical implementation, emphasizing the need for enhanced data quality, model transparency, and ethical considerations. By harnessing AI, businesses can achieve more efficient, responsive, and resilient supply chains, positioning themselves competitively in an increasingly complex global market.

1.6. Logistic Sector in Organization

The impact of using AI in logistics sector and examines the opportunities and challenges of using AI in logistics sector. Besides, it suggests solutions for improving AI use in the logistics sector in organization. The main objective of this paper is to investigate the impact of using AI in logistics sector. The specific objectives are to identify the opportunities for using AI in the logistics sector in organization, identify the issues surrounding using AI in the logistics sector in organization,

and recommend possible solutions to improve the use of AI in the logistics sector in organization. The study used both primary and secondary data based on mixed methods: quantitative and qualitative. The quantitative approach via a questionnaire tool to collect data from many respondents (Akerkar, R. 2019a). The qualitative method has been observed using interviews and web articles to accumulate further information from people's opinions and thoughts. The outcomes indicated some advantages of AI: improving efficiency and reducing the challenges currently facing the logistics sector, diversifying the income sources, and enhancing organization's economy. Findings revealed that the most significant AI challenges are unemployment, a long time and the high cost for implementation, lack of awareness of AI potentials, and requiring training with new skills. The findings came up with solutions related to educating students, spreading awareness, and training employees. The study has limitations such as insufficient information on the research subject, difficulties finding respondents who have enough experience to answer the questions efficiently, and time constraints

1.7. Application Model

This systematic review investigates the applications of artificial intelligence (AI) in supply chain demand forecasting, focusing on the performance of AI-driven models compared to traditional forecasting techniques. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a comprehensive search was conducted, yielding a final selection of 65 peer-reviewed articles for in-depth analysis. The review explores the advantages of AI models, particularly machine learning (ML) and deep learning (DL), in improving forecasting accuracy, scalability, and responsiveness to real-time data. It also examines AI's applications across various industries, including retail, manufacturing, e-commerce, and logistics, where AI-driven models have significantly enhanced inventory management, production scheduling, and operational efficiency. However, the review highlights challenges related to data quality, model complexity, and high implementation costs, which limit the broader adoption of AI in demand forecasting. This study provides valuable insights into the current state of AI applications in supply chain management and suggests areas for future research, particularly in improving data management and developing more interpretable AI models to facilitate wider implementation.

2. Introduction

The Covid-19 pandemic will permanently change the way the global supply chain operates. Unconventional fluctuation of commodity prices, disrupted supply networks, fragmented logistics systems, and shifting consumer demands are common types of risks that have occurred during the pandemic and will continue to affect business transactions even in the post-pandemic world. Current supply chain models may not be as effective in mitigating risks compared to the pre-covid period, which urges researchers to quickly identify more suitable models for supply chain collaboration. Before the pandemic, firms along the supply chain practiced integrating themselves with their partners up and down the supply chains to improve supply chain and firm performance as well as to mitigate risks. Supply chain integration (SCI) has been proven to be positively correlated with firm performance (FP) at various levels, including supply chain performance, supply chain resilience, operational performance, financial performance, and risk management (Shen, Z. M., & Sun, Y, 2023).

A higher level of integration will lead to higher firm performance. Among the factors that contributed to the success of SCI efforts, information sharing (IS) plays an enormous role in any integration efforts and helps increase the depth of integration among supply chain partners. However, post Covid-19 environment requires businesses to revisit their supply chain strategy, especially how to efficiently capture the full potential of IS, to ensure productivity and efficiency. We have witnessed a magnificent development of information technology (IT) since the dawn of the 21st century. Within the two decades, numerous IT terms have been made available and have been accepted globally, such as Internet of Things (IoT), Big Data, Data Analytics, Artificial Intelligence (AI), and Industry 4.0, to name a few. In just over 20 years, we have come a long way in digitalizing our transactions in all industries, which implies a paradigm shift for all businesses (Tan, Y., & Zhang, X, 2018).

In this new era, firms that have the capability to adapt and use suitable technologies that harness the power of data to be more competitive, resilient, responsive, and manage risk well, will flourish. Since the success of SCI is strongly correlated with the extent to which information is shared among supply chain entities, the adoption of advanced information systems and software to manage and make sense of massive, complicated real-time data is of utmost. In fact, pointed out that data creation will only increase faster and that companies will emphasize analyzing this vast amount of data to coordinate better with their partners and leapfrog their competitors (Russell, S., & Norvig, P., 2020).

However, the discussion of advanced analysis and autonomous tools like AI in the SCI domain is limited, and the impact of this key element in this new digital era on information sharing and supply chain integration (IS-SCI) relationship has not been clearly discussed. Hence, the objectives of this research are to combine the systematic review of the past articles in the IS and SCI field to identify the role of IT adoption and to propose future research directions in which AI is a key element. The paper will review the articles published from 2010 to 2021 in the Scopus database and other indexed journals. The paper will explicitly address the following research questions (RQs): Over the past decade, supply chain management and information technology management have attracted much attention from practitioners and researchers. As can be deduced from information technology, companies have a strong tendency towards integration; integration is therefore considered an effective technique in the supply chain by sharing effective information to improve the performance of the sensitive supply chain (Noja, G.G., 2018). Thus, the growing interest in supply chain management has been driven by competitive pressure and has led to its eventual promotion to become an essential part of corporate operations and strategy. On the other hand, due to the high speed of changes in the market and customers, companies need to continuously improve their supply chain management systems to provide the right product to the right customer and at the right time. The integration of new technologies in the supply chain has made it possible to improve the exchange of information and facilitate the monitoring of physical goods throughout the supply chain. Information technology developments play an essential role in increasing the planning, implementation and flow control, and storage of goods, services, and information from the point of origin to the point of consumption to increase customer satisfaction. The Internet of Things (IoT) is one of the latest developments in information technology and a new revolution in this field, which has provided a paradigm shift in various fields, including supply chain management. When artificial intelligence (AI) is added to IoT, it means that devices can analyze data, make decisions, and act on these data without human intervention (Regulatory Compliance Review, 2019).

The complete combination of the IoT with artificial intelligence, known as AIoT, allows companies to take advantage of both at the same time. This technology's capabilities, such as transparency, agility, and adaptability to the supply chain, offer tremendous opportunities to address supply chain management challenges more effectively. As smarter, more technology-driven, and more intertwined supply chains grow, research into the IoT and its innovative applications in supply chain management is growing faster. There are several devices in IoT and artificial intelligence in the supply chain, such as autonomous and self-driving vehicles, warning sensors, and customer information. However, the most interesting use of the IoT and artificial intelligence is to embed intelligent sensors in a product's packaging and analyze their data to allow customers to track their goods across the supply chain until the final delivery stage. Of course, due to the presence of Internet and network technology and analyses based on them, and the complexity of using these technologies, it can be realized that the simultaneous presence of these technologies can bring challenges (Petrick, I., McCreary, F., 2019)

Disasters are one of the key contributors to supply chain disruption. For instance, General Motors was not able to run its plants in the U.S. due to its inability to source auto components from Japan following a tsunami in 2011, it incurred millions of dollars in losses. In another example, the eruption of the Bardarbunga volcano in Iceland had a considerable impact on air commerce and resulted in huge revenue losses of billions of dollars. The worldwide supply chains are being disrupted due to Covid- 19, where suppliers, distributors and manufactures must change their strategies frequently and hence they need more information from enterprise resource planning (ERP), customer relationship management (CRM), and electronic data interchange. Existing literature lack in exploring information systems as an enabler for supply chain disruptions caused due to diverse events including Covid-19 due to traditional information systems. Hence, traditional information systems may not have sufficient analytical power to make supply chains resilient due to their limited risk prediction and guidance towards alternatives. A system is defined as resilient if it quickly and efficiently guards its acute capabilities from a disruption triggered by contrary events and circumstances. Due to the availability of large data, organizations are adopting AI-based technologies to address supply chain disruptions despite numerous challenges. It may therefore be interesting to know how organizations are employing AI to minimize supply chain disruptions (Liu, H., Wei, S., Ke, W., Wei, K.K. and Hua, Z., 2016).

Artificial intelligence (AI) is the intelligence demonstrated by computers and machines to perform tasks that require typical human intervention. RIS can contribute significantly to the return to normal or transform the operations of a business due to a disruption as soon as possible. The literature indicates the strategies around information systems and their alignment to business. However, the literature lacks to identify the capabilities of resilient information systems that can facilitate the response to global disruptions.

The digital transformation has driven hyper-connected organizations. An example of this is Industry 4.0, which represents a concept of intelligent manufacturing networks in which machines and products interact with each other without human control. In this context, the new Information and Communication Technologies (ICT) allow obtaining precise data in real time. Since SCM requires the comprehension of complex and interrelated decision-making processes, their integration with the above

technologies can improve their efficiency, sustainability, flexibility, agility, robustness and resilience. The supply chain (SC) operations planning is crucial for this. However, the increasing uncertainty and the dynamic environment make the synchronized planning necessary. Synchronized planning describes a state in which a constant flow of data from the supply network enables organizations to accurately plan production to match the actual demand. But this new paradigm of SC planning will require transforming data, facilitating real-time decision making using online data, automating decision making and making it smarter, not only for pre-programmed decisions but also with some learning capability. These necessary capabilities can be achieved using techniques that fall within the broad spectrum of AI (M. Gupta and A. Kohli, 2016).

In general, the application of AI techniques to not only analyze data or automate decision-making but also to optimize the whole supply chain is highly relevant and an enabler for a supply chain's digital transformation. Nonetheless, the question on what exactly AI is, and which methods do belong to the set of AI techniques remains and has not been answered by scientific literature yet. Instead, the term AI is viewed and defined from different angles focusing e.g. on "agents that receive percepts from the environment and perform actions" or on "computational systems that perform tasks commonly viewed as requiring intelligence". It can be subsumed, that there is no common definition of what AI is. Moreover, the understanding of "intelligent" has been changing over the years, which is described by the AI effect (Leuschner, R., Rogers, D. S. & Charvet, F. F., 2013).

It describes the circumstance that the notion of AI changes due to advancements in the field as well as the emergence of new technologies. If something a computer can do becomes common enough that most of the people are used to it, it is no longer considered as AI. So, while approaches such as genetic algorithms or expert systems are no longer considered to belong to the set of AI techniques anymore, recent progress in the fields of information processing or sensing technology as well as the shift to a data-driven paradigm have led to major advances in the field of AI such as deep learning, reinforcement learning, robotics, computer vision or natural language processing. Therefore, it is necessary to answer the questions which approaches from the field of AI are applied within the SCM domain as well as which SCM problems or tasks are addressed with AI approaches.

2.1. Background

Organizations with dynamic capabilities can successfully develop, integrate, and reconfigure external and internal proficiencies and capture adequate resilience to deliver long term performance in the era of disruption Firms with RIS are able to sense changing customer demand patterns and customize their schedules and processes to develop the required products via real-time feedback systems through social media, newspapers, and blogs. Information systems can facilitate resilience in supply chains in three ways: (i) day to day supply chain operations (ii) support for network optimization and (iii) identify opportunities to deploy internet of things (IoT), blockchain, and artificial intelligence (AI). Therefore, it is important to have intelligent and flexible information systems that can facilitate discovery, recovery, and redesign of supply chain operations when a disruptive event strike (Li, M., Shao, S., Ye, Q., Xu, G., & Huang, G. Q., 2020).

Successful firms have made a focused and clear idea of value creation, no matter if it is related from high-end products to custom-tailored services or generic and cheap commodities. However, how good your marketing is, no one may buy it if

the product or service cannot be delivered to the consumer at an acceptable cost. Many companies should improve their SCM because their products spend time in inventories at least six months to a year or more. Since the products spend a lot of time in inventory, there is a huge opportunity to increase flexibility, reduce costs, make better deliveries, reduce cycle time, and lead to a more corresponding reduction in inventory. Several companies have improved their supply chain with internal operations. They have recognized that it has a relation to external customers and suppliers and with it they can gain further improvements in operations. SCM to the decision-making process which manages different activities that create beneficial profits to suppliers, retailers, and customers. The efficient planning of activities can be cost-effective for production, sourcing, product development, logistical solution and for all flows that is linked between these activities. It can also be a process which optimizes a set of decisions. The process generates profitable solutions to provide efficient plans for acting on numerous levels while considering all decision-making standpoints. Operations and SCM is critical for everyone to learn, no matter what your major is. They stated that even if your interest is in financial field, convert all values to the currency of your choice and after that, you will understand that it is about currency moving, storing, and exchanging the value. SCM is a vital aspect of making business today. For reader to understand what supply chain is, the research provides a formal definition of supply chain. There is a set of entities and relationships which are called supply network. In this supply network information and material flows are called downstream and upstream. Downstream goes towards the customer and upstream towards to the first supplier (Lahkani, M. J., Wang, S., Urbański, M., & Egorova, M., 2020).

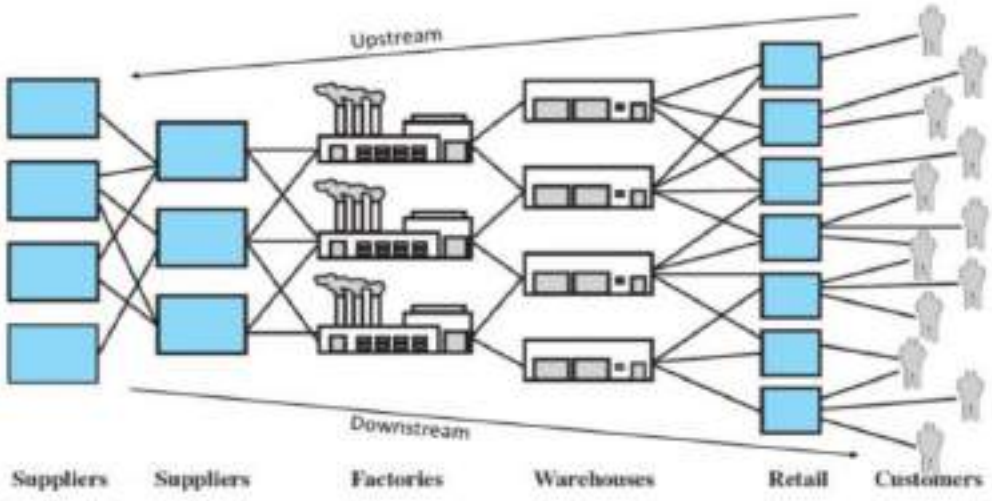

Fig. 1. Supply Chain Overview

According to **Fig. 1**, SCM is a vital aspect of making business today. For reader to understand what supply chain is, the research provides a formal definition of supply chain. There is a set of entities and relationships which are called supply network. In this supply network information and material flows are called downstream and upstream. Downstream goes towards the customer and upstream towards to the first supplier. Downstream from the supplier to the customer consists of materials and requisite information, for example, usage instructions, invoices, inventory levels etc. and it flows until materials are transformed to the final product and sold to the end customer. Upstream from the customer to the first supplier

consists returned materials like defective units, customer returns, recyclables etc. and requisite information like forecasts and demands. With information of forecasts and demands, it is easier for suppliers to plan capacity and inventory level.

Artificial intelligence (AI) has entered almost all spheres of life and is now coming to help improve the perimeter of supply chain management operations. This issue is critical in view of considering how AI will eventually influence the automotive industry, since AI can allow a complete redesign and reformulation of the processes involved in vehicle production for end consumers. AI allows for improving both performance and flexibility in automotive supply chains by applying machine learning algorithms together with predictive analytics. Since this paper focusses on the level of development, the consequences of AI in the European automotive supply chain will be carried out using two qualitative research methods: the document analysis method and the case study method. Some of the key inferences from the paper are that AI exists as a key driver of change in the automotive supply chain throughout Europe. Moreover, the case study on supports the fact that Germany is ahead in terms of using AI in the automobile industry (Iyer, L. S., 2021).

2.2. An Overview of Artificial Intelligence

According to, recent years have shown that artificial intelligence has raised curiosity in SCM area. Since the late 1970's, development of AI has focused on to increase business productivity and ability to understand phenomena and patterns of business. Time-consuming and routine work tasks can be done by robotic process and machine learning as algorithms learn from data and analytics. With these, customer relationship management solutions reveal information for company to serve a customer with better knowledge. According Bughin report for McKinsey Global Institute, companies invested $26-$39 billion on AI in 2016 and high-tech companies used 90 percent of their investment in AI in the research and development (R&D) and deployment sector and 10 percent to AI acquisitions. AI is defined as computers' ability to solve problems independently when they have not been programmed explicitly to do task (McKinsey & Company, 2020). The modern AI platforms have ability to gather information from surroundings. This kind of AI is made to use logicality and probability to choose and act within the highest likelihood of success. AI uses big data sets, objects and sounds to act intelligently and recognize with distinguished precision. AI gives ability for machines to feel environment in the same way as human being. This means completely new way for businesses to interact with their customers and offer them more holistic experiences such as intelligent products, service, and automated processes. AI is the most powerful technology of mankind. In the most basic form, AI exploits data for calculations or algorithms and makes decisions or predictions. This basic form runs into difficulties when calculating algorithms and calculations are more complex or user cannot describe the rules. In modern AI, for example, face recognition from different angles replicates this by using neural networks. Instead that human creates the rules for algorithms and calculations, machines program the rules themselves. As a conclusion, definition of AI can be explained as machines that use big data to compare it to algorithms and calculations and make predictions of what is the most successful result. It can be used in many ways and today's AI technology is capable to do individual, holistic and complex decisions considering many aspects (Albergaria M, Jabbour CJC, 2019).

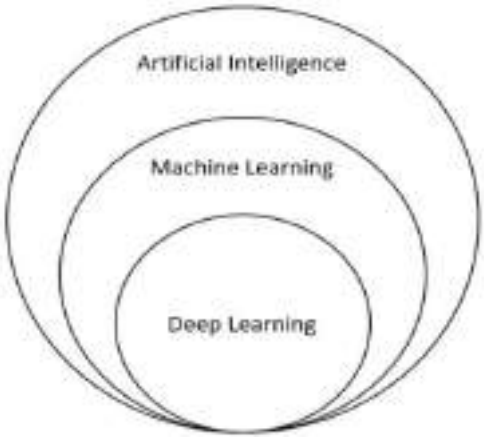

Fig. 2. Basic structure of artificial intelligence.

2.3. An Overview of Artificial Intelligence in Supply Chain Management

According in research "Application of Artificial Intelligence in Automation of Supply Chain Management", they have classified AI helping businesses in four areas. These four value creation areas are vital for gaining competitive advantage. Those areas consist of aspects as: Reach almost 100% accurate forecasts including customer demanding and projection. Gain production with decreasing costs and increase quality with optimizing their R&D. Helping in promotion as defining the price, demography, recognizing target customers and create the right message etc. Provide better experience for customers.

SCM is one of the most competitive areas in business which emphasize the interaction with different sectors, marketing, production, and logistics. In recent years, AI has been proven to be vital aspect for SCM. Modern machines with AI platforms can gather information from available data and use it to choose most probable and logical act with likelihood success. **Figure 3** AI integration to SCM can be divided into three sections. Expert systems contain inventory planning, make-or-buy decision, and supplier selection. Genetic algorithm containing network design and agent-based systems takes over demand planning, forecasting, customer relationship management, negotiations, and order picking. AI is presented as a useful decision tool to help companies connect with customers, suppliers, and network partners to change informational knowledge. Especially areas where forecasting is highly needed such as replenishment, the use of AI is scientifically and practically highly developed. The pioneers of AI have integrated broad spectrum of applications in their everyday businesses, while the competitors invest strongly in new ideas. However, some of the companies does not actively use or do any effort to adopt such technology (Akerkar, R. 2019b).

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According, to make better optimization of processes and assets, AI has made a significant impact in production. AI can organize and design the best solutions of robots and people to make reliable and high-quality production. Also, prevention of downtime for maintenance can be predicted by AI. Automation, robots, and robotic solutions led to advanced technology implementations which can recognize objects and materials with camera-equipped robots and taught to recognize empty shelf place. This dramatically increases the speed of picking objects compared to conventional methods. Describe that

logistics visionaries have talked many years that the role of inventory in modern supply chain will be eliminated or at least affect radically. In the future, inventories would not need any buffer because supply and demand will be in a perfect sync. This means dramatical reduction of logistical costs. Most companies have not honed their technologies and networks to the point where they could abandon one's principles, inventory. For end consumers, inventory might be the most visible action of SCM. The most important operations management's responsibility is inventory management because inventory ties up capital and affects to the delivery of goods to customers. Inventory management affects to many business functions (Kim, H.J., 2017).

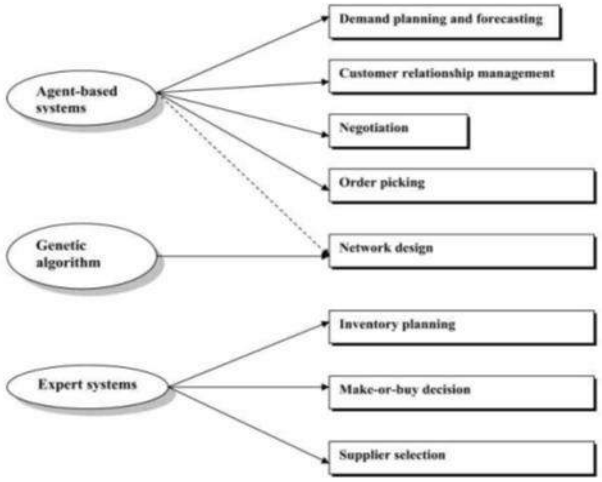


Fig. 3. Link between popular AI tools and their SCM applications areas

2.4. Enterprise Risk Management

It has been a recurring theme on the business organization agenda for many years. A successful risk assessment depends on many different factors. These include clearly defined scope, valid documentation impartiality, the maturity of the risk analysis process, methods and organization of information collection and data security, the competence of the staff involved in the risk analysis, experience, and their role in the organization. It is also necessary to assess the maturity of the organization itself in terms of risk identification and management before starting the risk analysis. One area of risk management refers to an organization's supply chain risk management (SCRM) as the competition is increasingly established among the supply chains of organizations. "The enterprise risk analysis should consider a scope beyond the boundaries of the organization, that is, the enterprise risk analysis of the organization should include the enterprise risk analysis of its supply chain" (Keith, O. R. & Webber, M. D., 2013).

The purpose of this article is to define the scope and nature of challenges in applying artificial intelligence for supply chain risk management. It is supposed that the implementation of artificial intelligence might help to fix most of the current imperfections in SCRM. This article further explores what potential attributes are required to implement AI to business practices for managing risk in a supply chain. SCR decomposition in terms of risk events and risk indicators contributes SCRM field with the idea to define the challenges of incorporating AI in SCRM. Since technically and methodically AI is

already specified, it is expected that these challenges and guidelines of how a better SCRM supplemented by AI techniques will serve as missing link integrating SCRM and AI research fields (Ivanov, D., Tsipoulanidis, A., & Schönberger, J., 2019).

2.5. Potential Prerequisites

One of the potential prerequisites of incorporating AI in SCRM is the need for particular data. Companies usually collect different sets of data, struggling to use it constructively. Although when it comes to the analysis of the collected data here the human hypotheses steps into the play, as a value was largely driven by goals of internal decision support rather than advanced predictive capabilities or cognitive insights. The decision-maker may construct his or her decision-making behavior to constrain the opportunity for new information to alter the initial perception and choices made. Even the same set of data or ratios might be interpreted differently by different employees at the same company, and it affects the decision-making process as well as implies the space for intuitive conclusions and therefore human mistakes. As appeared in our interviews, even large commercial enterprises struggle to manage risk occurring in the supply chain process as managers faces challenges in understanding the impact of different internal and external factors on the risk. They strive to judge and interpret the available evidence on the possibility of loss and how to take individual actions to manage the risk. Not only numerous risk management definitions, models, techniques, and tools make the complexity in the individual decision but also different information streams and business intelligence tools. In this paper two data categories – SC risk events registry and their predictions indicators – are considered as two distinct fields in the scope of challenges in applying AI for SCRM (Harvard Business Review., 2021).

The paper is organized in the following way. The theoretical framework delineates a research territory: risk of a supply chain is perceived from the approach of the maturity level of enterprise risk management and potential implementation of AI in SCRM. A supply chain risk and company's maturity in assessing and controlling it appropriately is discussed as one of the important factors affecting the ability to foster supply chain risk management by moving towards more mature risk identification and control as well as incorporate such tools as artificial intelligence for risk management efficiency. The methodology part explains the selection of case analysis in a complex holding company, conducting 7 interviews with the representatives of different subdivisions to assess the approach f a focal company to a supply chain risk and its management. Management practices of various kinds in supply chain risk events' and risk indicators' data collection, storing, management, exchange, and application are discussed in a result part of the paper, followed by conclusions (Rodrigues, R., 2020).

2.6. Significance of Inventory Optimization in Supply Chains

Inventory optimization is a critical component of supply chain management that maintains the ideal balance between supply and demand. Efficient inventory management ensures that companies can meet customer demands without overstocking or understocking, which can lead to increased costs and reduced service levels. The significance of inventory optimization extends beyond cost savings; it also encompasses improved customer satisfaction, enhanced operational efficiency, and

competitive advantage. Effective inventory management is more crucial than ever in today's globalized market, where supply chains are becoming increasingly complex and dynamic (Rubel, 2021).

Traditional inventory optimization methods, such as Economic Order Quantity (EOQ), Just-In-Time (JIT), and Material Requirements Planning (MRP), have been widely used in supply chain management. EOQ focuses on determining the optimal order size to minimize total inventory costs and balance ordering and holding costs. JIT aims to reduce inventory levels by aligning production schedules closely with demand, thereby minimizing waste. MRP involves using detailed production schedules and inventory records to ensure materials are available for production and products are available for delivery.

Despite their widespread use, these traditional methods have notable limitations. EOQ, for instance, often assumes constant demand and lead times, which are unrealistic in today's volatile markets. JIT, while effective in reducing inventory levels, can lead to supply chain disruptions if there are any delays or fluctuations in demand. Conversely, MRP can become overly complex and rigid, making it difficult to adapt to changing market conditions. These methods typically rely on historical data and predefined rules, limiting their ability to respond to real-time changes and uncertainties in the supply chain (Van Looy, A., & Shafagatova, A., 2016).

2.7. AI Investing and Benefit

In Europe alone, most corporations are investing a huge amount of money into the research and development of AI technologies to just outdo their other competitors across the globe in such technologies. These currents of digitalization and interconnectivity are a trend that constitutes rates much higher in comparison with most parts of the world because of technological advancement driven by research into AI. Thus, AI finds an application in automobile distribution, though with its challenges. It is to be noticed that some tasks performed by people, by going automated or mechanized, may lead them to lose their job.

Emphasizes that AI can benefit supply chains by increasing their efficiency and reducing the impact that could be generated by having only a small number of employees. Applications for AI are present throughout supply chains, from manufacturing all the way through consumer-facing. Believe that AI can automate manual supply chain tasks, which could drastically reduce time and costs. Tags that use Internet of Things technology are used to track inventory and promptly notify the supply chain companies about potential problems. The European Union (the EU) is trying to cope with green policies using digital transformation and attempting to build resilience within its member states to secure the current dependencies and the skilled workforce missing in the automotive sector. The most common challenges EU automotive producers are facing are linked to high dependencies on non-European suppliers, which lack both competencies in key development areas, but also cost competitiveness (Van Looy, A., & Shafagatova, A., 2016).

Points out that AI is amazing at cutting costs and improving operations, while highlights the need for higher investments in smart algorithms to be able to keep up with the changes in the automotive industry. Discusses that the COVID-19 pandemic worsened issues such as labor shortages and increased demand for vehicles but managing supply chains with AI can help make operations more predictable, transparent and quick. Believes that adopting AI technology will improve key areas of the supply chain in the future, although he agrees with that the COVID-19 pandemic highlighted the weak points of supply chains (Tan, Y., & Zhang, X, 2018).

2.8. Logistic Sector

The logistics sector in company is playing a pivotal role in the promising modern economy. It has great importance in increasing incoming investments, non-oil exports, and the competitiveness of organization. However, it is facing some limitations and challenges, either are visible or invisible, and that affects the decisions making directly. AI has affected most industries and the logistics industry without exception, and this development has revolutionized the logistics field. The most critical AI technology advancements are represented in autonomous vehicles, warehouse automation, predictive analytics, and intelligent roads. So, logistics partners can implement AI in several supply chain operations for a bright future for organization (Ivanov, D., Dolgui, A., & Sokolov, B., 2019).

2.9. Supply Chain Transportation through Artificial Intelligence and Machine Learning

In the dynamic realm of supply chain management, the confluence of technological advancements, particularly Artificial Intelligence (AI) and machine learning, has ushered in an era of unprecedented transformation. This introduction encapsulates the multifaceted landscape of supply chain transportation, unraveling the intricate interplay between AI, machine learning, and the pursuit of operational efficiency and automation. As we navigate this vast terrain, it becomes evident that these technologies are not merely tools but catalysts, reshaping the very fabric of how goods traverse the intricate web of global logistics networks (Flynn, B.B., Huo, B. and Zhao, X.,2018).

The foundation of modern commerce rests upon the seamless movement of goods across a complex network of suppliers, manufacturers, distributors, and retailers. Historically, supply chain transportation has been a linchpin in this intricate dance, ensuring that products reach their destinations in a timely and cost-effective manner. However, traditional approaches often grappled with challenges such as inefficiencies, suboptimal route planning, unpredictable maintenance issues, and a reliance on reactive rather than proactive strategies (Fraser, J.R.S., Simkins, B.J., 2016).

Enter the era of AI and machine learning, **Figure 4** where the historical challenges of supply chain transportation are met with innovative solutions that redefine the benchmarks of efficiency and automation. This introduction contextualizes the historical evolution, setting the stage for an exploration into how these technologies have become indispensable tools in the contemporary supply chain management arsenal.

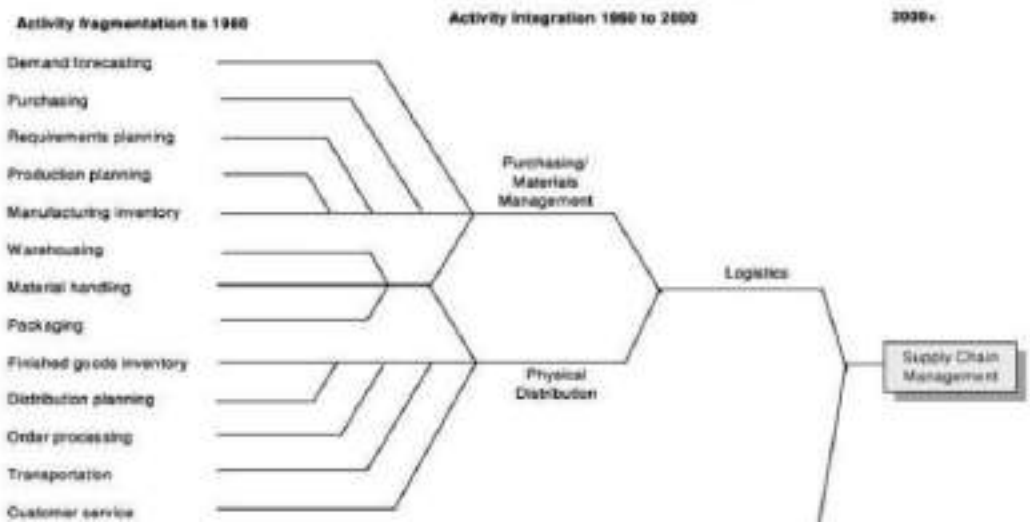


Figure 4 Evolution of Supply Chain Transportation

2.10. Supply Chain & Logistic

Supply Chain Management (SCM) and logistics play an essential role in modern businesses, acting as the backbone for ensuring the smooth flow of goods and services from suppliers to consumers. Over time, as industries and markets have globalized, the need for more integrated and interconnected supply chains has grown. Today, businesses face the challenge of maintaining high levels of customer satisfaction while minimizing costs, and efficient supply chains have become critical for achieving this balance. Interconnection within the supply chain—the seamless linkage of various elements, from raw material procurement to product delivery—is now a key determinant of business success. This paper explores the significance of interconnection in supply chain management and logistics. It investigates how improved coordination and communication between suppliers, manufacturers, distributors, and retailers contribute to overall business efficiency and profitability. Moreover, the advent of digital technologies such as AI, IoT, and blockchain has transformed traditional supply chain processes, enhancing real-time data sharing and decision-making. This research aims to provide insights into how businesses can leverage interconnection to build stronger, more resilient supply chains and maintain a competitive edge in today's fast-paced market environment (Drake, M.J., 2023).

2.11. Global Supply Chain Landscape

The global supply chain landscape is undergoing a significant transformation driven by several key factors, including globalization, rapid technological advancements, and the increasing expectations of consumers. As businesses operate in a more interconnected world, traditional supply chain models are increasingly challenged to adapt to new demands and complexities.

In response to these challenges, organizations are turning to innovative solutions that can streamline their operations and improve overall performance. One such solution is the integration of Artificial Intelligence (AI) into supply chain management (SCM). AI has the potential to fundamentally change the way supply chains operate by automating processes,

optimizing logistics, and providing actionable insights from vast amounts of data. By leveraging AI technologies, companies can enhance operational efficiency, reduce costs associated with inventory management and logistics, and ultimately boost customer satisfaction through improved delivery times and service levels (Dash, R., McMurtrey, M., Rebman, C., & Kar, U. K., 2019).

This article delves deeper into the multifaceted role of AI in supply chain management, examining its various applications ranging from demand forecasting and inventory optimization to supplier relationship management and risk assessment. It will also highlight the numerous benefits AI can bring, such as greater accuracy in decision-making, the ability to anticipate market shifts, and enhanced responsiveness to consumer needs.

However, the integration of AI into supply chains is not without its challenges. Organizations must navigate potential barriers such as implementation costs, data privacy concerns, and the need for skilled personnel to manage advanced technologies. Looking ahead, this article will discuss the future directions of AI in SCM, exploring emerging trends and technologies that could further influence supply chain processes and strategic decision-making in the coming years (Christopher, M., 2016).

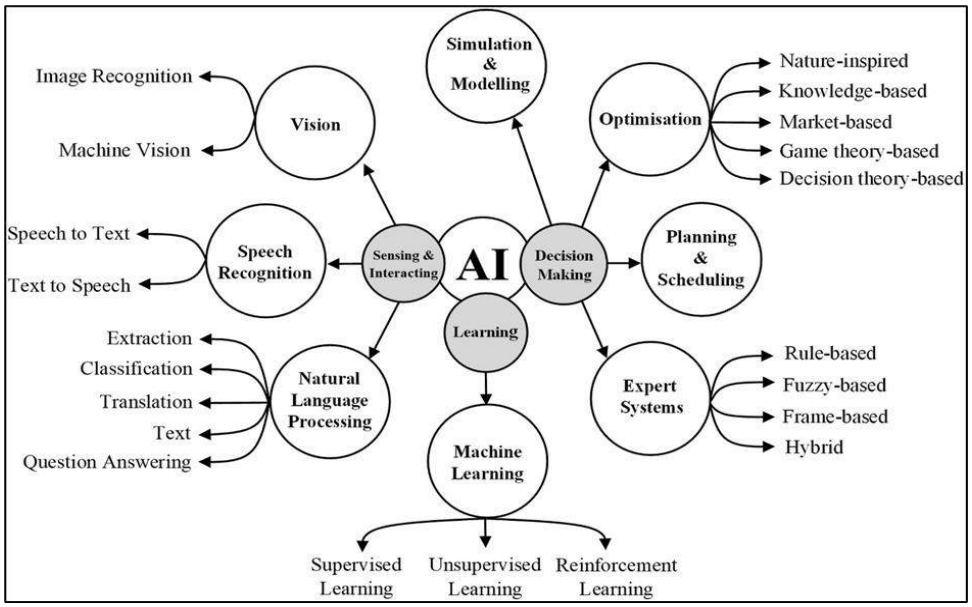
2.12. Integration of Artificial Intelligence (AI)

The integration of artificial intelligence (AI) into supply chain management (SCM) has revolutionized traditional practices, particularly in demand forecasting. As global supply chains become more complex, organizations face significant challenges in predicting demand with accuracy and agility. Traditional demand forecasting models, which rely heavily on historical data and statistical methods, have been found inadequate in addressing the uncertainties and dynamic nature of modern supply chains. In response to these limitations, AI technologies such as machine learning (ML), deep learning (DL), and natural language processing (NLP) have emerged as transformative tools that enhance predictive capabilities by analyzing vast and diverse data sources. AI-based demand forecasting models leverage real-time data, provide more accurate predictions, and improve the decision-making process across supply chain networks (Fan, Y., Stevenson, M., 2018).

AI-driven demand forecasting has evolved through various stages, from simple predictive models to advanced techniques capable of learning from data in real-time. Early applications of AI in SCM focused primarily on automating routine tasks and optimizing inventory management. However, the rapid growth of data generated through digital platforms and the development of more sophisticated algorithms have enabled the evolution of AI applications in demand forecasting. The use of machine learning algorithms, particularly those that incorporate reinforcement learning and deep neural networks, has expanded the scope of forecasting models beyond mere pattern recognition to advanced prediction capabilities, accounting for various market trends, consumer behaviors, and external factors such as economic shifts or disruptions. This shift reflects the broader trend of AI adoption in supply chain management, where AI is now seen as a critical enabler of digital transformation. Several studies have demonstrated the effectiveness of AI models in improving demand forecasting accuracy compared to traditional approaches. For instance, highlighted that AI techniques, such as ML and DL, can capture

complex, non-linear relationships in data, which are often missed by conventional statistical models. These AI systems utilize a range of data sources, including social media sentiment, weather data, and real-time market fluctuations, which contribute to more robust and adaptive forecasting models. Additionally, recent advancements in AI have allowed for the integration of unstructured data, such as textual data and images, further enhancing forecasting precision. The ability to process and analyze such diverse datasets positions AI as a vital tool in addressing the challenges of fluctuating demand in volatile supply chain environments (Ha, N, Akbari, M., and Au, B., 2022).

Figure 5: Applications and Components of Artificial Intelligence (AI) in Decision-Making and Learning



As AI continues to evolve, its role in demand forecasting is expected to grow more prominent, especially with the integration of big data and cloud computing technologies. The scalability of AI models, supported by cloud-based platforms, allows organizations to process large volumes of data in real-time, offering more timely and accurate demand forecasts. In addition, cloud computing enhances the accessibility and deployment of AI tools, enabling even small and medium-sized enterprises (SMEs) to adopt sophisticated AI-driven forecasting systems. These advancements highlight the growing recognition of AI as a key component of supply chain strategy, particularly in enhancing responsiveness and reducing the risks associated with demand volatility. Despite the significant progress in AI applications for demand forecasting, challenges remain in terms of model interpretability and the integration of AI systems with existing SCM infrastructure. Researchers such as have pointed out that while AI models offer superior predictive performance, their complexity often makes it difficult for supply chain managers to understand how the forecasts are generated. This lack of transparency can hinder the widespread adoption of AI tools in some industries. Furthermore, the successful implementation of AI-driven forecasting requires seamless integration with enterprise resource planning (ERP) systems and other supply chain software, which may involve substantial investment and technological readiness (Ivanov, D., Sokolov, B., & Dolgui, A., 2019).

Nonetheless, the potential of AI to transform demand forecasting processes remains immense, with ongoing research focusing on overcoming these challenges and expanding the applications of AI across various sectors. An essential objective of this systematic literature review is to comprehensively analyze the existing research on AI applications in supply chain demand forecasting, focusing on how AI technologies have evolved and contributed to improving forecasting accuracy and efficiency. By synthesizing studies that explore the implementation of machine learning (ML), deep learning (DL), and other AI-driven techniques, this review seeks to identify the specific models and algorithms that have been most effective in various supply chain contexts. Additionally, this review aims to evaluate the challenges and limitations associated with the adoption of AI in demand forecasting, as well as highlight areas where further research and development are needed. Through a critical assessment of the literature, the objective is to provide insights into the current state of AI applications in demand forecasting and offer recommendations for future research directions in this field (Jingyi, Q., Hua, L., Xiu, C., Wen, F., 2020).

3. Conceptual Background

3.1. Supply Chain Integration

The Supply chain concept and supply chain management are not very old disciplines, which were introduced in the 1980s. Despite a short presence in the industry and the academic world, this discipline has always been the center of academic study and research in recent years. The core value of supply chain management and its contribution to the success of any business lies in how well the supply chain partners build relationships and gain competitive advantages by co-utilizing network resources. Highlighted that the ability to coordinate efficiently among business partners in their supply chain is the key contributor to managing the supply chain successfully. The role of coordination has been focused in the subchannel of supply chain management which is SCI. This subdomain emphasizes how supply chain entities work together collaboratively to establish various platforms to make the coordination more efficient. Companies can achieve such efficient coordination by integrating externally with their supplies and customers and internally with theirs. Other authors found that integrating processes can also help companies attain such benefits. Planning synchronization, logistics integration, alignment of incentives and information integration are the remaining facets of supply chain integration (Keith & Webber, 1982).

3.2. Information Sharing

Data and information are only valuable when shared. The importance of sharing and integrating information among supply chain entities is highlighted in a vast majority of articles in this domain. Various articles have confirmed the significant impact of information sharing and integration on firm performance in the current literature. Firms occasionally decide to direct the integration efforts to their internal functions to ensure the efficient flow of information within the system. However, greater efforts for information integration have been put into external information integration. Several authors have recognized the movement in this domain from companies that try to integrate their information technology system with their supply chain partners to optimize business transaction efficiency. The involvement of more advanced

communication technology has been confirmed to have a direct impact on the information integration effort. Information sharing and information technology are significant factors that influence the information integration efforts of supply chain entities (Jones, J. A., & Brown, A. L., 2021).

3.3. Information Sharing and Supply Chain Integration

There are three primary flows in any supply chain which include material flow, cash flow and information flow. Information has been confirmed to be one of the most significant factors contributing to efficient communication across entities in the supply chain by contemporary scholars. Despite the obvious importance of information, it does not directly influence the performance of firms but rather indirectly influences a firm's performance through supply chain integration. This finding aligns with the current body of knowledge in the supply chain integration field, in which pointed out that information sharing and organizational coordination are crucial for the success of supply chain integration. **Figure 6.** Further studies into this information sharing – supply chain integration relationship in various contexts is getting the same positive results. Since this is an important topic, the authors have brought the analysis to the next level of depth which describes the relationship between the subdomains of information sharing and those of supply chain integration. The ability to ensure the information is shared efficiently and effectively across all functions within a firm is vital to its success. This internal information sharing mechanism and top management support are the key drivers of internal integration (Lau, A.K., Yam, R. and Tang, E.P., 2015).

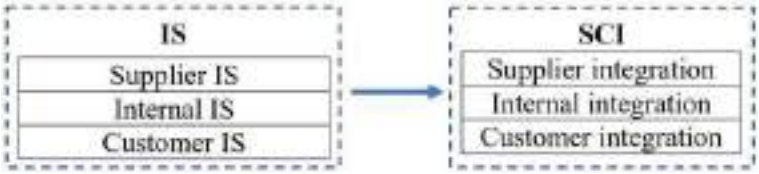


Figure 6 - The IS-SCI Relationship

A larger amount of data and information is transferred to and from an entity to its supply chain partners will improve its supply chain alignment and, therefore the business performance. In addition, accurate and timely communication across companies improves the agility and flexibility of their supply chains. External information sharing includes information sharing with customers and with suppliers. While the internal information sharing on supply chain integration.

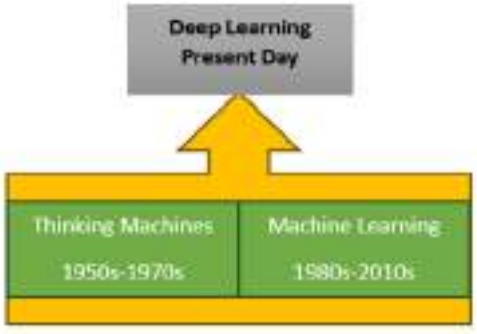
3.4. Artificial Intelligence and Information Sharing

In the new era of industry 4.0, most of the latest research in the past decade focused on AI because of its profound impacts on both society and academia. AI is defined in many ways with various approaches and perspectives. Summarized and defined AI as the ability of machines to have similar human cognition such as learning, reasoning, identifying, and solving problems. From the start of the concept, AI has been developing rapidly and has become a wide spectrum discipline that has various applications in different summarized the various branches of AI, which include expert systems (ES), machine learning (ML), multi-agent systems (MAS), neural networks (NN), and fuzzy logic and fuzzy sets (FLFS), and metaheuristics (MH). The two main categories of AI that most business-related authors refer to are ES, which includes deep learning neural networks and fuzzy rules, and ML. With the advances in hardware system capability developed in the

past few years that can capture and analyze the amount of data we have never seen in the previous period, AI, with its functions, could be able to assist businesses (1) in integrating and make data more relevant to business operations; (2) to allow companies to automatically make an impactful real-time decision; and (3) to allow mistakes, improvements to be documented for future improvements. This new generation of AI has the potential to completely change the way business has been sharing information for decades and could trigger innovation in the way companies integrate their supply chain to be more competitive in the marketplace. Moving forward in this digital era, the amount of information exchanged across the supply chain will only get larger. The ability to grasp and process information faster and more accurately, whether the improvement is incremental or significant, will help firms to be more resilient and risk-tolerant in the marketplace. The traditional sharing mechanisms with insufficient use of information technology will hold the position any longer by the overwhelming amount of data that needs processing. As information technology is adopted more frequently in improving the quality of information sharing, AI-powered intelligent systems will be crucial to strengthen the impact of information sharing on supply chain integration (Malviya, R. K., & Kant, R., 2015).

3.5. Logic of Artificial Intelligence and Data Volume in Supply Chain Management

The rapid increase of human-computer interaction in recent years has called for further exploration of how human and machine co-exist in an existing artificial intelligence environment. Artificial intelligence, machine learning and internet of things are a major source of generating information among others in a variety of ways, such as the volume of information, diversity of information and divergence of information are a few data flashpoint for big data that can be used for decision making. For the supply chain problems which are predominant by uncertainty, in that case, Artificial intelligence is more effective than other tools of information technology. The extensive use of artificial intelligence is understood by researchers as important and necessary for shaping the future of the supply chain of industry 4.0. The term" artificial intelligence" (AI) is used to describe the process involved in machines learning to recollect patterns and features directly from the data to take actions using algorithms. The origins of AI as an area of scientific research are not a new concept; its conception goes back to 1965 from "Dartmouth conference" then the term typically referred to as "intelligent machine". However, looking back, the term intelligent machine did not convey the scope of human and machine interface. Therefore, later on, the term artificial intelligence emerged. Figure 1 illustrates the history and developments in AI. **Figure 7** is adapted from (SAS, n.d.) (Kamble, S. S., Gunasekaran, A., & Arha, H.,2018).



AI. Figure 7 is adapted from (SAS, n.d.)

3.6. Rapid Development of Economy

With the rapid development of the economy and science and technology, the supply chain operation process has become more complicated. Supply chain logistics is key in daily enterprise work and has gradually attracted more attention. However, for the existing supply chain logistics patterns, there are still problems like information barriers, high difficulty, a long time to integrate information and lack of trust. In recent years, under the context of big data, some enterprises have achieved the goal of reducing costs and increasing efficiency through artificial intelligence or blockchain technology, and certain results have been achieved. This paper will take the existing mode of supply chain logistics of JD and Alibaba as an example, introduce the advantages of the application of AI technology and blockchain technology in the field of supply chain logistics, respectively, and then discuss the application practice of the combination of AI and blockchain in the site selection of logistics warehouses, intelligent warehouse management and intelligent logistics path management (Huo, B., 2014).

As one of the largest users, developers and promoters of logistics systems in China, JD Logistics adheres to the core concept "people and enterprises have no room for each other, goods have no boundaries, and scenes have no boundaries", realizing intelligent logistics parks and building highly efficient and coordinated international supply chain networks, with the help of AI and big data technologies to make accurate forecasts of unit volumes and intelligent site selection of warehouses. They research and develop a variety of intelligent equipment independently, such as the Wolf Goodsto- People System, the Wolf Intelligent Handling and Picking Robot, the Automated Distribution Wall, the Unmanned Forklift Trucks, Packing Machines, and Transportation Machines. These facilities have participated in the cooperation of major e-commerce, medicine, industrial electronics and other fields of enterprises so that each link of logistics has the ability of self-awareness, self-learning and self-decision-making, forming a technical service capability covering the entire supply chain scene, greatly reducing the hidden costs and invariably improve the efficiency of each link (Fosso Wamba, S., Akter, S., Edwards, A., Chopin, G., & Gnanzou, D., 2019).

4. Methodology

Systematic review papers summarize the peer reviewed publications to provide the academic community with cohesive findings in a period and a specific area of knowledge so that researchers can build upon and identify their research potential. Although researchers have published a few systematic review articles in the SCI domain, the review of IS and SCI in the past decade was neglected. This situation urged us to conduct this systematic review paper to summarize the findings of peer reviewed articles and to identify research gaps and future research directions in this field. **Figure 8** describes the detailed steps that we took to collect, evaluate and conclude this paper. The author has developed the five steps research method for systematic review and applied it in this article. The method has been adopted. In the initial search through the Scopus database and other publishers, the structural examination resulted in estimate 112 relevant. The last screening phase eliminated 82 articles that did not strongly discuss the connection between IS and SCI. As a result, 30 qualified articles will be used in this SLR article (Tanaka, M., Tanaka, H., & Nagai, Y., 2021).

Step 1: This investigation collects the articles from 2010 to 2021 to draw a comprehensive picture of current literature about information sharing and supply chain integration in the last decade.

Step 2: The articles are collected from an aggregated Scopus database and from publishers' websites, including Emerald (Emerald.com), Elsevier (Elsevier.com), Growing Science (Growingscience.com), Taylor & Francis (Tandfonline.com), Springer (Springer.com), ScienceDirect (ScienceDirect.com), Wiley (Wiley.com).

Step 3: The author uses the keywords "supply chain", "integration", "information" "sharing" to search for articles in the databases as per the methodology in Akbari (2017), and Akbari & McClelland (2020).

Step 4: The selected articles were included in an Excel database and examined carefully. The data was processed by Excel.

Step 5: The paper will combine the findings from the article classification with the analysis of AI to discuss (1) the gap in the literature, (2) the significant findings, and (3) future research directions.

Figure 8 - SLR Methodology

4.1. Research Design

The qualitative approach undertaken in this study proposes exposing the potential of RIS to resolve and minimize supply chain risk-related issues. Detailed discussion with executives from logistics and supply chain fields concerning various aspects of supply chain disruption and information systems were interviewed. Such research is exploratory rather than explanatory. A flexible approach is helpful in creating comprehension and insights into a phenomenon for which hardly any research has been conducted, hence smaller samples are recommended to generate in-depth insights. As per the guidelines, we interviewed 29 executives. Thematic analyses were used to classify promising subjects. The qualitative

records and data helped generate themes using the inductive theory approach. Data arrays were recognized and three-layered coding used to arrive at main themes (Shao, X.F.; Liu, W.; Li, Y.; Chaudhry, H.R.; Yue, X.G, 2021).

The respondents considered for the interview have the experience of supply chains in recent Small Medium Enterprise in various countries, Asia, Europe and Australasia. For reliability and validity of the findings, we followed an approach described by Brink and referred to the articles and industry reports indicated in Table 1 and Table 2. To address the issue of researcher bias we adopted, triangulation approach (Table 2) through a variety of sources that ensures the rigor and adequacy of the research findings supported by research design presented in Figure 1. In this study, we ensured reliability and validity through stability, consistency, and equivalence as suggested by Brink. To ensure stability, we asked similar questions at different times to examine the consistency (the second and fourth question are intended to examine the stability of responses shown in **Table 1**) (Rodrigues, R. (2020).

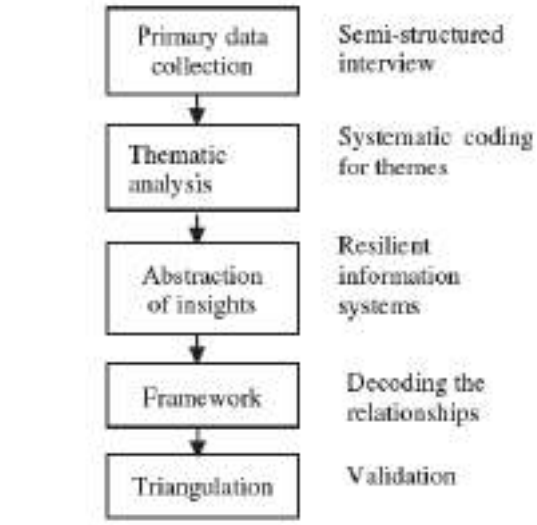


Table 1: Steps followed for qualitative enquiry and thematic analysis

To ensure consistency, we examined the concordance of a respondent throughout the interview and presented through the views of 10th respondent. We also tested equivalence when we compared our findings with those of other researchers. **Table 2** indicates the measures of reliability and **Table 3** the validity through triangulation.

Table 2: Measures of reliability

Stability	Consistency	Equivalence
Q.2 How do you think modern technologies and information systems can help tackle these disruptions? Q.4 How important it is to develop resilience in information systems through artificially intelligent technologies to prevent disruptions in the supply chain?	For example, Respondent 10 explained that AI can be helpful in developing the best capabilities of an information system, and also said that it may initially look complex and require a large investment, but could help reduce disruptions in supply chains.	Referring to the findings of [19], [36] and [85], RIS can offer more flexibility, adaptability, and transforming capability for a supply chain in a disruptive environment. Furthermore, RIS can proactively help identify potential failure stages and appropriate action [82].

Table 3: Validity through triangulation

Reports	Articles	Emerging Themes
A report from TCS [75] highlights the role of information system capabilities to address unplanned and unanticipated disruptions. Therefore, resilient information systems do not only offer proactive solutions, but also facilitate sharing secure and relevant information that is timely even during a crisis to enable further actions across the globe.	System resilience involves having the capabilities to develop the trust, governance, privacy, and security of the supply chain. Both flexible and resilient elements can help supply chains function adequately during disruption [74]. The success of information systems depends on employing data acquisition technologies for processing and learning capabilities [55].	-Cybersecurity -Data acquisition -Data processing -Geopolitical information -Risk minimization -Self learning

5. Material Evaluation

This article has summarized the publication by time to analyze the trend in this domain of IS and SCI. The analysis of the distribution of publications by time is described in **Figure 9**. The column chart shows the number of publications per year in the period of 12 years, the years with the highest publications and the trend toward the number of publications through time. In the period of 2010-2015, the number of publications on this topic, although 2011 and 2015 added some weights, started to get some tractions which created a good foundation for strong development in the period of 2016-2021. Although we may receive more publications in 2021, 2018 is the year with the highest number of publications. The increasing number of articles in recent years shows that more researchers, as the trajectory trend indicates, are concentrating on this topic.

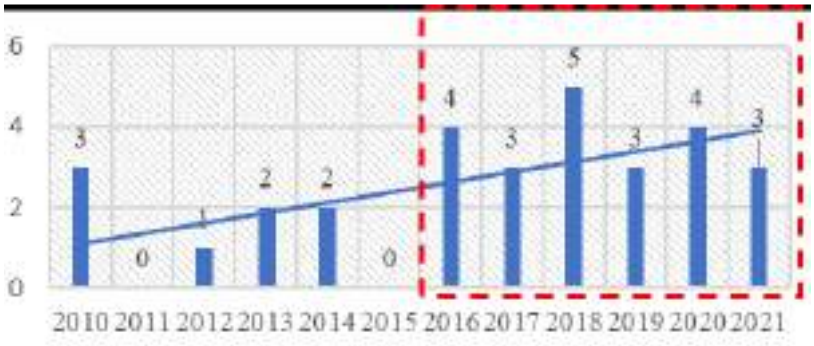


Figure 9 - Distribution of Publications by Year

5.1. Distribution of Publications by Country

Figure 10 summarizes the classification of reviewed papers by the country from which the data is collected. The column chart on the left illustrates the number of articles in each country as well as the ranking of the country. The world map on the right with purple circles explicitly visualizes the locations where high concentrations of articles populate. The larger circle indicates a higher concentration of articles, and smaller circles indicate a lower concentration of articles. The circle at the bottom of the map represents the number of articles that have been conducted at the global level. Overall, this topic has been studied in a number of countries around the world which resides in four continents: Asia, Europe, North America, and Oceania. At the country level, China tops the list with nine articles, followed by Australia with four articles, Vietnam and Malaysia with three articles, and Hong Kong, EU, Korea, UK, USA, New Zealand, Turkey and Indonesia with 1 article for each country. The world map shows that most articles studied the Asian Pacific regions.

However, the statistical data indicates that China really stand out with 9 articles but articles in Australia really took another step toward the adoption of more advanced technology. Confirmed that the IoT did have a significant impact on information sharing and process integration with customers and suppliers while also found that the adoption of cloud-based technology will enhance the ability of firms to process data and information and therefore influenced supply chain integration. The distribution of publications by country indicates an imbalanced distribution of articles among regions worldwide.

Figure 10 - Distribution of Publications by Country

5.2. Classification Of Publication

Figure 11 summarizes the number of articles published in each journal. The chart indicates that there are no clear leading journals in this domain in which the number of publications is not significantly different across all journals. The journals that have the largest number of publications include International Journal of Production Economics, International Journal of Operations and Production Management, Uncertain Supply Chain Management, Supply Chain Management: An International Journal, followed by International Journal of Logistics Management,

Production Planning & Control, Industrial Management & Data Systems and Journal of Operations Management. Journal of International Logistics and Trade, Operations Management Research, Procedia Manufacturing, Australasian Journal of Information Systems, International Journal of Production Research, Chinese Management Studies, Journal of Systems and Information Technology, Benchmarking: An International Journal, Business Strategy and the Environment, International Journal of Construction Supply Chain Management, International Journal of Physical Distribution & Logistics Management.

The summary shows that, although there are no leading journals in the SCI and IS domain, this topic has been well-recognized among prestigious journals. Hence, it has to potential to attract much more attention to broaden this exciting literature to bring more value to both academic and practitioners' communities.

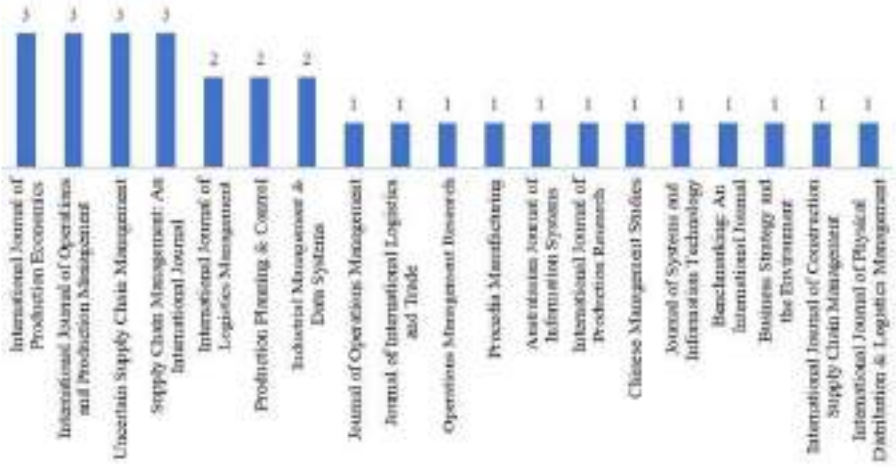


Figure 11 - Classification of Publications by Journals

5.3. Classification of Publication by Publishers

Unlike the classification of publication by journal where there are no clear leading journals, **Fig. 12** shows that majority of articles in this area are published in Emerald with 14 publications, followed by Elsevier with four publications, Growing Science with three publications, Taylor & Francis with three publications, Springer with one publication, Science Direct with one publication, and Wiley with one publication. Three are three other ISI/Scopus databases with one publication each. The details of this classification are presented.

The statistical data shows that a number of researchers are paying attention to this topic and that group of researchers usually publish their papers in Emerald. The listed publishers are prominent in the academic community, increasing number of publications in these prestigious publishers signals a promising research outlook for this research area.

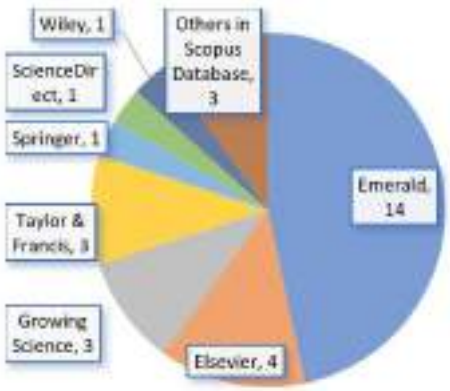


Figure 12 - Classification of Publication by Publishers

6. Artificial Intelligence of Things

The IoT and artificial intelligence are powerful technologies. When AI and IoT are combined, Artificial Intelligence of Things or AIoT is obtained. In other words, the IoT is a digital nervous system, and artificial intelligence is the brain of this system.

AIoT is revolutionary for both types of technology and beneficial for both types of technologies because artificial intelligence values the IoT through machine learning capabilities and IoT values artificial intelligence through connectivity, signaling, and data exchange. As IoT networks are spread across large industries, there will be large amounts of human-centered, machine-generated data. AIoT can support data analysis solutions that can add value to the data generated by the IoT. Although some IoT systems are designed for simple event control in which the sensor signal generates a similar response, such as turning on/off a light based on changes in ambient light, many events are much more complex and can be used to interpret events using analytical techniques. AIoT is in place to take the proper steps to achieve this. It places smart tools on edge and gives devices the ability to perceive data, observe their surroundings, and make the best decisions—all of which can be done with minimal human intervention. With the power of artificial intelligence, AIoT devices are not merely messengers that deliver information to the control center, but have become intelligent machines capable of self-centered analysis and operating independently. In terms of data analysis, AIoT technology combines machine learning with IoT networks and systems to create "learning machines". This can then be applied to enterprise and industrial data to control IoT data, such as network edges, to automate tasks in a connected workplace. Real-time data are of key value for all AIoT applications and solutions.

In a specific usage example, AIoT solutions can also be integrated with social media and HR platforms to create an AI decision as a service function for HR professionals. There are four main areas that AIoT affects: wearables, smart home, smart city, and smart industry. Some research has been done in these key areas. Proposed an AIoT-based system for the real-time monitoring of tunnel construction. They showed that the AIoT-based system improves information and automation during construction, facilitates decision-making, and prevents accidents. Created a prior-dependent graph for data clustering and dimension reduction at the AIoT edge. Presented an energy-efficient and fast design for hybrid storage-class memory in an AIoT terminal system. They showed that the proposed system could reduce energy consumption by an average of 46.2% compared to the traditional system. Examined the virtual store of AI-enabled objects (AIoT) using an automated sensor-enhanced robotic software manipulator. Their findings showed that using IoT analysis and artificial intelligence (AI), a virtual store can provide customers with real-time feedback on product details. In a paper examining the implementation of an intelligent linking service on AIoT, examined the hierarchy for material flow management. Proposed a new two-step unsupervised error detection framework combining feature extraction and fuzzy clustering for common AIoT used industrial AIoT to improve quality at an HP plant. The results showed the high impact of this technology on quality improvement.

7. AI and IoT-Based Supply Chain

Many businesses have embraced artificial intelligence and the IoT as part of their processes and products in today's world. Recent studies have shown that these are two well-known technologies that are used seamlessly today. They were also found to be the best technologies that companies invest in to increase efficiency and create a competitive advantage. Thus far, several definitions have been proposed for the IoT. However, the definition provided emphasizes the concept of the IoT and supply chain management and, therefore, has been considered in this paper. Based on this, the IoT can be defined as follows: the Internet of Things is a network of physical objects that are digitally connected to sense, monitor, and interact within a company

and between the company and its supply chain, enabling agility, visibility, tracking, and information sharing to facilitate the timely planning, control, and coordination of the supply chain processes.

Thus, IoT technology has played a vital role in operations excellence in supply chain management. This technology has significantly contributed to industrial automation, allowing the integration of industrial sensor networks, radio frequency identification networks, factory control networks, and information management systems. The IoT as a new technology has become more popular since the advent of wireless technology and has attracted the attention of supply chain activists.

The IoT has enabled companies to simplify the flow of information and, at all stages of the supply chain, produce significant profits for companies by improving productivity and facilitating the integration of disorganized communications. Through the use of the IoT, companies can make significant gains in productivity at all stages of the supply chain and facilitate in-house and inter-organizational communications.

Artificial intelligence also has numerous applications in the supply chain. Areas of impact of artificial intelligence in the supply chain and logistics areas include operational procurement using smart data and chat bots, supply chain planning to forecast supply and demand, warehouse management to optimize inventory, transportation, and faster and more accurate shipping to reduce delivery time and shipping costs and optimally select suppliers through the use of up-to-date data. In addition to artificial intelligence, machine learning is also used in transportation. Organizations now embrace and use machine learning to refine core strategies for issues such as warehouse optimization and day-to-day activities such as availability, costs, inventory, transportation, suppliers, and staff.

Combining these factors has made the IoT and artificial intelligence topics of interest among researchers and industry activists in the supply chain. According to the research work done in IoT and artificial intelligence and supply chain management, it is clear that the research conducted in this field covers a diverse range of topics and different industries. Moreover, some researchers have identified and analyzed the issues emphasized in the theoretical foundations. For example, some have studied the dimensions of using these technologies in the logistic industry. Some studies have pointed to the role of these technologies in creating smart cities. In addition, some review studies conducted in this field have specifically studied the IoT in the logistic industries and have considered the results of the application of this technology in the supply chain. Provided a framework for IoT-based supply chain and big data analysis. Their research showed how to implement a supply chain emphasizing IoT technologies. Investigated the effect of integrating artificial intelligence with an IoT-enabled supply chain. In a study, presented an integrated framework based on the Chinese solutions of integrating blockchain, IoT and big data to evaluate service chain performance. Provided a framework for using a supply chain emphasizing AIoT in a study. Many studies have pointed to the effects of the simultaneous use of these two technologies and its key role in today's world. These technologies always play positive roles in today's world. However, using these technologies can lead to challenges, which will be evaluated in the next section.

8. Challenges in AIoT-Based Supply Chain

Technology, as a driving force in accelerating processes in the face of various activities, has played a significant role; one of these important branches of technology is IoT technologies and artificial intelligence, which today plays a significant role in the industry. Nevertheless, these technologies, like other emerging technologies, face challenges. In this paper, we try to examine the challenges in the IoT and artificial intelligence within the supply chain as one of the most important parts of manufacturing organizations. Although the concept of smart industries has only been around for a few years with the presence of technologies such as the IoT and the development of the concept and tools of big data analytics, and research has been done in this area, its rapid repetition and upgrading also pose many challenges. In this section, the influencing factors are identified and summarized using a systematic literature review of published articles and studies.

These challenges are also assessed using expert opinions, and the most important challenges facing a power supply chain are extracted from IoT technologies and artificial intelligence. In order to analyze the data, experts active in the fields of supply chain and information technology working in FMCG industries were used. The reason for choosing these industries was the availability of this field for researchers. Therefore, in companies were considered as a case study. Since there has not been much proprietary research for the AIoT-based supply chain, the first step was to search for the key words artificial intelligence and the IoT and their relationship with the supply chain to extract the most important challenges of a smart supply chain. For this purpose, a research question was developed in the first step. In this research, the main questions are: What are the most important key challenges in implementing supply chain based on artificial intelligence, and what category do they have? The statistical population and the search period were determined in the same step. Articles indexed in Scopus and Google Scholar databases were considered to determine the statistical population. It was also considered in light of the background in the field literature.

In the second step, studies related to the research questions were identified. For this purpose, the appropriate keywords for the search must be determined. Keywords for search were: AI and IoT challenges, smart supply chain challenges, IoT-based supply chain implementation challenges, AI-based supply chain implementation challenges, and AI and IoT challenges in the supply chain. In order to extract relevant studies in this field, Scopus and Google Scholar indexing databases were referred to. After searching for keywords in these databases, 278 related document titles were found.

In the third step, the studies that should be reviewed were identified by determining the inclusion criteria. Criteria for inclusion included the English language, quality findings, and the key challenges of using AI and IoT simultaneously in the supply chain. Thus, out of 278 articles published during the review years, 51 non-English items were removed from the review list. After reviewing the titles of the articles and abstracts of the remaining 227 articles, according to the inclusion criteria and the subject, question, and purpose of the research, 24 articles were deleted and 203 articles were considered to review the full content of the article. By reviewing the content of the articles, 20 articles did not have the necessary features for use in the present study and were removed from the study process, and 183 articles with the necessary features for in-depth review and use in this study were identified.

Then, using the modified Delphi method and using the 5-level Likert scale proposed by with the opinions of experts, 29 challenges as the most important key challenges in implementing the supply chain based on the use of artificial intelligence and IoT were extracted during the studied years. These challenges were then presented to twenty-five experts active in the field of supply chain and information technology in companies and fifteen experts from the university in this field. Using a questionnaire and a five-level Likert scale, nine major challenges were selected as the most important challenges in this field. These challenges are shown in **Table 4.**

Table 4: Units for magnetic properties.

Code	Challenges	Category
C11	Cybersecurity	Security (C1)
C12	Lack of Trust in AIoT	
C13	Connectivity	
C21	Environmental Risks	Environmental (C2)
C22	Managing Energy	
C23	Smart Waste	
C31	Managing Transportation	Managerial (C3)
C32	Lack of Proper Infrastructure	
C33	Lack of Professionals	

8.1. Cybersecurity

There is a combination of physical and digital systems in an intelligent factory and, accordingly, in an intelligent supply chain that, in addition to generating and maintaining data using IoT technology, uses artificial intelligence for analysis, enabling real-time collaboration, but there is a risk of expanding the level of attack. With multiple machines and devices connected to single or multiple networks in intelligent processes, vulnerabilities in any of these devices can open the system to attacks. Companies must anticipate both organizational system vulnerabilities and machine-level operational vulnerabilities. Companies are not always prepared to deal with these security threats, and many rely on their technology and solution providers to do so.

8.2. Lack of Trust in AIoT

Trust is often at the level of interpersonal relationships. In today's intelligent modern life, people's trust is increasingly systemic. Lack of trust in artificial intelligence and the IoT may slow the development of a strong and intelligent supply chain. However, by reviewing the literature, one of the basic features of systems based on artificial intelligence is their high reliability. However, studies show that there is always concern and distrust of text-based intelligent systems on the IoT. It is seldom claimed that an IoT system works perfectly accurately for any environment, context, and unusual event that the system can experience. Trust means that reliability assessment is highly dependent on accurate knowledge of the context and environment and flexibility to handle unusual events and data. Rarely will such knowledge exist and provide complete flexibility

8.3. Connectivity

Wired connectivity is popular in the industry, so pushing the IoT to wireless connectivity could signal a change in network infrastructure design. The use of wireless networks may lead to security concerns. In the IoT, digital devices connect and communicate with each other via the Internet, and in small, multi-device networks, the connection is seamless. However, when the IoT is used globally and a number of devices and sensors are connected and communicate with each other, connection problems arise. Moreover, the Internet is not merely a network; it includes heterogeneous networks with cell towers, slow connection, fast connection, proxy servers and firewalls, and different companies with different standards and technologies that can disrupt the connection. Connection is considered one of IoT's important components because data transfer depends on a good connection. In addition, big data analysis using artificial intelligence and with many connections has its own complexities and is one of the main challenges of a supply chain based on these technologies.

8.4. Environmental Risks

Businesses are increasingly vulnerable to environmental risks and climate change. A smart supply chain powered by the IoT and artificial intelligence must have highly responsive and agile disaster management systems, such as alerting stakeholders to risk prevention measures and reducing pollution levels. Artificial intelligence and the IoT can be used in the design phase to minimize environmental risks in the business environment as well as product development. Automated drones have been used in various fields, such as detecting and recording environmental hazards, regulating traffic for product distribution, and monitoring environmental pollution. Air quality sensors on online platforms in supply chain processes, especially in manufacturing, can support the measurement of environmental hazards.

8.5. Managing Energy

The advantage of IoT devices is that they enable automation. However, a significant amount of energy is required to connect the billions of connected devices to each other. This need for energy, unless managed, can be an obstacle to the full implementation of IoT systems. Technological advances and changes in consumer habits are leading to increased energy demand, and energy producers are now seeking the help of artificial intelligence and IoT to optimize the energy distribution needed.

8.6. Smart Waste

Waste management is one of the main concerns of many industries. This waste is also very high in the production process and has many environmental effects. Waste management from start to finish is one of the key challenges for industrial warehouses worldwide. With the current lifestyle situation in which most food and other items are packaged in plastic or paper packaging, dealing with the waste generated in the manufacturing and industrial sectors is a major concern. Garbage collection must be completed on time, as they require smarter collection. Artificial intelligence and the IoT must address collection, transportation, refining, recycling, and intelligent disposal issues through optimization techniques. Using these technologies, the whole process can be centrally monitored and, as a result, services are provided in a smart supply chain.

8.7. Managing Transportation

In today's world, transportation is one of the most critical sectors of the economy. Although transportation has greatly improved modern life, many problems in this area are still unresolved. Current modes of transportation are heavily dependent on crude oil products such as oil, diesel, and so on. Electric vehicles are a good alternative to combat greenhouse gas emissions. Electric vehicles use batteries and electric motors to generate the power needed to drive. If existing fuel stations are upgraded to hybrid modes that offer petroleum products as well as electronic charging stations, the charging requirements of electric vehicles can be met. To avoid traffic jams, urban design is important to minimize the need for daily public transportation, filling this gap and reducing residents' travel time. Machine learning methods that are an essential part of artificial intelligence must be sufficiently capable of analyzing past data from public and private transportation activities to address the root causes of frequent congestion or most accidents and disruption and distribution. Preventive measures are needed to address them.

8.8. Lack of Proper Infrastructure

The smart industries, and consequently the smart supply chain, need the latest highly advanced infrastructure, and every piece of equipment must be connected to the Internet to monitor it. In the smart supply chain, IoT-connected devices collect data from physical media to optimize decisions to improve all supply chain processes from supply to distribution. Creating an information service to support information is one of the tasks of smart companies to create a smart and robust supply chain. Digital supply chain services must have the infrastructure necessary to build cyber and physical systems. Smart factory services must have the infrastructure components necessary to complete the technological operation of the product in automatic mode with cyber equipment. The smart supply chain infrastructure must have the infrastructure necessary for personnel to control the item during remote operation.

8.9. Lack of Professionals

To successfully implement new technology and maintain operations, a company must have a workforce with "digital skills"—people must understand both the production processes and the digital tools that support those processes. In the absence of forces familiar with digital developments and the IoT or artificial intelligence, in addition to slowing down all progressive activities, there is organizational resistance to implementing AIoT-based intelligent processes in organizations. Thus, training in digital tools and skills (which is important in today's world but vital to the future) must be provided. Incorporating concepts related to cybersecurity, digital infrastructure, artificial intelligence, big data, storage, and computing needs into the educational content of the actors involved in supply chain activities must be implemented to continue to succeed in the world to come.

9. Handling of Multi-Dimensional Data with Speed and Accuracy

Respondents indicated that at times it becomes difficult to get information on time to process and make decisions to avoid the impact of disruption. The data are generated in the form of emails, phone calls, audio, video, networks and maps of the supply

chain. As Respondent R23 (Senior Manager from the logistic sector) noted, “in disruptive events, we have a multitude of data coming from the internet, print media and our suppliers, customers and other social media platforms in different forms ranging from images of floods/fires/lockdowns of affected areas to videos and phone conversations and it becomes extremely difficult for us to combine all the data for accurate and fast decisions. Additionally, it reduces the efficiency of our supply chain and poses challenges to business continuity”. Therefore, the handling of multidimensional data not only affects the productivity of supply chains but also costs firms in terms of reducing service levels and the availability of necessary products in affected areas.

9.1. Lack of Insight Generation

Built-in, pre-defined boundaries drive traditional system operations. It was pointed out by the respondents that the existing systems play an important role in day-to-day, routine supply chain operations, but not enough for disruption scenarios. As Respondent R27 (Vice President in the logistics and supply chain field) noted, “the mission of our business has been redefined to meet the current challenges of supply chain disruption through our information systems, where we are employing machine learning and AI-based algorithms to detect, respond and recover early on”. Our respondents explained that there had been instances when they required information that was not a part of the existing system and database, and due to central bias, these types of scenarios are ignored by traditional information systems.

9.2. Integration of Physical Operations and Computing

Supply chains typically run through the physical network, where the movement of goods becomes a challenge when disruptions occur. In this regard, Respondent R9 (Manufacturing and Supply Chain Director in the logsitic domain in a conglomerate) noted that, “the design of our distribution network and its seamless integration with our information system and its flexibility in providing access to system data, components, and external assets helps us to be aware of any potential vulnerabilities early on”. On similar lines, Respondent R24 (Supply Chain Director from a confectionary firm) noted that, “digital twin-like simulation models can help our supply chain planners experiment with disruption scenarios and their impact on the physical supply chain to safeguard against the disruption impact”.

9.3. Lack of Process Maturity Across the Value Chain

Supply chain network success depends on the maturity of informed supply chain nodes to ensure visibility and demand on a collaborative basis. Respondent R14 (Purchasing Manager from an electrical equipment company) noted that, “value chain stakeholders should consider appropriate elements for supply chain integration and extension with AI technologies to bring end-to-end visibility. For instance, with the rising need for customization, there are multiple stock keeping units (SKUs), so to account for large amounts of data, too many applications and various intelligent systems are required”. The success of any supply chain in a disrupted environment depends on what needs to be achieved in the situation. Therefore, it is important for all partners to define and adhere to the common objectives of the value chain.

9.4. Lack of Trained Workforce

To handle data driven environment, firms require data-literate professionals who can interpret data and make decisions quickly. In this regard, Respondent R18 (Vice president in a retail company) noted that "today's firms are looking for data science talent and AI professionals to stand out from the crowd, whereas organizations are not training their workforce on recent technologies; instead, they prefer to hire externally". Hiring the right person has been always a challenge for companies seeking to meet certain expectations.

9.5. Potential Support for Strategic Assessments

Today, information systems are designed with room to extend and enhance multi-dimensional capabilities in the future, if required. Our Respondent R28 (Manufacturing Director in logistic company) noted that "the design of information systems both from soft and hard perspectives is being considered to maximize risk intelligence and to have a long-term effect, through characteristics of sensing, comprehending, acting and learning, where in learning, approaches from deep learning to genetic programming can be adopted. This strategic orientation can be infused with modern information systems with the help of interconnected devices.

9.6. Potential Support for Operational Assessments

The information systems decode and analyze the data of company operations and present them to the decision maker to make the final call. Our Respondent R13 (Senior Executive from the Food & Beverage Industry) noted that "an information system can evaluate and forecast figures on the basis of current expenses, workforce, manufacturing activities, and sales. For instance, with the recent floods in the region, our information systems indicated an approximate production figure with 95% confidence to divert and plan manufacturing activities, which has further helped us to make changes in our supply chain". The decisions depend on the data and assumptions made during analysis by information systems. Modern information systems can help make decisions when multiple options are available.

9.7. Opportunity to Restore Customer Loyalty

In the recent past, there have been numerous catastrophic events including Covid-19 that have caused serious disruptions in the supply chain and attracted the attention of firms to refine the recovery strategies. Our Respondent R15 (Purchasing Manager from a logistic company) noted that "disruption retrieval processes affect value chain relationships through the level of accessibility, ethical behavior, and sensitivity towards the delivery of goods to affected areas, and AI-driven systems can employ natural language processing to deliver goods to the exact location and customers". If a supply chain fails or slows down, then customer satisfaction is at risk and an opportunity can be lost.

10. AI Learning From other Disciplines

AI is being used today in the form of automatic programming, neural networks, natural language processing and predicting market competition with case-based reasoning. Our Respondent R3 (Supply Chain Senior Executive from a business services

company) noted that “AI can be used to detect fraud in a business and can help improve customer relationship management with a rule-based approach, where intelligent systems can make use of interdepartmental and external information to find gaps”. AI can also use Bayesian networks and machine-learning techniques to detect fraud. As indicated earlier, AI simulates human intelligence and can learn from other disciplines.

10.1. Human Interface

The analytical capability of AI and psychological and emotional elements of practitioners can be combined to make more accurate decisions. Our Respondent R16 (Logistics and Supply Chain Manager in the oil and gas sector) noted that “AI assists firms in creating products and services by helping remove their focus from data and the difficulty of drawing insights from big and different types of data”. Supply chain disruption and other firm operations generate multi-format data that may be extremely difficult for a working executive to manage.

10.2. Non-Inclusion of Experience of Senior Managers

AI does not include their experience and emotional quotient in decision making and predicting the scenarios. Our Respondent R26 (Supply Chain Senior Manager from the logistics industry) noted that “the action of top management shapes the behavior and interaction among employees, whereas AI may not have that capability of affecting the behavioral characteristics in the organization, on the supplier side or even the customer side”. The experience of customers and practicing executives at firms is of the utmost importance and plays a significant role in strategic decisions.

10.3. Fear of Not Acclimatizing to New Technologies

Many organizations are training their workforce with the help of consultants to utilize AI systems, but many firms want to substitute them with new, young people who are good at programming and extracting insights. Our Respondent R21 (Demand Planning Manager from a consumer healthcare firm) noted that “companies today are looking for the right combination of talent, who can perform managerial as well as technical tasks to accelerate the value chain and strengthen the resilience of their information systems and understand the technical know-how of the value chain”. Many organizations are living in fear that they may not be able to adapt to new technologies such as AI and they want others to experiment first to see the results of adoption.

11. Finding the Data

These themes are explained in the following sub-sections and were analyzed qualitatively to generate sub themes and main themes.

11.1. Gaps in Traditional Information Systems

We asked our respondents to give examples of operational level challenges with typical information systems referring to disruption. The issues raised by our respondents are described.

11.2. Dynamic Decision-Making Capability

The role of information becomes critical in the decision-making process during supply chain disruption [84]. Hence, the RIS can play a key role in mitigating the risk involved in disruption events.

11.3. Cooperation Among Stakeholders Towards Resilience

Modern information systems can help rebuild trust and capture market share by choosing more accurate forecasts and appropriate modes of supply with the help of different stakeholders. However, our respondents indicated that many supply chains lack the desired characteristics for resilience based on the support of information systems.

11.4. Information System Resilience as The Basis for a Firm's Orientation

The appropriate degree of resilience in information systems helps firms recover quickly, maintain the customer base and develop a growth orientation. Our respondents indicated how they view the RIS and their fit in the firm's strategy.

11.5. Challenge and Enriching the Capability of AI for RIS

AI uses the computer network to simulate human intelligence and collect data from sensors to make appropriate decisions. The impact on labor and control of complex systems is a challenge that AI poses for today's information systems. Certain on-site adoption challenges are delineated in the subsections

12. Application of Data Analytics and Machine Learning - in Supply Chain Industry

Big data modelling is an emergent field. Big data refers to as "the information asset characterized by high Volume, Velocity and Variety to require specific technology and analytical methods for its transformation into Value. This implies that big data is a plausible set of unstructured large data sets that provide an opportunity for organizations to apply scalable algorithms to capture, store, and analyze the information to gain business intelligence. Big data focuses on the extraction of data form micro and macro level of the system and to offer a transparent process to make the process easier. Thus, big data provides a viable picture with details of relevant characteristics to spot trends between different data nodes to find new correlations. Big data and machine learning induce more value-added infrastructure towards a new era of technology. Particularly, when it comes to supply chain performance. The large amounts of collected data sets irrespective of qualifying to be big data is now an integral part for improvement, competency, and superiority in the supply chain for companies to avail smart benefits. The benefits are manifold as big data deals with massive amorphous data which is required for high-velocity detaining information for business, government agencies and private entities.

This information supports the fundamental models of logistic companies for including estimation of the real-time supply chain, supply chain sanctuary hazards, evaluation and forecasting of demand-supply determinants, appraising supplier performance, process and cost-effective optimization, resourceful interaction between business to business (B2B) and business to consumer (B2C), and competent strategic decision making. According to large amounts of data sets provide opportunities to manufacturing industries for efficient realization of output by improving process quality in terms of minimizing the risk of out

of stock. Various companies, software developers and analytics are offering sophisticated and advance tools and platforms to enhance the supply chain performance in stock and operation planning. Like routes and location distance trailing, tracking unforeseen disasters, delivery time cycle, parts assembling operations, storage capacity and approaches, limitation of goods distribution to retailers, customer behavioral patterns, and competitor standing point. For example, 'Blue Yonder' are developers of data intensive forecasting methods, 'IBM' links production planning and weather forecasts, 'Google trend' provides information on supply disruptions. Similarly, 'Caterpillar' is a massive information provider on an industrial quotation, 'Forklift 3' is trying to achieve a big data hub for warehouses, 'Logivations' is a developer of cloud-based 3D warehouse layout planning and optimization tool, 'UPS' is a developer of Optimization and Navigation system (Orion), Amazon's Dash service is for consumer's Internet-connected for reordering.

13. Challenges and Opportunities to Implement AI in SCM

AI as robots, IoT (Internet of Things) or supporting decision-making as intelligent agents can enrich human experience. Otherwise, it can fail and cause physical injuries, financial loss, and more subtle harms such as instantiating human bias and damaging individual dignity. These failures can cause unreliability because strange, unpredictable, and new dangers can lead to general inconvenience and abandoning AI. It is deeply transformative technology which is fast developed omnipresent in everyone's life. AI approach must be holistic, and it must reflect to many ways which AI can fail. Mannes stated in their research that data reliability is top of challenges of AI. The data and technology are not mature yet enough to implement AI solutions. According to, challenges of AI-tools integration in SCM are currently following:

- User has no free will and that is why it leads strongly to computer program which can cause wrong decisions if it is programmed wrongly.
- Implementations are not easy to establish because they are esoteric and for ordinary decision-makers hard to follow.
- Cross-border and cross-functional SC decision environments where AI may not be capable to function properly which is due to its knowledge acquisition bottlenecks. According to The World Economic Forum (2016), optimizing machines to serve peoples' needs with AI has attracted attention to the ethical questions and risk assessments which are related to AI:

- Does AI increase unemployment?
- Does AI lead to bigger gap between wealthy and poor people?
- Does AI and robots influence in peoples' behavior and intercourse?
- How can we get protection against mistakes?
- Do machines learn to be biased?
- How do we guard AI systems from adversaries?
- Can AI occur negative side effects?
- How do we control a complex intelligent system?
- How the humane treatment can be defined for AI?

13.1. Opportunities

Recent studies have shown that well-structured AI-tools in SCM are limited to tactical and operational problems. Agent-based systems have the most potential in SCM to solve strategic issues in customer relationship management, relationships of outsourcing, B2B negotiations, strategic alliances among SC partners and collaborative demand planning to eliminate bullwhip effect. To understand the drivers of new demand patterns, companies can exploit AI to take over decision-making, routine planning and activities in SC. Demand planning usually suffers of inefficiency when reacting in unpredictable demand patterns. Deep learning automatically recognizes patterns from external signals and can distinguishes inappropriate signals to relevant signals. With signals it can fine-tune demand forecasts. Advances of AI consist of tracking weather, spot market capacity, identifying key variables of demand drivers, feedback from product quality, and gathering data from production machines to make better planning. Genetic algorithms can identify batches related to SC planning and decision-making cycles. These reroute orders and address near-term supply delays. Identifying batches with genetic algorithms helps to recognize in-house expenses and automate procurement of alternative capacities. The solution is not to buy latest planning software from AI-company. AI solution is a holistic ecosystem with the right algorithms, - mix of internal and external data and rights of decisions. Sustain solutions lead to strong end-to-end change management. To achieve successful SC planning, companies must identify new technological solutions that helps them in complex business environment.

13.2. Summary of Artificial Intelligence in Supply Chain Management

According in a planning level, AI concentrates in SCM field to forecasting, demand planning and optimization. These areas increase customer experience and make better assessments for processes and assets. The most potential areas of AI in SCM can be considered agent-based systems as it can operate in many SCM areas. AI can operate on strategical-, tactical -, and operational decision-making levels, but mostly on operational levels as forecasting, production, and warehouse actions. Increasing competitiveness, demand uncertainty and higher supply risks make companies invest enormous amounts of money to R&D when modern AI technology is implemented, and they are trying to find best AI solutions for business actions. However, companies should not be blind-folded when investing to AI solutions but consider exactly what serves them in the most sustainable and comprehensive way. Also, they must think what challenges AI may bring for the company in ethical and data maturity point of view. SCM value creation via AI are to reach almost perfectly accurate forecasts and decreasing costs of production. It also increases quality by optimizing their R&D and helps recognize target customers and provide better customer experience. With accurate forecasts, companies can minimize the waste and thus be more sustainable. They also can reduce costs and optimize sourcing. Weather-related solutions can predict the best supply and demand variation based on local weather forecasts. This solution could be great key for retail stores to optimize their sales e.g. in hot summer days. In production, AI can predict maintenance downtime and make production more reliable and high quality. Camera-equipped robots can recognize objects and materials and increase speed of picking. AI can make remarkable impact for inventories when supply and demand are being in perfect sync. This leads to decreasing capacity of inventories and satisfies customer needs rapidly.

13.3. AI Applications in Supply Chain Management

The use of AI in supply chain management is wider than just a single functionality. Machine learning algorithms, for example, help in predictive maintenance, demand forecasting, and optimization of inventories based on historical data patterns. Other SCP forecasting improves decision-making by offering real-time market trends and customer and supplier data to a business. Robotics and automation technologies help to minimize labor expenses and increase the efficiency of order picking in warehouses.

In **Figure 13 & 14**. The third major area of supply chain management being transformed by AI is risk and risk management or risk resilience. Given enough data, supply, geopolitical issues, disasters, and demand fluctuation risks are just examples of what AI algorithms can discover. By identifying these risks beforehand, AI prepares supply chain managers with the best contingency plans and measures to avoid disruption in supply and continuity of business. With this strategic risk management, operational robustness and organizational versatility are achieved in handling hitches and ambiguities in global business.

Figure 13 - Predictive risk management AI powered

In conclusion, AI's role in supply chain management involves a wide range of activities that significantly transform existing affairs and promote ongoing advancements within the area. From increasing the accuracy of forecasts and optimizing the procurement of materials to managing analytics and decision-making, AI allows organizations to improve their efficiency, flexibility, and competitiveness in the modern world. Hence, AI's visibility, risk, and resilience strengths mean that uncertainties can be managed more adeptly while improving customer and stakeholder value. **AI Applications in Supply Chain Management**

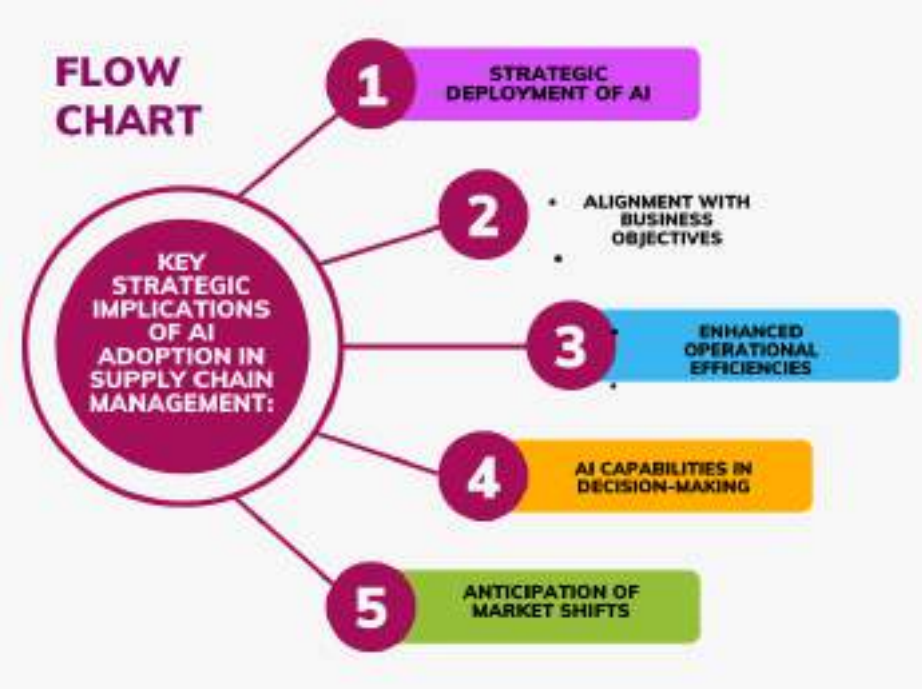
Figure 14 - AI Applications in Supply Chain Management

13.4. Strategic Implications of AI Adoption

AI has strategic implications for SC and supply chain management. Leveraging AI is a deliberate effort by organizations to realize business outcomes such as cost efficiency, performance, and sustainability in the supply chain. AI-generated insights enable companies to be adaptive when making decisions based on market changes and lead to better cooperation with the members of the supply chain.

AI enhances the strategic management decision-making processes by providing details that aid executives and managers in delivering adequate planning and precautions. For example, **Flow Chart 1**, AI can process customer behavior patterns, future trends, and competitor information quickly so that organizations can make the right decisions on time. Such capabilities enable the Supply Chain Executives to forecast future market conditions, manage inventory effectively, and create effective partnerships that enable Supply Chain agility and effectiveness. Therefore, the application of AI in business operations helps organizations enhance their performances while at the same time promoting their competitiveness and the ability of an organization to manage constant change and innovation in a global context.

Flow Chart 1: Strategic Implications of AI Adoption



13.5. Challenges and Limitations

The use of AI in supply chains has its drawbacks. Adopting AI technologies and related systems requires an initial capital outlay, which can be a burden, especially for firms with limited resources. Data credibility and security are essential as AI solutions depend greatly on data quality and quantity. Other challenges include resistance to change and training employees to be compatible with the new AI technologies.

Figure 15. Data quality and protection are other significant issues that must be addressed when considering AI in supply chain management. AI systems rely on data inputs to provide recommendations and solutions; therefore, data quality is critical. Problems like data dispersion, disparities, or discrepancies can negatively impact AI solutions by making faulty decisions and business disruptions. Hence, adopting strict policies for data management and governance becomes critical as it helps attain data accuracy, security, and legal compliance.

The lack of willingness to change other major headlines hinders AI integration in supply chain management. Employees and stakeholders may be reluctant or skeptical to adopt AI technologies because their roles may be altered or they fear losing their jobs. To overcome this resistance, active change management measures like communication, training, and encouragement of an organizational culture of innovation and cooperative teamwork are needed. Leaders need to make their employees ready for change by showing them how AI can help them in their work and make it more productive and engaging them in implementing AI in the organization to ensure compliance.

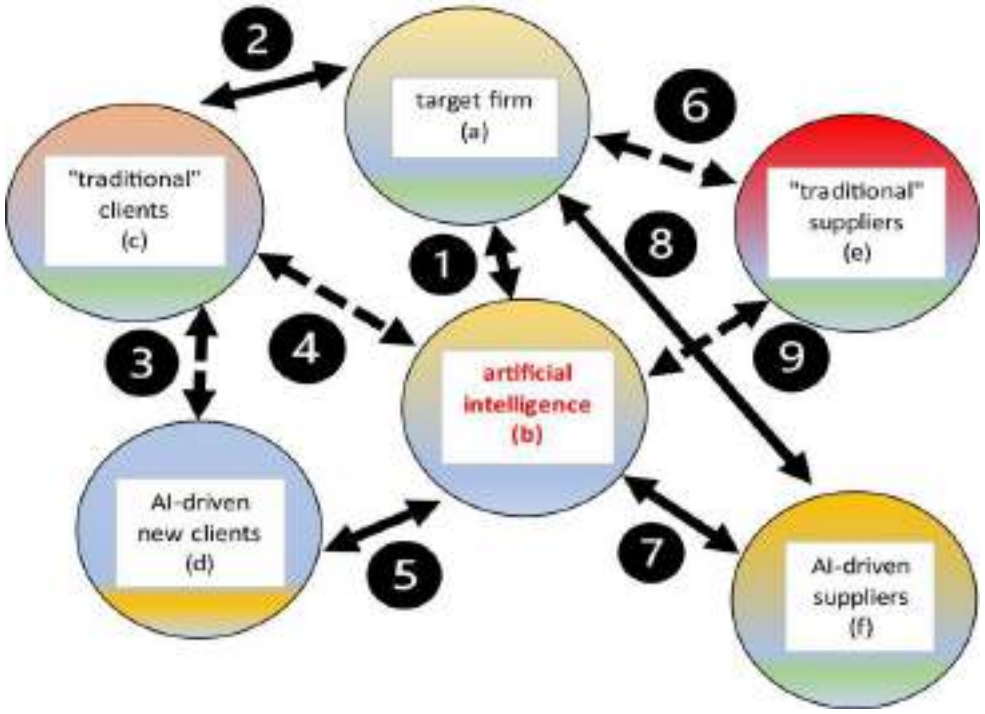
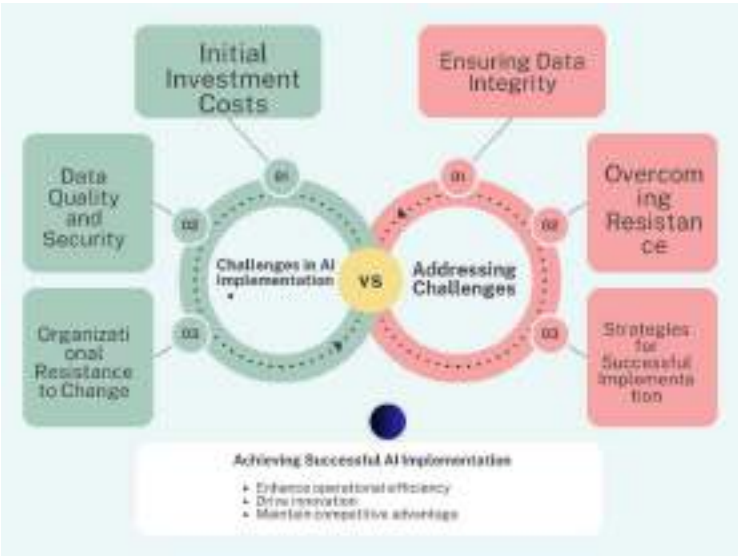


Figure 15 - AI-driven-procurement-supply-chain-Relationships-in-a-supply-chain-with-traditional-and

In conclusion, the implications of AI in the supply chain are promising; however, many risks and issues need to be resolved to achieve effective application. If initial costs of investment, data quality and security, organizational resistance to change, and continuous upskilling and training of employees are well handled, AI can be a force multiplier in improving organizational performance, innovation, and sustaining competitive advantage in the current evolving business environment.

Comparison of challenges and considerations in AI implementation in supply chains



13.6. Data Information

Data is collected through semi-structured interviews with the supply chain managers and IT professionals of highly ranked organizations across various industry sectors. Interviews here aim to identify the reasons for adopting AI, the implementation issues, organizational adjustments, and performance consequences. They particularly include secondary data in industry reports, academic research, and organizational performance data.

Table 5. Quantitative data entails getting statistical data from other secondary sources supporting interview findings. New in business and industry has more information on the trends and people's utilization of AI technology in several business lines in the supply chain. Peer reviewed sources supply strain information and concept frameworks that assist in presenting the results and analyzing AI's influence on the supply chain's progression. However, another major source is organizational Performance Indices or KPIs derived from the data obtained from organizational websites and annual reports, which may provide the numbers and quantifiable outcomes of how the AI integration has impacted the firms' economic returns, production, and positions in the market.

Combined, the usage of qualitative and quantitative forms of data in this research methodology offers a broader and more elaborative subject analysis on the utilization of AI in improving SCM. Thus, concerning secondary data along with the primary data collected from the professionals involved in supply chain management and working in the SCM industry through the semi-structured interviews, it attempts to establish the research reasons, issues, operational change, and strategic changes related to the integration of AI within the existing SC context.

Table 5: Data collection and research methodology:

Data Collection Method	Description	Sources
Semi-Structured Interviews	Interviews conducted with supply chain managers and IT professionals from highly ranked organizations across various industry sectors to identify reasons for AI adoption, implementation issues, organizational adjustments, and performance consequences.	- Supply chain managers/IT professionals
Secondary Data	Incorporates data from industry reports, academic research, and organizational performance data to support interview findings.	- Industry reports Academic research Organizational performance data (Van Looy & Shafagatova, 2016)
Quantitative Data	Statistical data obtained from secondary sources to support interview findings.	- News in business and industry - Peer-reviewed sources
Organizational Performance KPIs	Performance indices or KPIs derived from data obtained from organizational websites and annual reports to provide quantifiable outcomes of AI integration impacts on economic returns, production, and market positions.	- Organizational websites- Annual reports
Combined Data Analysis	Usage of qualitative and quantitative data to offer a broader analysis of AI utilization in improving supply chain management (Benzidia et al., 2021).	- Primary data from semi-structured interviews - Secondary data sources

13.7. Data Analysis

Utilizing the participants' interview responses allows for coding interviews and developing themes, patterns, and conclusions regarding the use of AI in the supply chain and its advantages. **Figure 16**. Hypothesis testing involves using statistics to compare numbers that Acton considers important before and after the adoption of AI, such as the costs for the products, circulation of inventory, time taken to deliver products, and scores from consumers' satisfaction surveys.

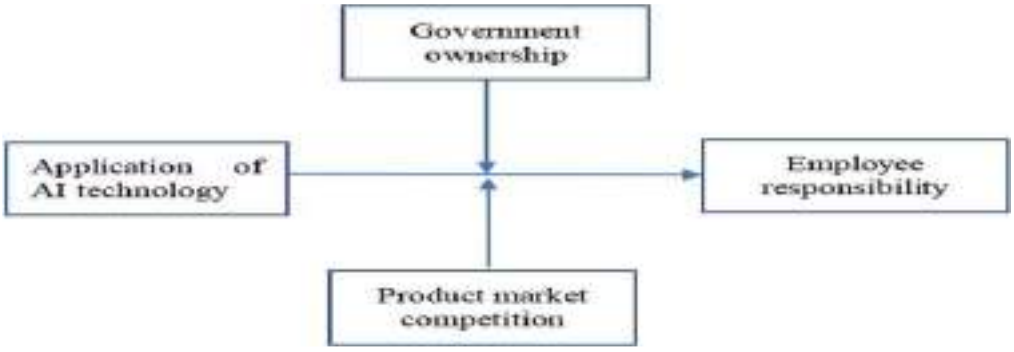


Figure 16 - AI technology application and employee responsibility

Improving the KPIs in the firms before the implementation of AI is an added advantage captured through quantitative data analysis using statistical tests. These KPIs span various aspects of supply chain performance, including but not limited to the following: These KPIs span various aspects of supply chain performance, including but not limited to the following:

• **Cost Reduction:** Quantifying the actual dollar amount that has been saved by deploying artificial intelligence leveraging. Some examples are procurement costs, inventory holding costs, or the operating cost of logistics.

• **Inventory Turnover:** When assessing the pre- and post-AI, convert the turnover ratios, which evaluate the turnover rates following AI implementation by the rate at which stock is sold or used in any given period.

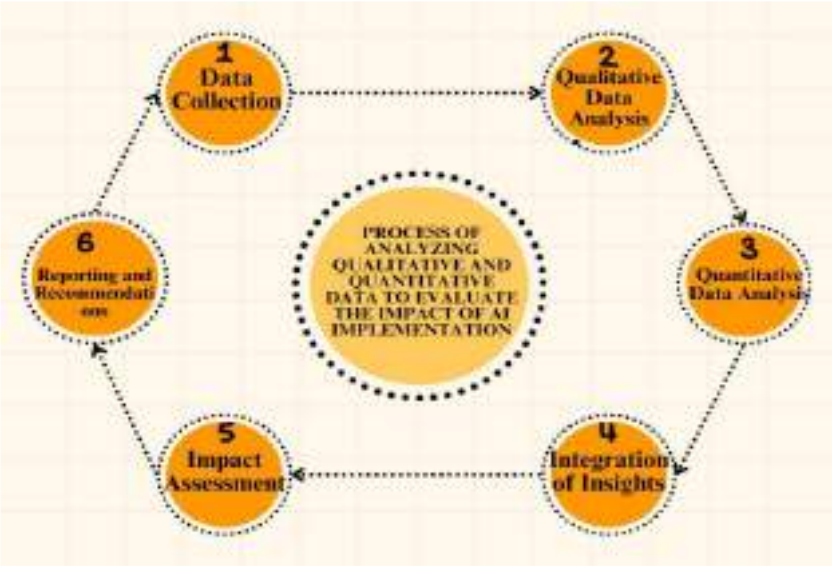
• **On-time Delivery Rates:** Calculating order or shipment analysis in percentage terms that were delivered on or before the due time or date per participating customer to portray the rise in the supply chain's response and reliability factor.

• **Customer Satisfaction Scores:** Customer feedback scores and indices such as NPS or retention rates compared to the implemented service delivery thanks to AI.

The quantitative **Flow Chart 2.** approach focuses on a cross-sectional analysis of the results both before and after the implementation of AI to determine the improvements that can be achieved through the application of the new technology and the consequent boost in efficiency that can be attributed to an enhancement in the Sphere AI. The quantitative data generated by integrating AI in the supply chain could be analyzed using regression analysis, t-tests, or correlation analysis to validate the change and establish pre-and post-AI assimilation and supply chain performance. Consequently, this

research aims to utilize both quantitative and qualitative analysis to examine and identify the effects of AI on the supply chain and offer several critical findings essential for both theory and practice organizations.

Flow Chart 2: Summarizing the process of analyzing qualitative and quantitative data to evaluate the impact of AI implementation on supply chain optimization:



13.8. Case Study 1: Corporation

The application of artificial intelligence technology in Corporation's Global Supply Chain Management Division provides a good example of how operational efficiency and strategic decision-making have been boosted. Predictive models for demand forecasting and equipment failures give product control over holding costs and improve planning precision.

AI has improved corporation’s capacity to address supply chain disruptions and any market changes **Figure 17**. Another benefit, which is enabled by integrating AI-powered intelligent adaptive planning for demand and inventory, is the improved ability to predict changes in customer demand with better Proactivity. Apart from reducing cases of stockouts, it also works on the principle that there is the right quantity of products at the right time. Furthermore, through AI for predictive maintenance, Corporation can predict equipment failures before occurring, reducing maintenance costs and increasing efficiency. These outcomes highlight the relevance of AI in improving operational performance and sustaining the efficiency of the automotive industry.

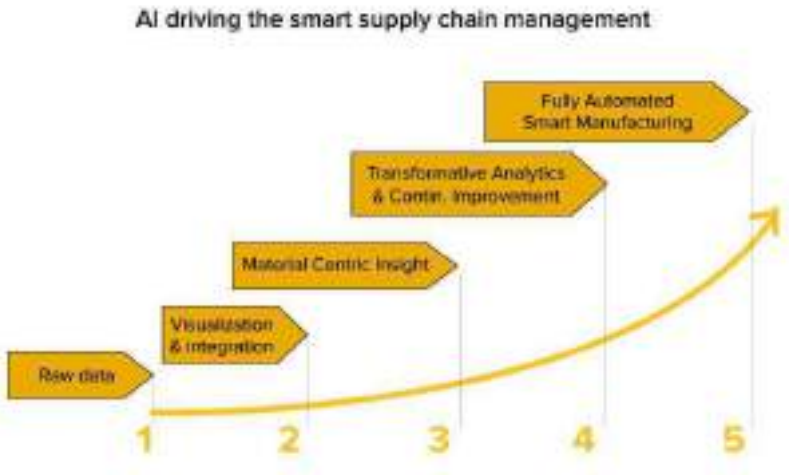


Figure 17 - AI-driving-the-smart-supply-chain-management

13.9. Lessons Learned

The success of Toyota's AI integration in supply chain management offers several key lessons for other organizations:

Holistic Approach to AI Adoption:

What product has done reflects that AI technologies must be adopted systemwide, and the way has to be planned and executed to achieve such system integration. Integrating machine learning for demand forecasting and equipment maintenance guarantees a holistic improvement of the operations' performance, be it inventory management or reduction of production downtimes.

Data-Driven Decision Making:

Another key aspect of product's strategy is its strong focus on the increasing use of AI-based **Table 6** data analysis and decision-making. By examining voluminous historical information, market trends, and other outside conditions, product can make precise prognoses and adjust maintenance needs promptly. This approach also reduces the supply chain's susceptibility to fluctuations in market dynamics and increases flexibility.

Table 6: AI-Driven Innovations for product

AI Technology	Application	Outcome
Machine Learning	Demand Forecasting	Reduced inventory holding costs
Predictive Maintenance	Real-Time Machinery Monitoring	Minimized downtime and maintenance costs

Predictive Maintenance

It focuses on real-time monitoring of machinery and equipment to predict failures in the equipment before they actually occur. Smart sensors and AI algorithms can be applied to analyze production line data suggesting signs of wear and tear. This way, we pre-empt any halt in production and unnecessary maintenance, which, in the long run, reduces costs.

13.10. Case Study 2: Unilever

AI has improved Unilever's supply chain flexibility and management through predictive analytics. By applying AI algorithms to analyze consumer data and predict changes in its dynamics, Unilever has been able to improve its inventory management, minimize stockouts, and improve product availability in its distribution channels.

13.11. Lessons learned

Unilever and other companies convinced by the potential of advanced AI will most assuredly concur with this view; however, the story shows that data drives decision-making. By integrating consumer behavior and market trends through AI, Unilever was able to develop a deep understanding of customers and their buying behaviors. It also allows real-time management of manufacturing and distribution plans to achieve the best stock positioning and
reduce stockout instances.

13.12. Advantages of AI Implementation in Supply Chain Management

The case of Unilever shows that applying AI could benefit the company's supply chain when implemented strategically. Demand forecasting and minimizing inventories help minimize the high costs associated with holding excess inventory and increase supply chain performance. This alignment of strategy fosters Unilever's business goals, achieving competitive advantage and sustainability in a dynamically changing environment.

13.13. Persistent Adaptation and Innovations in handling AI

Additionally, the case of Unilever **Table 7.** demonstrates that even the best implementation of AI technologies must be continuous and proactive. Unilever does not only fine-tune the models and algorithms underpinning AI applications with the ongoing data analysis but also sustains a competitive advantage and market responsiveness. Such an approach also helps to develop an innovative culture, enabling the organization to adapt to various changes and grow stably during disruptions in the field.

Table 7: AI-Driven Innovations at Unilever

AI Technology	Application	Outcome
Predictive Analytics	Consumer Data Analysis	Optimized inventory levels
Machine Learning	Demand Fluctuation Prediction	Enhanced product availability

13.14. Consumer Data Analysis

Unilever uses AI to process data, including consumer buying patterns, social media activity, and other attributes. The integrated system analyzes this data and feeds it to predictive analytics tools to make demand pattern predictions possible, which helps Unilever optimize its production and distribution plans.

13.15. Inventory Optimization

The kind of Artificial Intelligence currently deployed in the Unilever inventory system involves consistently monitoring relatively massive inventory storage centers. Software must process sales data, seasonal fluctuations, and supply chain disruptions to advise for proper inventory levels and product availability.

13.16. Discussion

The results highlight AI's significant role in supply chain management through the provision of insights on enhancement, cost cuts, and customer experience. AI technologies **Figure 18.** provide opportunities for organizations to increase operational effectiveness through predictions, automation, and improved decision-making. The application of AI in supply chain management helps organizations drive substantial cost reductions. AI alleviates the expenses related to inventory planning, vehicle transportation services, and other labor costs by simplifying repetitive tasks. Reducing overstocking and stockouts enhances control of working capital and, consequently, the organization's overall financial performance. This cost-saving potential makes AI appealing for improving revenue and maintaining profits in more competitive markets.

Impact of Artificial Intelligence (AI) On Supply Chain Optimization

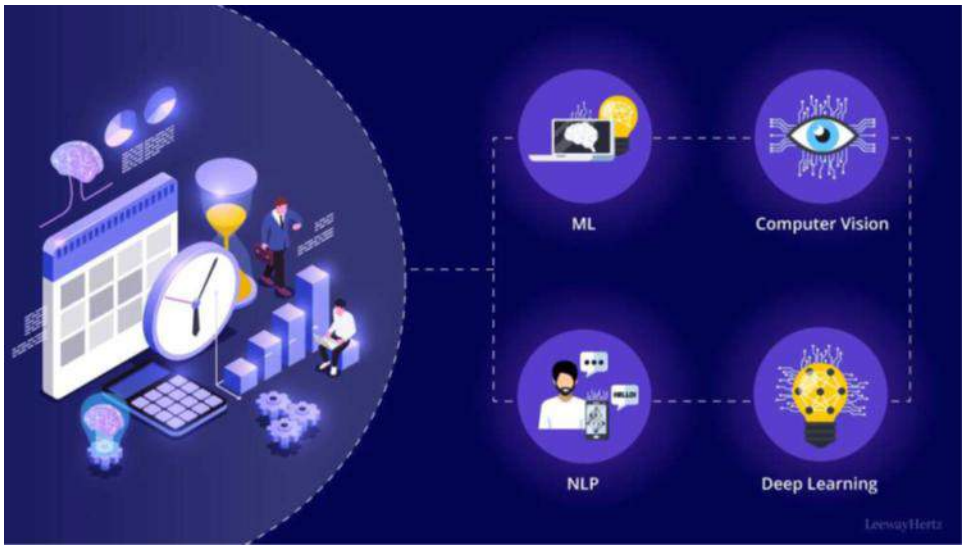


Figure 18 - AI-for-Operational-Efficiency

AI increases customer satisfaction through product availability and timely delivery. **Figure 19.** with the help of currently available data regarding customer preferences, previous purchasing behavior, and global market trends, organizations can effectively ensure a state of supply chain solutions to address customer needs and demands. Such an individual approach

to clients also contributes to increased sales and brand recognition and, thus, competitiveness in the market. In conclusion, AI supports the reengineering of various supply chain processes and activities and provides significant value-added opportunities that enable supply chain modification and growth in the contemporary volatile economy.

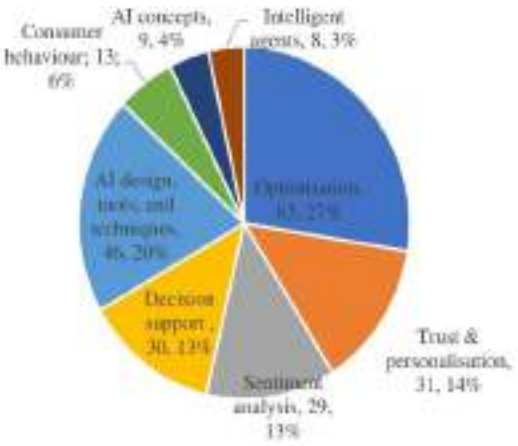
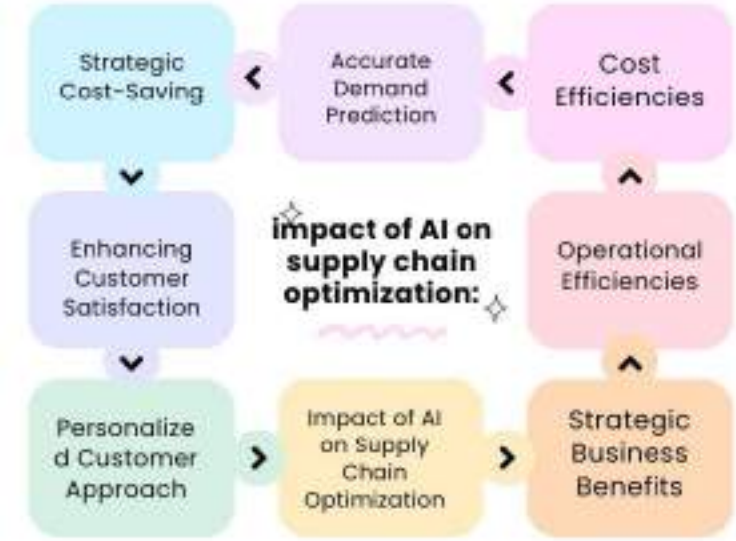


Figure 19 - AI in commerce

Chart summarizing the discussion on the impact of AI on supply chain optimization:



13.17. Strategic Implications

Tactically, AI integration supports the supply chain objectives and drives competitive advantage and sustainability across the organization. Leveraging the discussed AI technologies helps organizations adapt to market shifts more quickly, minimize risks, and foster better cooperation with other stakeholders.

AI technology can improve competitive positioning and differentiation in the marketplace by facilitating innovations that enhance organizational operations. By using AI, companies can have better demand forecasting, product differentiation,

and supply chain management to meet new customer expectations. The ability to align strategy gives a company a competitive advantage over its competitors by achieving higher levels of value for customers at lower costs and in shorter timeframes. By offering value-creating insights and networking, the framework adds increased integration to supply chain partners who can share data and decisions otherwise disconnected from single applications or disparate systems.

AI implementation in a logistic company makes it sustainable by enhancing resource utilization and lowering their impact on the environment throughout the supply chain. Regarding transportation networks, using AI could make significant cuts in the overall usage of resources, maintenance waste, or energy utilized to achieve the objectives of CSR. The strategic focus on sustainability improves the brand image, minimizes risks associated with regulatory changes, and meets the changing customer needs to use sustainable products and services. However, the application of artificial intelligence in the supply chain focuses on more than efficiency gains but strategic profits that enhance supply.

14. Theoretical Framework

Maturity of risk analysis in a context of supply chain risk management: Risk is one of the negative factors that decrease and destroy the competitiveness of any business. ISO Guide 73 defines a risk assessment as the overall process of risk identification, risk analysis, and risk evaluation (ISO, 2009). Assessing the level of maturity of an ERM is very important as it allows identification of strengths and weaknesses from which the organization can obtain the means for filling existing shortcomings and improve corporate governance and risk management. Only by determining the level of maturity, appropriate risk analysis and management methods can be identified.

Table 8: Supply chain risk management maturity levels based on the general approach of enterprises risk management

1	Not present	The organization does not recognize or does not meet SC risks. SC risk managementprocedures are not defined.
2	Initial/Ad hoc	There is general recognition of SC risks in the organization. Standardized processes are not developed. Risk management procedures and respective decisions are made on the ad-hoc bases, at the individual level. Management typically depends on the actions of specific individuals, with improvised procedures and poorly understood processes. Risks are managed case by case. The response from managers and functional executive officers is based on personal experience, analytical and data management tools are developed on the backgrounds of personal experience, skills, and capabilities.
3	Iterative/ In Silos	Different people performing similar functions apply similar procedures, which are not unified and still performed on the personal or separate department bases. Risk is managed in silos, with little integration or risk aggregation. The responsibility remains personal. SC risk management relevant data is collected and systematized by individuals, which results in data and process duplications. Procedures are not defined, but they are performed.
4	Defined/Repeatable	SC risk management procedures are defined and standardized. These procedures include SC risk-relevant data collection, management, and standardization. Though procedures are defined, they are not obligatory. People use them occasionally, which results in collected data fragmentation, shortages in analytical processes. Approaches to risk management are established and repeatable
5	Manageable	SC risk management activities, such as monitoring, measurement, and reporting are integrated and harmonized with measures and controls established. However, data management automatisation, systematization, and technical analytical tools are used only occasionally. Most of analytical procedures are made manually. The general understanding of SC risk management is common across organization and different management levels, but analytical processes could be interrupted due to shortcomings of systematized data about potential risk events and indicators for estimation of events' probability.
6	Optimized	Risk-based discussions are embedded to a strategic level, such as longterm planning, capital allocation, and decision making. SC risk estimation and management are performed by technical tools, which automatically collect needed data, calculate risk events' probabilities, and deliver respective management decisions suggestions. SC risk management is integrated into all other business processes. Connections with internal and external data sources are established and properly working.

Source: Adapted from Farrell and Gallagher (2015), ISACA (2019), Lindberg and Seifert (2011).

Enterprise supply chain risk analysis, as an important part of the overall enterprise risk management, plays an important role. Supply chain risk analysis seeks to identify the key risks that affect business processes and relationships: relationships with suppliers, relationships with customers, managing relationships with customers. Organizations strive for continuous process evolution, which is also found in risk management. "The unpredictability of the business environment, variable consumer demands, actions by competitors, along with market dynamics and continuous improvement initiatives within organizations imply that the supply chain never actually reaches a stable steady-state". The data and methods of analysis differ from company to company, from industry to industry, and every company has its own set of data, tools, and practices. However, some parts of commercial processes as SC management have some common elements.

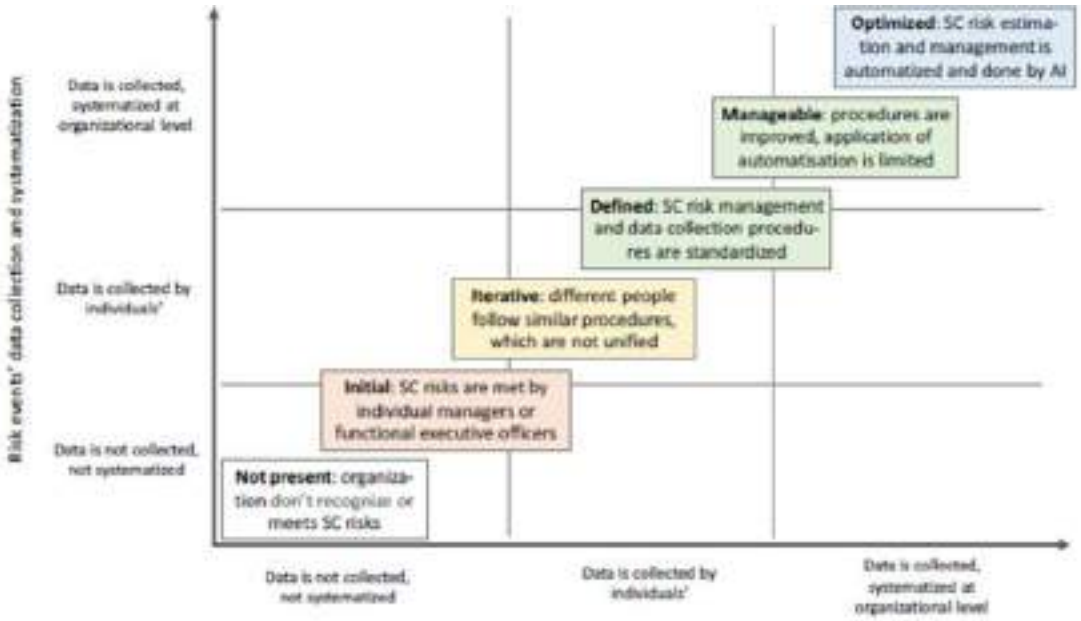
SCRM is defined as referring to “the extent of information availability about randomly changing supply chain parameters”. The SC thus is seen as a set of interactions that start in supplier’s premises and end when the buyer receives products and uses or consumes them. The focal company, which manages the SC process, i.e., makes orders, pays suppliers in advance for ordered goods, contracts carriers, ships the goods to buyers, delays payment requirements, receives payments from buyers, etc. is a subject at SCRs. Risk events cause losses of money or products which are suffered by the focal company. Not material losses of reputation also could be caused by risk events, but these negative SCR outcomes are relatively rare. SCRM respectively covers managerial decisions and actions aimed at mitigating risks and potential losses caused by risk events if they occur.

14.1. Incorporating AI into Supply Chain Risk Management

Supply chain risk identification, assessment, and management require to consider a wide range of indicators defined both inside and outside the organization. Not only data abundance but also potential biases, personal attitudes, and judgments, implicitness, the limited scope of considered risks - are issues caused by conventional business analytics applied in supply chain risk assessment and management. Intensified use of innovative technologies, such as artificial intelligence for the company's risk management, is a way to achieve the company's goals faster and to run organizational processes more smoothly. It is supposed that the implementation of artificial intelligence would help to eliminate most of the current imperfections. This is why the conceptual basis is needed to facilitate artificial intelligence development.

Definitions and processes of AI development were defined by other authors. It was conceptualized that the development of AI tools or the process of embedding AI into the business process covers a set of steps starting with problem recognition, following with identifying data sources, and finally finding an appropriate AI solution. The identification of data sources as the most challenging phase is explored in this research. Made three conceptual assumptions regarding AI: first: AI is made of the set of programs, then: “AI is a step device and, on every step, it inputs from outside a portion of information and outputs a portion of information”, and third: “AI is in some environment which gives it a portion of the information on every step and which receives the output of AI”. Transferred to the context of AI application for SCRM the AI environment providing it with the needed information and then receiving outputs is a business organization managing its supply chain processes. And this environment should be able to serve AI with needed information and then receive outputs. This research is focused mainly on this point – challenges in business organization arising when it deals with the requirements to develop and maintain AI in SCRM providing it with appropriate data. The level of progress towards the application of AI in SCRM in organizations could be estimated following the general risk management maturity framework. The core and very essence of AI in supply chain risk management is a prediction of potential risk events, that could cause business losses, i.e., AI in SCRM is expected to do some predictive analytics. The prediction as a mathematical construct is based on calculations that estimate the probability of events. Probability estimation is done on the backgrounds of the set of prediction variables. This simple logical chain suggests that core pillars in AI development are data on risk events (as the set of predicted variables) and data on risk factors (as the set of prediction indicators). In general, the AI works with data; the case of supply chain risk management also is the same.

Figure 20 - Risk management maturity levels in association with the scope and nature of challenges in applying AI for SCRM



Risk indicator's data collection and systematization

14.2. Data and Systematization

The data collection and systematization practices in organizations are not an unambiguous phenomenon. These practices could be realized both at individual and organizational levels. Collected data of the company's operations gives us the facts and information that allows us to conclude, various business intelligence tools provide the basis for making good business decisions in order to understand business opportunities, strengths, and weaknesses. The research data indicates that individually performed data collection and systematization are not suitable for AI tools development due to the implicitness and limited opportunities to integrated different data into a single framework of organization wide SC risk estimation and management. Individual initiatives and practices mostly are based on individual experience and solutions, they lack systematization, integration, often are based on basic analytical and data management skills. The prevalence of individual experience-based practices of supply chain risk management relevant data collection and systematization is one more limitation and respective challenge in applying artificial intelligence for supply chain risk management.

As a principal theoretical-conceptual attitude taken by this research it is stated that the potential application of artificial intelligence tools requires for few supply chain risk management practice attributes. These attributes in current day business practices are seen as prerequisites for AI tools development. The attributes of supply chain management practices are defined as risk events' data collection and systematization and risk indicator's data collection and systematization. If the data in these two categories is not collected, not systematized in organization's supply chain management practice, then the potential for AI development would be limited, restricted, and thus challenged. Data collection, storage, management, exchange, and application attributes of SCRM practices represent a scope of potential challenges for AI applications. The

improvements in either of these two dimensions would increase the potential to develop AI-based supply chain risk management, but challenges would be noticeable due to limitations in data on either predicted (outcome) variables either prediction indicators. Besides, this variation is considered as the nature of challenges. The most desirable situation from this perspective is a combination of both indicators' and outcome variables' data collection and systematization. It would correspond to an optimized state according to the generalized risk management maturity estimation framework. It is expected that organizations that meet these prerequisite conditions would reach high potential for developing AI tools for supply chain risk management.

14.3. Research Methodology

The theoretical considerations on SCRM and potential for application of AI in SCRM suggest that the scope of challenges in applying AI for SCRM extends along management practices appointed to data needed to predict risk events collection, storing, exchange, management, and application. Two data categories – i.e. SC risk events registry and their prediction indicators – are considered as two distinct fields in the scope of challenges in applying AI for SCRM. The nature of the considered challenges is captured by the categorization of managerial practices according to their maturity levels which are set by the concept of risk management maturity. On the background of such a theoretical framework, the empirical research was done to find illustrative practices (organizational features), that could be used in other research as indicators to estimate the level of progress towards the application of AI in SCRM. The case study research method allows us to explore the phenomenon more precisely within its natural define that case studies are the strategies of inquiry, which explores a real-life, contemporary bounded system over time, through detailed, in-depth data collection involving different sources of information.

14.4. Case Selection

In selecting a case for the study, the aim was to identify an information-rich case, from which much can be learned about the phenomenon. Application of AI for SCRM is not an established concept and the levels and types of adoption in the company are currently unclear. Several criteria were imposed when selecting the target case to study. The firm (for confidentiality referred to as The Holding Company) has extensive experience in a range of different industries and markets. Second, the selected case company had to be performing its business in supply chains on width and depth bases. Third, selected the Holding Company initiated the implementation of AI for SCRM during the research period. We think that these criteria ensured that collected primary data is appropriate and sufficient to achieve the above-stated aim of empirical research. The Holding Company is specialized in the supply and distribution of commodities and raw materials. It is one of the most diversified commodity and raw materials distribution groups in Eastern Europe. The activities are grouped into several business segments (biofuel, agricultural products, textile, processed food, energy, packaging, industry, services, and plastic materials). Today, The Holding Company has trade relations in 70 countries worldwide, with the main trade markets in Europe.

14.5. Data Collection

Data were collected from May to July 2019 through 7 semi-structured interviews, lasting 145 minutes on average. We discussed with senior executives about which employees would be most appropriate to provide in-depth insights relevant to the research question. Heads of Finance (A), Accounting (B), Logistics (C), Law (D), Prevention and vindication (E), IT (F), and SEO (G) participated in the research. All informants were experienced and represented business support functions in the selected enterprise. They were able to critically examine the supply chain risk events and their indicators data collection and systematization practices in the large commercial company operating in a wide range of different industries. All interviews were conducted by three researchers, recorded and transcribed verbatim within 17hours estimate. The pages of transcriptions were officially approved by the Holding Company representatives to ensure the reliability of obtained information.

14.6. Data Analysis

MaxQDA 18 software was used for qualitative analysis of the interview transcripts. Each step of the analysis was conducted separately by the two researchers and thereafter jointly agreed. The transcribed interview data were coded by key researched categories (i.e., supply chain risk events' data collection and systematization practices; as well as a supply chain risk indicators 'data collection and systematization practices) defining the scope of challenges for the application of AI in SCRM. Coded data in each of these two main categories then were sub- coded into three subcategories defining the nature of challenges in applying AI for SCRM. Analysis of explored challenges nature, i.e. coding of observed data collection, storing, management, and application practices with the categories defining the nature of the challenges, revealed one more data category – i.e. reasons and causes that prevent from advancement to the desired state appropriate for AI – when risk events' and risk indicators' data is collected, stored, managed, exchanged, and applied for risk assessment and management at the organizational level through organization-wide infrastructure. Thereafter, a cross-analysis of coded practices was conducted by using data matrixes displaying each element with axial coding.

The outcomes of the research, discussed in the following chapter, due to the exploratory character of qualitative research design should help to understand better what challenges defined by the theoretically preassigned scope and nature prevent companies from the successful application of AI for SCRM and how to identify and notice these challenges.

14.7. Results

The qualitative data analysis was done to explore SCRM practice in the business organization that is in the transition to the organization-wide application of AI in SCRM. This context was found as appropriate for the empirical reveal of challenges in applying AI for SCRM of variating nature. **Tables 9.** provide primary research data quotes that were coded as management practices of various kinds in supply chain risk events' and risk indicators' data collection, storing, management, exchange, and application. The variation in nature of challenges in applying AI for SCRM is spanned by three kinds of observed managerial practices categorization: including the first level that is categorized and defined as "Data is not collected, not systematized", which corresponds to two initial levels of risk management maturity; the second

group of practices is categorized as “Data is collected and systematized by individual initiative-based practice”, which represents intermediate levels of risk management maturity; and finally research category “Data is collected and systematized by organization-wide systemic practices” is intended to represent the mature state of risk management.

These quotes from primary data then were redefined to provide a set of illustrative organizational features that could be used as checklist entries to estimate the level of progress towards the application of AI in SCRM. These research outcomes are considered in the discussion and implications chapter.

Table 9: Selected quotes from interviews depicting supply chain risk events' data collection and systematization practices as prerequisites for AI tools development

Research categories	Data is not collected, not systematized	Data is collected, systematized	
		Individual initiative-based practice	Organization wide systemic practices
Risk events' data collection and systematization	“when a contract is executed, youhave to ensure, that all entries aresafely kept, we did not have themall secured” (B),	“when contracts' details are needed to check after some time, managers not always can provide all of the details” (B),	
	“it happens that clients purchasedata do not match with ours' sales data, then it is difficult to trace where was the mistake” (E),	“we are ticking by hand when order is completed successfully, actually number of negative events is very small and it is not relevant to develop some system for this reason” (C),	we have all payments history stored in our system; at any time we can check if the payments are delayed, what is agreed payments period” (A),
	when data about events is not collected, no one takes care, no decision are being made” (G),	“it was that one of our managers during his holidays arranged with client that payment will be made, but this was not confirmed in the system,and products were shipped for another customer” (E),	our system can check all contracts, it sends automatic notifications when payments are delayed” (B), “if the transportation order is associated with the actual purchase, then the system can prove that order, orders are crosschecked” (C),

14.8. Data Collection

All three data collection, storing, management, exchange, and application practice categories defining the variating nature of challenges in applying AI for SCRM were observed in the selected case company. Clients' payments history tracking, delayed payment notifications, and transportation orders crosschecking are instances that reveal existing risk events' occurrence data collection practice. The quotations list of instances of risk events' indicators data collection and management on individual experience and individual responsibility based and pieces of evidence of no data collection are much more extensive and comprehensive **Table 10.** This is reasoned and explained by the fact that the researched organization currently founds itself in the transition towards the extensive application of AI for SCRM.

Not only those practices that were categorized as representing a mature state of risk management will be taken as empirical backgrounds to define illustrative organizational features that could be used to estimate the level of progress towards the application of AI in SCRM. Quotations representing not mature risk management categories also were treated as relevant organizational features; they were defined in the opposite ways to represent them as required practices.

The number of instances and respective quotations revealing supply chain risk indicators' data collection, storing, management, exchange, and application practices are larger. The indicators describing clients and suppliers, carriers, orders, appropriate contract documentation are collected, stored, managed, and applied for supply chain risk assessment through organization-wide infrastructure. But the mature state of risk management is not yet reached, and this is seen by quotations which indicate that a wide range of relevant data still is not collected, or their collection and storage is delegated to the individual managers, which is not an appropriate direction in the context of attempts to apply AI for SCRM.

Table 10: Selected quotes from interviews depicting supply chain risk indicators data collection and systematization practices as prerequisites for AI tools development

Research categories	Data is not collected, not systematized	Data is collected, systematized	
		Individual initiative-based practice	Organization wide systemic practices
Risk indicators' data collection and systematization	"data is not systemic, they are more like single messages"	we are looking for company details in CreditInfo, Infolex CFO could explain you more, it is his responsibility to check this data periodically, I am looking form law side"	"we have clients' insurance information on an extended form of client's card, it indicated where insurance was issued, we see these essential things" (G),
	we get data and we save it on our own, we do not put them into some system or somewhere" (A),	when dealing with a new client, they say to me: "look at them, how do they look from the law side? (D)	the data about changes in orders processing is stored in our system, but it is difficult to have all relevant data in chronological sequence" (C),

14.9. Challenge

Challenges in applying AI for SCRM are associated with the coded practices. As it already was explained, challenges are concentrated at the intersections of different scopes and kinds of nature. Most extensive challenges are expected when an organization does not collect, stores, manages, applies neither risks' events', nor risks' indicators' data. As it is suggested by the risk management maturity framework, these challenges will diminish by changing supply chain risk events' and their indicators' data collection, storage, management, exchange, and application practice from those based on individual experience and responsibility to ones embedded as organization-wide infrastructure. Besides the above-considered practices that reveal the scope and nature of challenges in applying AI for SCRM, the primary data also were explored for the reasons and other organizational circumstances that prevent the organization from progress towards the application of AI for SCRM. The following categories were considered and data coded as exposing general reasons limiting AI development:

- Employees and officers see no point: "I don't collect, I don't have it" (A)
- Experiencing new situations, experiences: "when you're making a deal somewhere… need to have that place to keep a record. We, of course, didn't have that" (B)
- Couldn't get the required data: "You can just go there, have a talk and that's that. Now who's going to open up their kitchen for you? It doesn't work that way. No such documents exist." (E)

- A need for such data arises unexpectedly: “I can identify this when some kind of event happens, that’s when you really need the data” (F),

It was also observed that situations arise in The Holding Company when data is being collected, but not organized or analyzed. The main reasons for this are:

- Incompatibility of data formats: “this data is usually scanned, not Excel” (A),
- Data is fragmented: “No no, in organizing it’s difficult to get, these are more of isolated message” (A),
- Difficult to process: “we are archiving them somehow, but we’re not entering them to the system, to have something run automatically” (A),
- Lack of needed competence: “there are many such things and how to organize them?”(E),

The individual experience-based practice is often encouraged by a general approach taken in the Company’s supply chain risk management. The establishment of these practices is often motivated by the following reasons:

- Aim to reduce risk in the single supervised area of work (expert’s area of responsibility): “when having the sum of these indications the restructuration has started. And bankruptcy procedure also. The beginning is enough, don’t even need the ending. When it begins it means that either way you already have a problem” (D),
- Elimination of human error: “Need to check it, because it’s not necessarily malicious - might be due to haste. Due to haste, because especially with large volumes, when you read the same thing for the hundred twentieth time” (B),
- Implementing new practices: “it’s still possible to keep everything in check, those emails, that what the row shows, for example, title with real IP addresses to check whether it matches” (A),

Finally, it is worth noting those benefits and improvements, which are associated with the expected organization-wide and systematic SCRM practices that are created and/or adapted in the company:

- Whole organization coverage: “guys have the information put together pretty good. We have a look at what is relevant from the legal perspective. The financial analyst could tell you more about this, he’s doing the whole review” (D),
- Complex evaluation of risks: “if this is for prevention, let’s say it’s some new client saying: now look at this from the legal perspective. So that mirror I look at that mirror from the legal perspective, which is indicating trouble for us” (D),
- Complex risk management: “when buying, when taking out the products, check that everything is right with the documentation; to avoid tax disputes and perhaps frauds. Because the more you demand, the more risks you are managing” (G),
- Improved risk management processes: “when the companies bankrupted, analyze them, add...variables. See what happened to them” (G).

All in all, the results of the exploratory primary data research are illustrative and with the potential for conceptual and empirical outcomes. Empirically, the above given summary is useful for the case company to develop and improve SCRM practices aiming at higher efficiency and wide application of AI tools. Conceptually, the results of the exploration are used to provide research data-based illustrative organization features, that could be employed as the research indicators or managerial checklist to assess the organization's progress towards the application of AI in SCRM. We are elaborating on this point in the next section of the paper.

14.10. Discussion and Implications

The in-depth analysis of collected quotes from empirical data let to provide a selection of illustrative features, that could be treated as indicators to be used to estimate the level of progress towards the application of AI in SCRM. It is noted here that the provided list should not be treated as an approved methodology. It is supposed to serve as an initial guide. The actual measurements or estimations could be done by using common categorical or nominal scales: yes/no counts, never, sometimes, often, always scale, and other measurement ways should be considered as appropriate. The number of points collected in two dimensions indicates the level of the progress towards the application of AI in SCRM. Respectively, the nature of challenges in applying artificial intelligence for supply chain risk management would then be defined. The positioning of identified challenges, restrictions, and limitations in the above discussed theoretical framework **(Table 10.)** would suggest the directions for needed developments and improvements. Two main directions are expected for these developments and improvements: either they will have to be focused on risk events' or risk indicators' data collection and systematization by the processes of storage, management, exchange, and application.

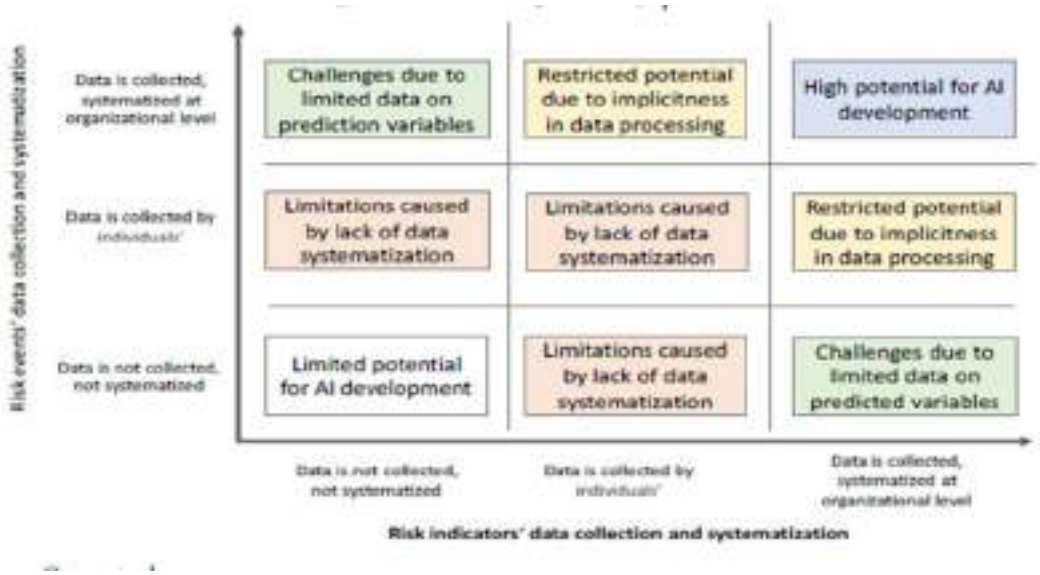
Table 10: Selection of illustrative organizational features that could be used to estimate the level of progress towards the application of AI in SCRM

	Risk events' data collection and systematization	Risk indicators' data collection and systematization
Data is not collected, not systematized	Sales contracts' details are entered manually by sales managers	The data about clients reach financial officers as separate massages from range of different data sources
	Occasions when clients' contracts data do not match company's entries	Financial statements and other data about clients is collected in scanned documents format
Individual initiativebased practice	Contracts related data is stored by managers personally	The data about clients is collected and stored by the chief financial officers
	Late paying clients are suspended by decisions of individual managers	Commercial contracts related data remains stored in managers e-mail correspondence
	Lists of debtors are updated by managers	Each functional department and managers have their own lists indicators to estimate risk potential
	Sorting of contracts to successful and failed is performed manually by managers	Financial officers are responsible for periodical clients' data updates from external data sources
	Managers are allowed to manage their contracts during the holidays	Law department officers are responsible for periodical clients data updates from courts
Organization wide systemic practices	There is the registry of the events which cause losses or other troubles	Operations of managers (e.g. number of sent emails) are tracked for potential risk issues
	Events which cause losses or other troubles are registered constantly, chronologically	Selected external indicators (e.g. average price) are observed to track performance of products categories
	Payments delays are checked and clients are notified automatically	Constant monitoring of clients data such as expiration of export-import permissions, registration code, VAT payer code, official address and similar
	Critical payments delay time is set and clients are suspended from purchases	Constant monitoring and updates of clients credit insurance policies, credit limits, and periods
	Trackable payments history is stored	Trackable data on contracts details changes
	Trackable payments history covers data on agreed payment delay periods	The exchange of contracts data among departments is automatized
	Transport orders are cross checked to ensure that corresponding purchase order actually exists	All contracts documents digitalized uploaded and processed for potential risks in supply and sales contracts
	e-mails are filtered and only approved senders are allowed to reach managers	Interactive profiles of clients, carriers, and other supply chain partners are used to manage data

Though this research did not consider different risk types or supply chain risk categories, empirical incidents, taken from real practice of certain case company, naturally, are related to the certain risk events or broader risk categories. The proposed list of illustrative organizational features includes SC risks related to buyers, clients (covering such events as delayed payments, underpayment, and other), contracts management-related risks (e.g. inappropriate quantity of shipped products, redundant transport orders), and internal managerial stuff related risks (loss-making contracts incompatible with the interests of an organization).

Regardless of certain risk events category, challenges in the application of AI for SCRM would occur due to limitations caused by lack of data systematization when SCRM management is dominated by practices based on individual experience and respective responsibility (as it is reported above representing results of empirical data exploration). The limitations of data on either risk events' (i.e. predicted) or risk indicators' (i.e. prediction) variables would cause challenges in applying AI for SCRM as long as both sides should be filled with appropriate data to employ tools of AI. Any implicitness in data processing covering collection, storing, data management, exchange still would cause challenges for the application of AI for SCRM as long as organization-wide infrastructure will be created and employed. **Figure 21.** represents this typology of challenges according to their scope and nature in applying AI for SCRM based on the risk management maturity concept.

Figure 21. - Typology of challenges according to their scope and nature in applying AI for SCRM based on risk management maturity concept



The proposed illustrative organizational features that could be used to estimate the level of progress towards the application of AI in SCRM are supposed to assist in indicating the current state and setting directions for required improvements. The selection of organizational features illustrating the variating nature of challenges is derived from a single case study and is expected to be expanded by other research in a different context in terms of sector of economic activity, geographical coverage, and other characteristics.

15. SAP Transportation Management (SAP TM)

The end-to-end (E2E) transportation management (TM) process is a comprehensive system that spans across multiple stages, from planning and execution to monitoring and optimization. Each phase plays a critical role in ensuring the efficient and cost-effective movement of goods within the supply chain.

In the planning phase, the system analyzes various variables to determine the most efficient and economical way to transport goods or services. This may include route optimization, carrier selection, and capacity planning to minimize costs while meeting delivery requirements.

The execution phase involves the actual allocation of resources, such as vehicles, drivers, and any necessary equipment. At this stage, the system also ensures that all required documentation - such as shipping labels, customs paperwork, and compliance forms—are accurately generated and processed.

During the monitoring phase, SAP TM tracks the real-time movement of shipments, providing visibility into the status of goods in transit. This allows for early detection of potential issues, such as delays or route disruptions, enabling proactive intervention and timely resolution.

Finally, the optimization phase leverages the data collected throughout the previous stages to identify areas for improvement in the transportation system. By analyzing performance metrics, SAP TM helps businesses optimize routes, reduce costs, and improve service levels, contributing to a more efficient and responsive supply chain.

Overall, the E2E transportation management cycle is a cornerstone of effective supply chain management, ensuring that goods are delivered on time, within budget, and securely. Figure 1 below illustrates the key processes that make up the E2E TM cycle, providing a visual representation of how these stages interconnect to drive transportation efficiency. Below is a **Table 11.** that summarizes the key stages of the end-to-end (E2E) transportation management (TM) cycle in SAP TM, highlighting the main activities and objectives of each phase:

Table 11: Key Features of SAP Transportation Management (SAP TM)

Phase	Description	Key Activities	Objective
Planning	Identifying the most efficient and cost-effective transportation approach.	- Route optimization - Carrier selection - Capacity planning	To design the optimal transportation plan that minimizes costs and maximizes efficiency.
Execution	Allocating resources and ensuring proper documentation for transportation.	- Assigning vehicles and drivers - Generating shipping documentation	To implement the transportation plan and ensure all logistics requirements are met.
Monitoring	Tracking real-time movement of goods and identifying potential issues.	- Tracking shipments - Identifying delays or disruptions	To gain visibility into the transportation process and resolve any emerging issues promptly.
Optimization	Analyzing data to identify areas for improvement and enhance system efficiency.	- Data analysis - Performance review -Identifying inefficiencies	To continuously improve transportation performance, reduce costs, and enhance service levels.

This table outlines the key functionalities and features of SAP Transportation Management (SAP TM), providing an overview of its core capabilities, benefits, and integration points within an enterprise's supply chain. SAP TM is designed to streamline the planning, execution, and optimization of transportation processes.

This illustrates the key steps and processes involved in SAP Transportation Management (SAP TM). Its shows how transportation planning, carrier selection, execution, and freight cost management are interconnected in the overall supply chain, ensuring an optimized and streamlined transportation process. The flow also highlights integration points with SAP S/4HANA, demonstrating how data is seamlessly exchanged between systems to improve decision-making and efficiency.

The diagram typically includes the following components:

- Transportation Planning: Starts with the creation of transportation plans based on demand and route optimization.
- Freight Order Management: Moves to the creation of freight orders, including tendering to carriers.
- Carrier Selection: Involves choosing the right carrier based on predefined criteria such as cost, service, and capacity.
- Execution: Tracks the transportation process, from shipment dispatch to delivery, ensuring accuracy and timeliness.
- Freight Cost Management: Monitors and manages the associated costs, enabling financial analysis and reporting.
- Event Management: Captures and manages any disruptions or issues in the transportation process.
- Integration with SAP S/4HANA: All steps are interconnected with SAP S/4HANA for seamless data flow and enterprise-wide process visibility.

This flow ensures that the SAP TM system supports end-to-end transportation management, from planning to execution, with a focus on efficiency, cost management, and customer satisfaction.

15.1. Adoption Barriers and Challenges

While there are significant benefits of integrating emerging technologies such as AI into SAP TM from a resiliency and efficiency standpoint, there are some significant barriers that need to be addressed to ensure the successful adoption of AI in TM. Some of the key challenges are as under –

15.2. Technological

Ensuring data integration, quality, and explainability is one of the main technology problems in adopting AI with TM. For AI systems to produce reliable insights and outputs, a vast amount of high-quality data is required to train and finetune AI models and algorithms. Organizations to date are operating in data islands and silos given their nature of landscape and disparate systems which causes discrepancies and leads to hallucination of models owing to poor integration and data quality. A study found that 48% of supply chain executives name data integration and quality as major barriers to the deployment of AI. Additionally, might be difficult to integrate AI technologies with present SAP TM infrastructures; this calls for advanced IT skills and frequently calls for major system changes.

15.3. Organizational Change Inertia

Employees and the workforce are reluctant to new ways of operating and are hesitant to adopt new technologies fearing disruption and job insecurity. Digital reskilling and lack of skilled personnel is another factor. A survey by found that 41% of respondents identified organizational resistance as a critical hurdle in implementing AI in supply chain management. There is a demand-supply deficit (high demand for the right skilled resources, short supply) which further hinders efforts to adopt newer technologies.

15.4. Financial

Every new technology comes with its financial implications and AI being an emerging technology is evolving and the cost of adopting and implementing AI is significantly higher today. Initial investment costs pertain to hardware, software, and training, grounding of models which are prohibitive. According to the Boston Consulting Group, 52% of executives consider the high cost of AI implementation a major barrier. Moreover, there is often uncertainty regarding AI projects' return on investment (ROI). Organizations may be reluctant to invest heavily without clear evidence of the financial benefits, leading to cautious or delayed adoption.

15.5. Ethical

As supply chain data is sensitive (including tier N supplier’s suppliers), data privacy and regulatory challenges are of paramount importance. Additionally, AI models must be transparent, responsible, and ethical in their outputs. Organizations must ensure that AI-driven decisions are explainable and that biases are minimized, which requires ongoing monitoring and validation of AI systems.

Cultural-organizational culture, values, and beliefs play instrumental roles in determining how new technologies are received, leveraged, and adopted. Employees might fear job displacement due to automation, leading to a lack of buy-in and support for AI initiatives. Research by Harvard Business Review indicates that cultural resistance is one of the top barriers to digital transformation, including AI integration.

Organizations need to navigate the barriers to ensure the successful adoption of AI technologies in unison with SAP TM. Addressing these barriers requires a holistic approach that includes robust data governance, effective change management, continuous learning, and fostering a culture of innovation and adaptability.

15.6. Benefits of Integration

Integrating AI with transportation management is revolutionizing the way supply chains operate and become more proactive and responsive. This synergy enhances operational efficiency, cost savings, resilience, risk management, and competitive advantage, making it a critical strategy for modern supply chains.

15.7. Supply Chain Resiliency

With the advent of AI, systems such as SAP TM can provide contextual insights to detect anomalies and predict disruptions before they occur. Patterns can be identified from vast amounts of fleet data, telematics, road conditions, and weather data to proactively track and predict unforeseen events. This allows organizations to develop contingency plans and mitigate risks proactively. Contingency plans such as rerouting shipments, and leveraging alternative carriers are common occurrences to ensure business does not get disrupted when faced with unexpected challenges.

15.8. Strategic Growth and Innovation

AI integration with SAP TM provides a foundation for innovation and organic growth for organizations as AI frees up human resources to focus on strategic and mission-critical tasks. Transportation planners can leverage AI for route optimization and another potential use case could be the intelligent summarization of notes for drivers, and carriers thereby improving service quality and productivity, World Economic Forum. "Blockchain and AI: Revolutionizing Supply Chain Transparency.

15.9. Operational Efficiencies

SAP TM provides a unified and comprehensive platform to integrate business processes across freight order, delivery, carrier tendering, freight settlement, and warehousing operations. This integration ensures that the entire transportation process is streamlined, leading to significant time and resource savings. Additionally, AI can be leveraged to optimize resource allocation by identifying the most cost- effective transportation routes and modes, thus lowering fuel consumption, carbon footprint, and overall reduction in labor costs.

15.10. Competitive Advantage

Integrating AI with SAP TM offers a competitive edge as it enables organizations to adapt quickly in the marketplace. Firms that adopt AI have first mover advantage as they are better equipped to anticipate customer needs, personalize services, and enhance customer satisfaction. AI can monitor disruptions in real-time by freeing up resources to focus on strategic value-added tasks and projects.

15.11. Transparency

With real-time insights and data analysis from AI, customers, suppliers, and organizations can experience improved communication and end-to-end transparency across the supply chain and can take targeted actions or decisions if needed. This helps build trust and facilitates all supply chain partners to collaborate nimbly. Organizations can make more informed decisions, optimize their transportation processes, and proactively address potential challenges, ultimately improving their overall supply chain performance.

15.12. AI and SAP TM in Action

The primary focus for AI has been centered around enhancing productivity, and operational efficiency, and enabling proactive action. However, AI algorithms can be effectively applied across multiple real-life use cases in integration with

SAP TM. We aim to delve into several key use cases identified through discussion with Supply Chain practitioners**.** AI and SAP Transportation Management (SAP TM) in action, you can conceptualize how Artificial Intelligence is integrated into the various processes of SAP TM to improve transportation planning, execution, and analytics. Artificial Intelligence (AI) enhances SAP Transportation Management (SAP TM) processes:

- SAP TM handles key transportation functions: Order Management, Planning (route/load optimization),
- Execution (shipment tracking), and Analytics (KPI reporting).
- AI powers Machine Learning for demand forecasting and route optimization, NLP for chatbots and document automation, and Optimization Algorithms for dynamic carrier selection and performance improvements.
- Data Integration from IoT devices (e.g., GPS, vehicle sensors) and historical data enhances real-time decision making.
- The End-to-End Process Flow includes Order Creation, Demand Forecasting, Execution, and Continuous
- Feedback for optimization.

15.13. Dynamic Route Optimization

Real-time data such as traffic congestion, road construction, weather reports, and telematics on drivers and vehicles can be fed into AI models to forecast and plan routes dynamically. Even though, this feature was available in SAP TM, technologies such as AI further enhance accuracy and predictability. The AI models analyze these inputs to recommend the most efficient routes for vehicles, considering factors like fuel efficiency, delivery times, and vehicle capacities. According to a study by McKinsey, implementing route optimization features resulted in a 15% reduction in transportation costs and a 20% improvement in on-time delivery performance.

15.14. Predictive Maintenance for Fleet

AI models analyze years of historical maintenance data of fleets, vehicular sensor readings, telematics information, and other operational engine parameters are keyed in models to predict potential equipment failures before they occur. This helps organizations to schedule repairs during planned downtime and reduce unplanned disruptions. It also helps in extending the lifespan of fleets thereby reducing the burden on the environment from a sustainability standpoint.

15.15. Demand Forecasting

As SAP TM has historical data on shipment volumes, delivery times, and freight volumes, AI models help organizations anticipate transportation needs and optimize routing and carrier scheduling thereby reducing costs in the long run. These algorithms are trained on historical data to improve the accuracy of predictions over time. Additionally, transportation planners can execute simulation scenarios to see the potential impact of different variables on demand ultimately preparing organizations for peak, cyclical, and seasonal periods.

15.16. Future Trends and Innovations

The integration of AI with SAP TM is well-positioned to transform the supply chain sector. Given the pace of technological innovations in the AI domain, there will be a profound impact on the logistics industry. The exhibit is highlighting the evolving nature of future supply chains across key areas of an organization.

15.17. Predictive Analytics

The supply chain of the future will see more accurate and advanced models and analytics powered by AI enabling better predictability of freight volumes with minimal disruptions. Organizations would be able to not only forecast future events based on copious data but also recommend specific actions to optimize business outcomes. For example, if a given transportation lane or road route sees a significant spike in demand, AI prescriptive analytics would adjust rerouting vehicles, calibrating shipment schedules on the go for efficient planning and execution.

15.18. Autonomous Vehicles

Another technology that holds the potential to revolutionize the transportation sector is the use of autonomous vehicles and drones. Self-driving trucks, and trailers equipped with AI technology will enable 24/7 operations. Companies like Tesla, and Waymo are already beta-testing trucks for long-haul shipment and are waiting on federal and state laws to make them legal as safety is of paramount importance. Drones can expedite last-mile delivery in urban congested areas or rural remote locations. AI models can coordinate drone fleets and ensure timely, safe, and efficient package deliveries.

15.19. Green Logistics

AI integration with SAP TM helps in optimizing load planning, and routes which leads to a reduction in fuel consumption and overall reduces carbon footprint due to transportation. AI can be used for simulating key features such as consolidating packages, and pallets to reduce the number of trips further helping companies achieve their sustainability targets, "Sustainable Supply Chains: The Role of AI.".

15.20. Freight Procurement

AI integration with SAP TM will help evaluate automated tendering bids and select the best carrier based on predefined criteria. Dynamic pricing models based on historical data can be built to analyze market conditions and provide guidance on reducing overheads and enhancing shipper-carrier relationships in the marketplace.

16. AI Techniques Applied in Supply Chain Management

Artificial Intelligence has revolutionized supply chain management by offering advanced tools for real-time data analysis, predictive analytics, and decision-making. Various AI techniques, including machine learning, deep learning, and reinforcement learning, have been applied to different aspects of supply chain optimization, demonstrating significant improvements over traditional methods.

Machine learning, a subset of AI, involves algorithms that learn from data to make predictions or decisions without being explicitly programmed. In inventory optimization, ML algorithms can process vast amounts of historical and real-time data to forecast demand more accurately. For instance, regression models, support vector machines, and ensemble methods like random forests and gradient boosting are commonly used for demand prediction. These models can handle complex relationships between variables and adapt to new patterns over time.

Deep learning, an advanced form of ML, utilizes neural networks with multiple layers to extract high-level features from raw data. Deep learning models, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), have shown remarkable success in various domains, including supply chain management. RNNs, in particular, are well-suited for time-series forecasting, making them ideal for predicting demand and supply trends in inventory optimization. By capturing temporal dependencies and nonlinear relationships, deep learning models can provide more accurate and robust predictions compared to traditional statistical methods.

Reinforcement learning (RL), another AI technique, focuses on learning optimal policies through environmental interactions. In the context of inventory optimization, RL algorithms can dynamically adjust inventory levels and reorder points based on real-time feedback from the supply chain. Techniques like Q-learning and policy gradient methods enable continuous improvement of inventory policies by balancing exploration and exploitation. RL has the potential to optimize complex, multi-echelon supply chains where decisions at different stages affect overall performance.

AI techniques are also being integrated into supply chain management systems through advanced software solutions. These systems leverage AI to automate routine tasks, optimize routing and scheduling, and enhance supply chain visibility. For example, AI-powered platforms can predict potential disruptions, recommend proactive measures, and optimize transportation routes in real-time. By incorporating AI, companies can achieve higher.

16.1. Identification of Gaps and Areas

Despite the significant advancements in AI-driven inventory optimization, several gaps and areas for further research remain. One major gap is the integration of AI techniques with existing supply chain systems and processes. While AI has shown great potential, its adoption is often hindered by legacy systems, data silos, and the lack of interoperability between different technologies. Future research should focus on developing standardized frameworks and interfaces to facilitate seamless integration of AI into supply chain management.

Another area for further research is the interpretability and explainability of AI models. Although AI algorithms can provide highly accurate predictions, their decision-making processes are often opaque, leading to challenges in gaining trust and acceptance from stakeholders. Research should aim to develop transparent AI models that offer clear explanations for their predictions and recommendations. This will enhance the usability of AI in inventory optimization and foster greater confidence among supply chain professionals.

Data quality and availability are also critical challenges in AI-driven supply chain management. AI models rely heavily on large volumes of high-quality data for training and validation. However, many supply chains suffer from data inconsistencies, missing values, and limited access to real-time information. Future research should explore methods for improving data collection, cleansing, and integration to ensure reliable inputs for AI models. Additionally, the development of robust AI techniques that can handle noisy and incomplete data is essential.

The ethical and social implications of AI in supply chain management are another important area for exploration. As AI becomes more prevalent, concerns about job displacement, privacy, and algorithmic bias need to be addressed. Research should investigate the societal impacts of AI adoption in supply chains and propose strategies for mitigating negative consequences. This includes developing fair and unbiased AI models, ensuring data privacy and security, and promoting the re-skilling and up-skilling of the workforce. Lastly, the scalability and adaptability of AI solutions in different supply chain contexts warrant further investigation. Supply chains vary significantly across industries, regions, and scales, each with unique challenges and requirements. Future research should assess the applicability of AI techniques in diverse supply chain environments and develop tailored solutions that can adapt to specific conditions. This will enable broader and more effective implementation of AI-driven inventory optimization across various sectors.

AI has significantly advanced inventory optimization in supply chain management, ongoing research is needed to address integration challenges, improve model transparency, enhance data quality, consider ethical implications, and ensure scalability. By addressing these gaps, researchers and practitioners can unlock the full potential of AI to transform inventory management practices and create more resilient, efficient, and responsive supply chains.

16.2. Benefits and Challenges of Implementing AI in Real-Time Inventory Systems

The implementation of AI in real-time inventory systems offers numerous benefits, though it also presents several challenges that organizations must address One of the most significant advantages of AI-driven models is enhanced accuracy in demand and supply forecasts. Traditional inventory management techniques often struggle to accurately predict future needs, leading to either excess inventory or stockouts. AI models, however, can analyze vast amounts of historical data and recognize patterns that humans might miss. This improved accuracy helps organizations maintain optimal inventory levels, reducing waste and ensuring that products are available when customers need them. As a result, service levels and customer satisfaction are significantly enhanced.

Another crucial benefit is the real-time adaptability of AI techniques. Supply chains today are highly dynamic, with conditions changing rapidly due to factors like market trends, geopolitical events, and natural disasters. AI systems can process real-time data and adjust predictions and recommendations on the fly. This adaptability allows supply chains to respond swiftly to disruptions, minimizing the impact on operations and maintaining continuity. This responsiveness is invaluable in a world where delays can lead to substantial financial losses.

Operational efficiency is also greatly improved through AI implementation. Routine tasks such as demand forecasting, stock level monitoring, and reorder point adjustments can be automated, freeing up human resources for more strategic and creative activities. This leads to cost savings and allows employees to focus on tasks that require human insight and innovation. As a result, the overall productivity and efficiency of the organization increase.

AI solutions are inherently scalable, meaning they can be applied across various supply chain segments, from procurement to distribution. This scalability is particularly beneficial for large organizations with complex supply chains. A unified AI approach ensures consistency and coordination across different supply chain functions, enhancing inventory management's overall efficiency and effectiveness. This ability to scale solutions helps companies manage growth and complexity without compromising performance.

16.3. Challenges

Several challenges must be addressed to successfully implement AI in inventory systems. Data quality and integration are fundamental requirements for effective AI models. Many organizations struggle with data silos, inconsistencies, and inaccuracies. AI systems need large volumes of high-quality, real-time data to function optimally. Ensuring that data is clean, integrated, and continuously updated is critical but can be daunting.

Model interpretability is another significant challenge, particularly with advanced AI models like deep learning. These models often operate as "black boxes," making understanding how they arrive at specific decisions difficult. This lack of transparency can hinder trust and acceptance among stakeholders, who may be reluctant to rely on systems they do not fully understand. Developing methods to interpret and explain AI model decisions is crucial for gaining stakeholder confidence and facilitating broader adoption.

The costs associated with developing and deploying AI solutions can be substantial. Significant investments in technology, talent, and infrastructure are required to build and maintain effective AI systems. Organizations must carefully evaluate these costs against the potential benefits to ensure a positive return on investment. Balancing short-term expenses with long-term gains is essential for sustainable AI implementation.

There is also a notable skill gap in the workforce when it comes to AI technologies. The development, implementation, and management of AI systems require specialized skills that are currently in short supply. Organizations must invest in training and development programs to build a capable workforce. This includes not only technical training but also education on how to integrate AI into existing processes and how to manage AI-driven systems. Ethical and security concerns are paramount in the use of AI. Issues such as data privacy, algorithmic bias, and the potential for cyber-attacks must be addressed to maintain stakeholder trust and ensure the responsible use of AI. Organizations need to establish robust ethical guidelines and security protocols to protect sensitive data and ensure that AI systems operate fairly and transparently.

16.4. Impact on Dynamic Supply Chain

AI-driven inventory optimization is revolutionizing dynamic supply chains by enhancing their efficiency, responsiveness, and resilience. Traditional supply chain models often struggle to cope with the complexities and uncertainties of modern markets, where rapid changes in demand, global disruptions, and increasingly complex networks are the norm. AI technologies offer a sophisticated approach to managing these challenges, bringing several transformative impacts.

AI-driven inventory optimization significantly improves a supply chain's ability to respond to fluctuations in demand and supply conditions in real time. Machine learning algorithms can analyze vast amounts of data from diverse sources, such as sales trends, social media activity, and economic indicators, to generate accurate demand forecasts. This predictive capability allows businesses to adjust inventory levels proactively, ensuring that they can meet customer demand without overstocking. Moreover, AI can help identify potential supply chain disruptions early, enabling companies to implement contingency plans swiftly. By optimizing inventory levels, AI reduces the costs associated with overstocking and stockouts. Excess inventory ties up capital and incurs storage costs, while stockouts lead to lost sales and customer dissatisfaction. AI's ability to predict demand accurately and optimize reorder points ensures that inventory levels are kept at an optimal balance, minimizing these costs. Additionally, AI can streamline procurement processes by automating routine tasks such as order placement and supplier selection, further reducing operational costs and freeing up human resources for more strategic activities.

16.5. Analysis of How AI-Driven Inventory Optimization Affects Dynamic Supply Chains

AI-driven systems provide supply chain managers with actionable insights and data-driven recommendations. These systems can simulate various scenarios and evaluate the potential outcomes of different decisions, helping managers make informed choices. For instance, AI can assess the impact of changing suppliers, altering production schedules, or adjusting shipping routes on overall supply chain performance. This capability is particularly valuable in dynamic environments where quick, evidence-based decisions are critical. AI-driven inventory optimization improves service levels and customer satisfaction by ensuring the right products are available at the right time. Accurate demand forecasting helps avoid stockouts, ensuring that customers can find the products they need when they need them. Additionally, AI can enhance personalization by analyzing customer data and preferences, enabling companies to tailor their inventory to meet specific customer needs and.

AI helps mitigate risks associated with supply chain disruptions, such as natural disasters, political instability, or supplier failures. AI can identify potential risks and suggest mitigation strategies by continuously monitoring the supply chain and analyzing external data. For example, AI can recommend alternative suppliers or adjust safety stock levels based on real-time risk assessments. This proactive approach to risk management enhances supply chain resilience and reduces the impact of disruptions.

16.6. Scalability and Adaptability of AI Solutions in Various Supply Chain Scenarios

The scalability and adaptability of AI solutions are crucial for their successful implementation across different supply chain scenarios. Supply chains vary significantly across industries, regions, and organizational sizes, each presenting unique challenges and requirements. AI technologies must be flexible and scalable to address these diverse needs effectively.

AI-driven inventory optimization solutions are highly scalable and can be tailored to various industries, from retail and manufacturing to healthcare and logistics. AI can help manage seasonal demand fluctuations in retail and optimize stock levels across multiple locations. AI can improve production planning and synchronize inventory with manufacturing production schedules. In healthcare, AI can ensure the availability of critical medical supplies while minimizing waste. The ability to scale AI solutions across different sectors highlights their versatility and broad applicability.

Supply chains often operate globally, with significant regional variations in demand patterns, regulatory environments, and logistical constraints. AI systems can adapt to these regional differences by incorporating local data and contextual factors into their models. For example, AI can adjust demand forecasts based on regional holidays, cultural events, or economic conditions. This adaptability ensures that AI-driven inventory optimization remains effective in diverse geographic contexts.

AI solutions can be scaled to fit the needs of both large enterprises and small-to-medium-sized businesses (SMBs). Large enterprises benefit from AI's ability to manage complex, multi-echelon supply chains with extensive product ranges and global operations. For SMBs, AI can offer cost-effective, cloud-based solutions that provide sophisticated inventory management capabilities without the need for significant infrastructure investment. This flexibility ensures that organizations of all sizes can leverage AI to optimize their inventory. The adaptability of AI solutions also depends on their ability to integrate with existing supply chain systems and technologies. Many organizations have invested in legacy systems that may not be fully compatible with new AI technologies. AI solutions must be designed to integrate seamlessly with these systems, allowing for incremental implementation and minimizing disruption. This integration ensures that organizations can gradually adopt AI-driven inventory optimization without overhauling their entire supply chain infrastructure.

16.7. Strength of the Model

One of the key strengths of AI is its ability to learn and improve over time. AI models can continuously update their algorithms based on new data and feedback, enhancing their accuracy and effectiveness. This continuous learning capability is particularly valuable in dynamic supply chains, where conditions are constantly changing. By continuously adapting to new information, AI systems ensure that inventory optimization strategies remain relevant and effective. Despite the significant benefits, implementing AI-driven inventory optimization is not without challenges. Data quality and availability remain critical issues, as AI models require accurate, timely data to function effectively. Organizations must invest in robust data management practices to ensure the reliability of their AI systems. Additionally, there is a need

for skilled professionals who can develop, implement, and manage AI technologies. Addressing the talent gap through training and development programs is essential for successful AI adoption.

16.8. Recommendations for Future

Future research should focus on addressing the challenges associated with AI-driven inventory optimization to maximize its benefits. One critical area is the improvement of data quality and integration. Research should explore advanced data management techniques that ensure clean, consistent, and real-time data inputs for AI models. Additionally, developing standardized frameworks and interfaces that facilitate seamless integration of AI with existing supply chain systems is crucial.

Another recommendation is to enhance the interpretability and transparency of AI models. As AI becomes more embedded in decision-making processes, stakeholders need to understand and trust these models. Future research should aim to develop AI algorithms that provide clear explanations for their predictions and recommendations, fostering greater acceptance and trust among users.

The scalability and adaptability of AI solutions across different supply chain contexts also warrant further exploration. Research should investigate how AI techniques can be tailored to various industries, regions, and organizational sizes, ensuring their broad applicability and effectiveness. This includes assessing the unique challenges and requirements of different supply chain scenarios and developing customized AI solutions to address them. Future research must also focus on ethical considerations and the social impact of AI adoption in supply chains. As AI technologies advance, addressing concerns related to job displacement, data privacy, and algorithmic bias is essential. Developing fair and unbiased AI models, ensuring robust data security measures, and promoting workforce upskilling are critical steps to mitigate these concerns.

Companies should adopt a phased approach to AI integration for practical implementation, starting with pilot projects to demonstrate value and build internal capabilities. Collaboration with technology providers, academic institutions, and industry consortia can facilitate knowledge sharing and accelerate AI adoption. Additionally, companies should continuously monitor and evaluate the performance of AI systems, making necessary adjustments to optimize their impact on inventory management.

16.9. AI Utilization

The research results indicate the prospects of AI utilization in altering the traditional supply chain management approach. Based on the goals formulated for the study, this paper has provided a qualitative synthesis of the gathered data using post-positivist epistemology. The conclusions drawn from the analysis might be beneficial to organizations that are keen on implementing AI technologies. To explain the research limitations, the authors stated that the research was only based on the data gathered before May 2019. Thus, it would be relevant for subsequent research to address new challenges to implementation and other potential approaches to leveraging AI to maintain supply chains and resilience.

The following are the potential research areas that should address new issues related to the application of AI technologies in Supply Chains. The challenges relate mostly to low initial investment, data protection and accuracy, and the organization's ability to change. Tackling all these challenges is important in realizing the possible use of artificial intelligence in managing the supply chain.

In addition, more research has been deemed crucial for discovering fresh AI applications for defining and modeling new, green, and resilient supply chain processes due to emergent market and environmental dynamics. Knowing how AI can integrate with such constraints will prove highly beneficial for any enterprise seeking to guarantee sustainability.

Further research will certainly shed more light on these areas, thus enabling better approaches to applying AI to enhance operational performance and address issues related to the environment and the supply chain. To support this argument, it is vital to underscore the following points: This kind of research is crucial because of the fast-changing environment in global markets and constant changes in supply chain management practices.

More studies and practice-oriented activities related to AI are needed for organizations that seek to maintain a competitive advantage and adaptability in the constantly transforming global context. Frequent use and development of new AI technologies will assist companies in staying on the cutting edge of knowing the best practices for creating and maintaining an efficient supply chain.

17. The Advantages and Drawbacks of Implementing Artificial Intelligence

On discussion, the balance between wages and industrial productivity is very important for competitiveness. If innovation and cooperation are not present, we might witness some regions of the world that risk losing market portion and new business opportunities. Considering long-term strategic planning, research, development, and innovation become crucial, especially in high tech sectors like automotive. Since into the selling price wages and production hourly rates have a significant impact, to secure competitiveness, each region should maintain stable wage levels corelated with robust industry performance, inter business collaboration, and a strategic focus on research activities. If this is not achieved, companies within the supply chain will look for cheaper options in low-cost countries to support their long-term project financial figures, moving business to more advantageous production locations.

Research brings following figures into study: automotive sector employs 14.6 million Europeans, thus proving to be a significant contributor to the EU job market. Additionally, the automotive industry is responsible for 11.5% of all manufacturing jobs in the EU, showing its importance and impact in the employment sector. Each year, 62 billion EUR are estimated to be spent on research and development within the automotive industry, which represents more than one third of the EU's total research and development spending.

Being an industry that carries significant amounts of technology, intellectual property, patents, innovation, and strategic planning, the automotive industry is the core of implementation from idea to product between the final customer, the personal or commercial vehicle, on- or off-road, and the car manufacturer.

It involves a complex supply chain, as the final product itself is the result of the cooperation of multiple industries for its assembly and delivery to market. Be it raw materials such as primary metals for building engine parts or complex chemical finishes for the hood, a large proportion is obtained through complex machining processes. All subcomponent producers need to manage their companies very well and cooperate to ensure that each project is completed qualitatively, on time.

Taking into consideration the many challenges that can appear in the automotive supply chain, professionals search constantly for methods to improve performance. As travelling became easier and markets were open to cooperation, a quality-to-cost orientation became noticeable, where typically a car is made from components coming from all over the world and can be assembled entirely or partially in completely different locations than the country of the car manufacturer. Financial services development and tax incentives brought a few countries to the attention of companies for headquarters settlement or research and development selection, including setting up plants in greenfield investment areas sustained by local governments that would enable the company to gain additional competitive advantages from price.

Table 12. Enumerates the business advantages of artificial intelligence in the supply chain, referring to accurate inventory management, warehouse efficiency, enhanced safety, reduced operating costs, and on-time delivery. By analyzing daily challenges in the international automotive supply chain, we state and detail below our own original ideas for potential uses of AI to support critical activities and improve general output in automotive supply chain management in Europe.

Table 12: AI implementation areas and risks

Department	Activity	Value added	AI Risk
Quality	Validation accelerated tests	simulation results	data cyber security
Quality	Quality tracking Data matrix	improved traceability	data quality
Procurement	Procure-to-pay	order to invoice to payment	data confidentiality
Logistics	Warehousing and goods receipt	inventory management	data confidentiality
Purchasing	Supplier selection	auction platforms	data confidentiality
Finance	Pricing indexation	real time escalation/de-escalation	data cyber security
Logistics	Demand and stock management	on time stock	data cyber security

However, the list above has limitations: these areas of applicability can be considered, ensuring that the benefits overcome the associated risks and that the necessary budget for implementation is justified and can be made available by the company. Therefore, we detail in the following our view on each of the proposed areas of AI implementation.

Safety regulations in the European Union and globally, together with the manufacturer's experience and field results, make validation one of the most complex and extensive activities in the automotive industry. Certain categories of components that withstand high amounts of stress, wear, temperature, and pressure need to be tested and validated in terms of material, performance, and durability to ensure no field incidents or recall campaigns will occur due to
their potential failure.

Data matrix implementation is an initiative through which AI helps to include in a quick response (QR) code all necessary agreed-upon information about the origin of the part, date of processing, number of operations executed, and other relevant information set internally in the company or agreed with the customer for it to be available for reading in their facility.

Figure 22 and 23. Many companies outsourced their functions of accounts payable and accounts receivable to countries that have low costs to ensure a better financial impact of these services. This can prove to be detrimental for the company, as any errors that could appear in this process could block payments to suppliers or from customers. Invoices posted late, wrongly categorized, accepted although they have missing information, or with major errors (that is, in the term of payment, account number, quantity, etc.) not addressed in time could even stop deliveries if the amounts are significant and if the parties' collaboration is at the beginning. The implementation of AI could also eliminate or reduce human errors. For instance, AI could automatically read invoices and post in an automated way, then send to payment. The risks associated with AI in this area of the supply chain come from cyber security.

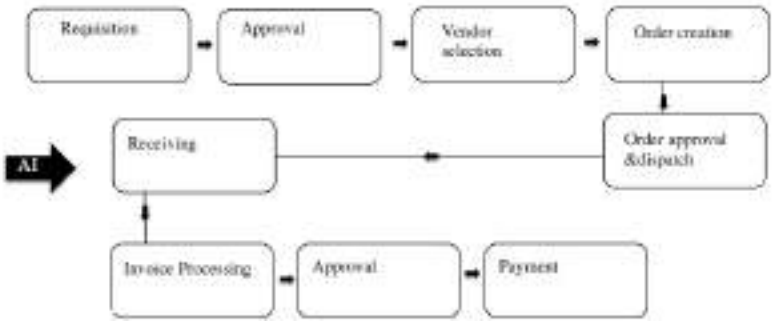


Figure 22 - The Procure to Pay Process – Options to utilize AI

AI has both advantages and disadvantages in the context of cyber security. AI-based cyber security systems can improve the capabilities to detect and respond through identifying patterns of cyberattacks and threat intelligence.

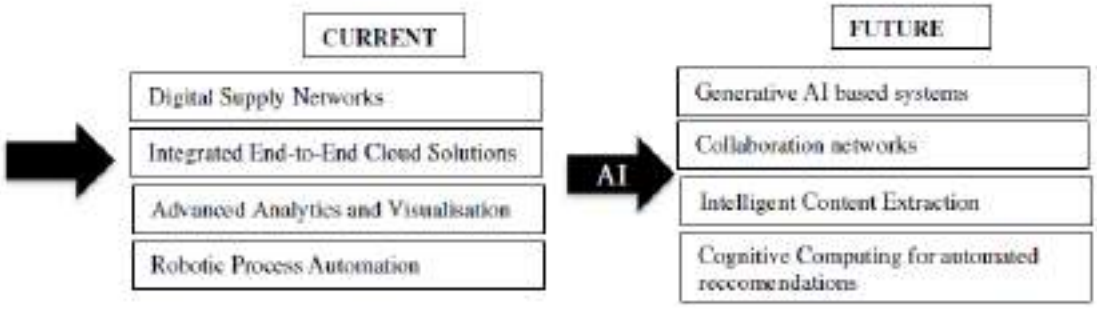


Figure 23 - Transitioning from the Current to the Future Supply Chain by Implementing AI

Choosing suppliers is critical in supply chains, because each product presents a set of benefits and risks in the relationship between supplier and client. When trying to decide for a supplier, customers usually compare the following variables: price, quality, on-time delivery, payment terms, the necessary investment, and the technical capabilities of the supplier. This decision is not always easy, which is why the implementing AI would dramatically improve the supplier selection process. The ideal process would start with the quotation phase where specifications would be automatically released to a pre-approved supplier panel, and it would continue with the supplier filling in the technical feasibility and quotation online.

As next steps, AI would select different types of data by interrogating fields and comparing them to both the budget allocated for the project and the internal assessment of costs. AI would then propose the suppliers target prices and would come forward with queries for improvement based on the analysis of costs.

AI can help significantly in repairing the risks associated with the transition to electric cars. AI is able to optimise charging schedules to be efficient and cost effective by learning from daily habits and real-time electricity prices. AI could notify about issues and suggest measures to be taken as aftermarket services for electric vehicles. The European Commission (2023) highlights the policies that the EU has in place to mitigate the risks posed by AI.

The EU's initiatives having the scope to increase the competitiveness in Europe, and more specifically in the auto industry, allow Original Equipment Manufacturers (OEMs) to increase their profits as well as benefit from the societal advantages of AI. It is very important to balance the safeguarding of AI consumers with fostering innovation and market growth. When examining the risks mentioned above, the role of AI becomes more and more relevant, because it can pose risks, but also offer potential solutions. German automakers launched the Catena-X Automotive Network, which has the purpose of improving the digital supply chain through an open data network and discusses the implications of this initiative in his work. By combining collaborative data utilization and AI, this network aims to improve supply security and promote digitalization.

17.1. Case study: Audi's AI Implementation

Audi is a German automotive company part of the Volkswagen Group. It is very popular worldwide because of its automobiles. The fact that Audi buys materials and components from different countries places it in a worldwide supply chain network. This network entails stakeholders such as manufacturers, suppliers, and dealers spread globally. This global presence allows Audi to use better resources and to optimize the costs of production.

Audi's manufacturing system is very efficient, because components and materials are delivered to the manufacturing line just in time, according to certain deadlines, reducing inventory expenses. Moreover, Audi's seriousness made its relationship with suppliers very strong. This guarantees the high quality of Audi's vehicles, as well as Audi's reliability. The company also has in place principles in its activities connected to the supply chain that have the scope of eliminating waste and making operations more efficient.

The fact that Audi is responsible regarding the environment implies, among others, that it aims to reduce the emissions of carbon, and it want to only use sustainable materials, while preserving the natural resources. Audi and the Volkswagen Group took measures to improve the resilience of their supply chain during the COVID-19 pandemic. Believe that algorithms based on AI can process data in real-time and offer options such as selecting personalized settings and features for safety. Audi checked the reliability of its AI-based software for more than 4,000 suppliers and concluded that AI is efficiency in responding quickly to supply chain risks (Supply chain monitoring: Audi uses artificial intelligence (AI) for sustainability, 2021).

AI also has an important role in the ecosystem that connects vehicles at Audi, in order for them to communicate and offer real-time traffic updates. It is described how AI was used to find links between issues found in supply chains and certain key performance indicators (KPIs). And discuss the supply chain vulnerabilities related to AI. Audi's AI adoption improved its supply chain operations and proved Germany's development in this respect.

17.2. Recommendation and Conclusion

Although AI can improve the efficiency, resilience and sustainability of automotive supply chains, it must follow ethics and, in some cases, must be accompanied by human supervision due to the risks associated with this technology. Moreover, companies that wish to implement AI successfully must invest in both technological and human resources.

By using AI, Audi improved its operational efficiency and product quality and set an example for being sustainable, resilient, and innovative in the automotive industry. This paper presents the opportunities to use AI in the automotive supply chain in Europe, bringing forward a case study of the car manufacturer Audi that is a true pioneer in this respect. The literature review shows how AI is able to mitigate high-impact supply chain risks while improving productivity and even creating a competitive advantage. The authors of this study gathered the hypotheses of recent and relevant studies available and compared them with the Audi case study and their own automotive supply chain experience to check and propose areas

that would benefit most from AI implementation, while bringing the awareness that AI regulation is in its infancy and there may be risks associated with AI usage, such as cyber security, data quality, and privacy rights. Our study offers a broader perspective using the combined qualitative research methods of literature review and case study. There are additional conclusions and hypotheses that could be validated through quantitative research, a goal to be achieved by the authors in future work.

18. The Freight Industry

The freight industry, a vital component of global commerce, is experiencing a profound transformation driven by the rapid advancement of Artificial Intelligence (AI) technologies. As the backbone of international trade and domestic supply chains, the freight sector is leveraging AI to revolutionize its operations, from logistics optimization to customer service enhancement. This paradigm shift is reshaping traditional practices in route planning, asset management, demand forecasting, and last-mile delivery, promising unprecedented levels of efficiency and cost-effectiveness. The integration of AI-powered solutions, including machine learning algorithms, predictive analytics, and autonomous systems, is not only streamlining existing processes but also opening new frontiers in freight transportation and management.

As companies across the industry grapple with the challenges and opportunities presented by this technological revolution, the potential for AI to drive innovation, sustainability, and competitive advantage in global logistics has become increasingly evident. This article examines the multifaceted impact of AI on the freight industry, exploring its applications, benefits, challenges, and prospects in shaping the landscape of worldwide cargo movement and supply chain dynamics.

18.1. AI Driven Optimization in Logistics

The integration of advanced algorithms and machine learning models has revolutionized logistics optimization in the freight industry. These AI-powered systems analyze vast amounts of data to enhance decision-making processes across various aspects of freight operations. One of the most significant applications is in route planning an optimization. AI algorithms can process real-time data on traffic patterns, weather conditions, and delivery schedules to determine the most efficient routes for freight vehicles. This not only reduces travel times but also minimizes fuel consumption, a critical factor in both cost reduction and environmental sustainability efforts.

Load distribution optimization is another area where AI excels. **Figure 24.** By considering factors such as package dimensions, weight, destination, and vehicle capacity, AI systems can calculate the optimal way to load freight, maximizing space utilization and ensuring balanced weight distribution. This optimization contributes to improved vehicle stability, reduced risk of damage to goods, and more efficient use of transportation resources.

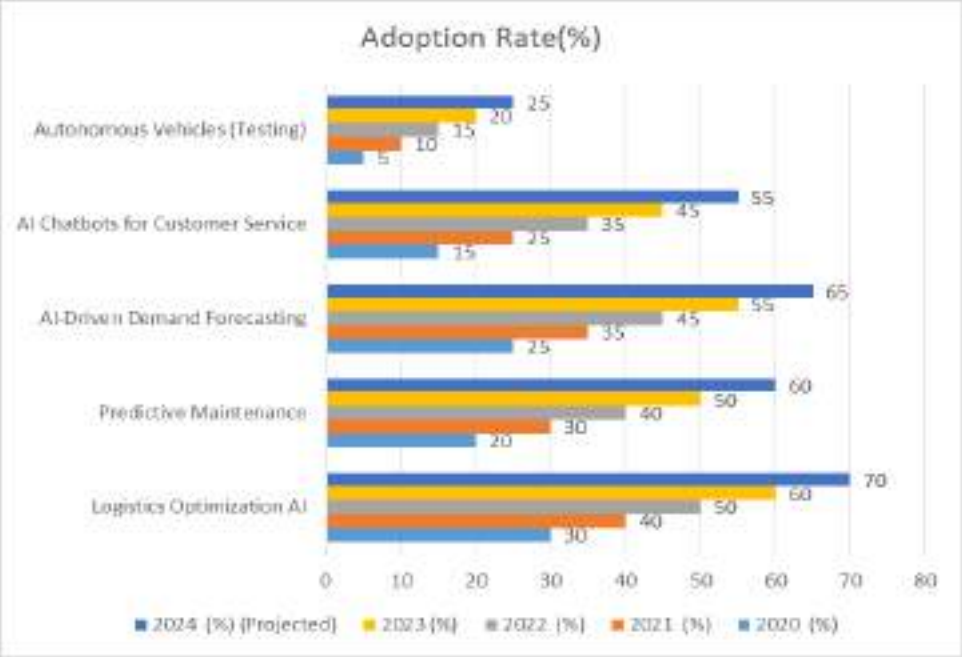


Figure 24 - Adoption Rate of AI Technologies in Freight Industry

The impact of AI-driven optimization on operational costs and delivery times is substantial. Companies implementing these technologies have reported significant reductions in fuel expenses, increased on-time deliveries, and improved overall supply chain efficiency. By minimizing empty miles and optimizing multi-stop routes, AI helps freight companies maximize their asset utilization and meet increasingly demanding customer expectations for faster, more reliable deliveries.

18.2. Predictive Maintenance and Asset Management

The advent of Internet of Things (IoT) sensors coupled with AI analytics has transformed asset management in the freight industry. These technologies enable the continuous monitoring of vehicle and equipment performance, collecting real-time data on various parameters such as engine temperature, tire pressure, and fuel efficiency. AI algorithms analyze this data to predict when maintenance will be required, allowing for proactive maintenance strategies that prevent unexpected breakdowns and extend equipment lifespan.

Proactive maintenance strategies facilitated **Figure 25.** by AI have led to a significant reduction in vehicle downtime. By addressing potential issues before they escalate into major problems, freight companies can avoid costly repairs and minimize disruptions to their operations. This approach not only improves the reliability of freight services but also contributes to enhanced safety on the roads. The cost savings associated with AI-driven predictive maintenance are substantial. Studies have shown that predictive maintenance can reduce maintenance costs by up to 30% and extend machinery life by 20-40%. Moreover, improved operational reliability translates into better service quality, higher customer satisfaction, and a competitive edge in the market.

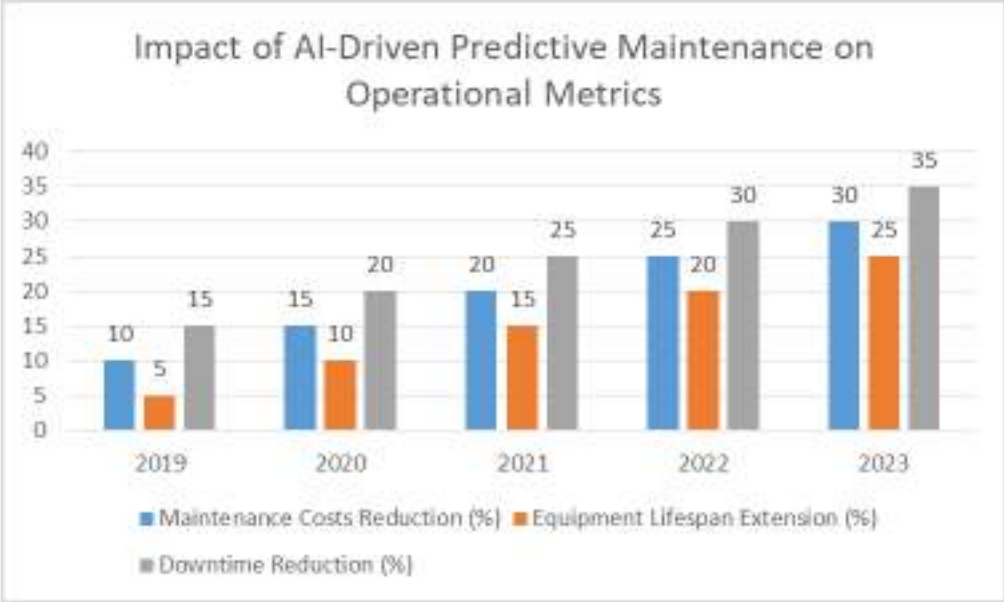


Figure 25 - Impact of AI-Driven Predictive Maintenance on Operational Metrics

18.3. Enhanced Demand Forecasting and Inventory Management

The integration of machine learning algorithms in demand prediction has significantly improved inventory management in the freight industry. These advanced AI systems can analyze complex patterns in historical data, market trends, and external factors to forecast future demand with unprecedented accuracy. By incorporating diverse data sources such as social media sentiment, economic indicators, and even weather patterns, AI models can capture nuanced influences on consumer behavior and market dynamics.

This enhanced forecasting capability enables the optimization of inventory levels across the supply chain. Freight companies and their clients can maintain just enough stock to meet demand without tying up excessive capital in inventory. The result is a substantial waste reduction, particularly critical for perishable goods, and improved customer demand fulfillment. AI-driven systems can quickly adapt to sudden changes in demand patterns, allowing for more agile and responsive supply chain management.

The agility and responsiveness afforded by AI in supply chain management have become increasingly crucial in today's fast-paced market environment. Companies can now react swiftly to emerging trends, seasonal variations, and unexpected disruptions. This adaptability not only improves customer satisfaction but also provides a competitive edge in the market. Moreover, the ability to accurately predict and meet demand contributes to sustainability efforts by reducing overproduction and minimizing the carbon footprint associated with excess
transportation and storage.

18.4. Autonomous Vehicles and Drones in Freight Transport

The development of self-driving trucks and AI-powered delivery drones represents a revolutionary frontier in freight transport. These autonomous systems have the potential to transform both last-mile delivery and long-haul transport. For last-mile delivery, drones and small autonomous vehicles offer the promise of rapid, cost-effective delivery to urban and remote areas alike. In long-haul transport, self-driving trucks could operate continuously, dramatically reducing transit times and increasing efficiency. The **Table 13**. potential impact on safety is significant, as autonomous systems can eliminate human errors that often lead to accidents. Additionally, the reduction in labor costs could be substantial, although this raises important socioeconomic considerations. The 24/7 operational capabilities of autonomous vehicles could revolutionize supply chain dynamics, enabling more flexible and responsive freight movement.

However, the current state of development and regulatory challenges present significant hurdles. While technology continues to advance rapidly, regulatory frameworks are still evolving to address the complex issues surrounding autonomous vehicle operation on public roads. Safety concerns, liability questions, and the need for infrastructure adaptations are among the key challenges that need to be addressed.

Despite these challenges, many major logistics companies and technology firms are investing heavily in autonomous freight transport solutions. Pilot programs and limited deployments are underway in various parts of the world, providing valuable data and insights for further development and regulatory considerations. As these technologies mature and regulatory frameworks adapt, autonomous vehicles and drones are poised to play an increasingly important role in the future of freight transport.

Application Area	Description	Benefits
Logistics Optimization	AI algorithms analyze data for efficient route planning and load distribution	Reduced fuel consumption, improved delivery times
Predictive Maintenance	IoT sensors and AI analytics predict equipment maintenance needs	Reduced downtime, extended equipment lifespan
Demand Forecasting	Machine learning algorithms analyze historical data and market trends	Optimized inventory levels, improved demand fulfillment
Customer Service	Chatbots and virtual assistants handle inquiries and provide real-time tracking	Improved customer satisfaction, reallocation of human resources
Autonomous Vehicles	Self-driving trucks and AI-powered delivery drones	Potential for 24/7 operations, improved safety

Table 13: Key Applications of AI in the Freight Industry

Real-time tracking and booking processes have been dramatically improved through AI integration. Customers can now access up-to-the-minute information about their shipments, make bookings, and receive instant confirmations, all through AI-powered interfaces. This level of transparency and efficiency has led to substantial improvements in customer

satisfaction, as clients feel more in control and informed about their freight movements. The implementation of AI in customer service has also allowed for the strategic reallocation of human resources. By automating routine inquiries and tasks, human staff can focus on more complex issues that require empathy, critical thinking, and personalized attention. This not only improves the overall quality of customer service but also enhances employee satisfaction by allowing them to engage in more meaningful work.

Furthermore, AI-driven analytics provide valuable insights into customer behavior and preferences. By analyzing patterns in customer interactions, purchase history, and feedback, freight companies can tailor their services more effectively, anticipate customer needs, and develop targeted marketing strategies. This data-driven approach to customer relationship management has proven to be a powerful tool for building loyalty and driving business growth in the competitive freight industry.

18.5. Challenge in AI Integration

While the benefits of AI in the freight industry are substantial, its integration presents several significant challenges. Data privacy concerns are at the forefront, as the collection and analysis of vast amounts of data raise questions about the protection of sensitive information. Freight companies must navigate complex regulatory landscapes, such as the General Data Protection Regulation (GDPR) in Europe, to ensure compliance and maintain customer trust.

Cybersecurity risks have become increasingly prominent as freight operations become more digitized. The interconnected nature of AI systems and the Internet of Things (IoT) devices used in logistics creates potential vulnerabilities that malicious actors could exploit. Protecting against data breaches, system hijacks, and other cyber threats requires ongoing investment in robust security measures and protocols.

Table 14. The skill gap and workforce adaptation present another significant challenge. The implementation of AI technologies requires a workforce with specialized skills in data science, machine learning, and AI management. Many companies in the freight industry face difficulties in recruiting and retaining talent with these skills, necessitating substantial investment in training and education programs for existing employees.

Category	Current Challenges	Future Opportunities
Data Management	Privacy concerns, cybersecurity risks	Blockchain-enabled smart contracts for enhanced security
Workforce	Skill gap, need for specialized training	New roles in AI management and data science
Technology Integration	High investment requirements, organizational change	AI-optimized warehousing and distribution centers
Regulatory Landscape	Evolving frameworks for autonomous vehicles	Potential for self-organizing logistics networks
Sustainability	Current focus on efficiency	AI-driven solutions for reducing carbon footprint

Table 14: Challenges and Future Outlook for AI in Freight

The investment requirements for AI integration can be substantial, encompassing not only the cost of technology but also the expenses associated with organizational change management. Implementing AI systems often requires restructuring existing processes and workflows, which can be met with resistance from employees accustomed to traditional methods. Overcoming this resistance and ensuring smooth adoption of AI technologies requires careful change management strategies and clear communication of the benefits to all stakeholders.

19. The Opportunities for Using AI in the Logistics Sector

The logistics companies in organization can get a great advantage of using AI in different supply chains. Thus, there are some opportunities in which AI can be used to revolutionize the logistics sector. AI can provide the knowledge needed to decrease operations and inventory costs and having a quick response to customers means having satisfied clients. For example, two AI applications can be implemented in this case, including Intelligent Robotic Sorting, high-speed and effective sorting of letters, palletized shipment, and parcels. Another application is AI-Powered Visual Inspection, a machine that takes photos of the cargo using unique cameras identifying the damaged place and identifying the appropriate corrective action to fix that.

Additionally, AI can use Enhanced Customer Experience. It can change and improve the relationship between the logistics partners and their customers by personalizing them. For instance, the cooperation between DHL Parcel and Amazon is an excellent example of a personalized customer experience. In this case, the delivery company offered the voice-based service to track the parcels and then get the shipment information using Amazon's Alexa-Powered Echo. Moreover, there are other advantages in which AI can improve the logistics sector, which are providing insights into improving the productivity of the supply chain management, having the ability to analyze massive volumes of data so boosting the accuracy of demand forecasting, improving the supplier selection and developing the supplier relationship management effectiveness, and improving factory scheduling and production planning. Security is considered one of the biggest beneficiaries of AI technology, and here in organization, AI has been implemented for image processing, facial recognition, and predictive analytics.

Companies can use AI technologies in manufacturing. This development has similarly appeared in Foxconn, which ranks first in EMS in the electronic industry. This company has developed 10,000 robots to balance the increase in labor costs in China. Another example is Japan, where it is one of the most leading countries in producing robots. Alteration of humans with the robot is followed in manufacturing that cannot prevent or stop since this technology embraces the low cost, high efficiency, and accuracy of the robot and will benefit the community on a vast level. In addition, the usage of the robotic unit for data related repetitive tasks can provide largely perks for the companies. Amazon employs more than 100,000 warehouse robots that can take over human employees in different aspects. EY is one of the largest accounting firms, and its statistics claims that this can provide cost-saving up to 65%.

Moreover, in Andover, England, a large warehouse that runs primarily by robots can fulfil 65,000 orders, about 3.5 million grocery items in one week. This warehouse uses hive grid- machine that is designed and built by British online grocer Ocado. The intelligent and automated warehousing system is completely capable of moving, lifting, and sorting the grocery items and then packaged and delivered by Ocado's employees. UPS is one of the leading parcel delivery companies that use AI-powered GPS called ORION to find the fastest and the most cost-efficient route for its fleet. With the data and information given by the customers, drivers, and vehicles, ORION uses the algorithm to find out the appropriate way for each delivery. It is a real-time system that modulates the routes depending on the present traffic and other circumstances. Another company that has taken the idea of applying AI is Marble. It uses robots that work on the same AI system as automated cars (LIDAR) to deliver cargoes to consumers. Its feature is cutting down the risk of the driver, eco-friendly, and saving cost and time. Lineage Company uses AI to forecasts which items store a long time and stay in a short period. Based on that, the things that take a long time will be held on the back, and the others that will leave early will be kept in the front. As a result, Lineage has increased its efficiency by more than 20%.

In 2019, the technology sector at Logistics Center in city had made achievements to digitize logistics sector and innovative, intelligent solutions in different logistics operations to benefit AI applications globally and regionally. Business has launched an initiative to display and test the emerging and modern technologies to face the logistics challenges by communicating with more than 40 local and global companies and testing these technologies. One of these technologies was a diver robot, and it has been used in Port. This technology helps diagnose the port infrastructure in depths and conditions that ordinary divers cannot withstand. Furthermore, in Port, drone technology was tested to identify and discover the damaged locations of berths and quay use AI to analyze the pictures captured by drones. Also, they used drones to deliver parcels in Muscat and Nizwa and use them in the warehouse inventories. More than that, other city Port has joined Tradelens Platform for tracking and tracing shipments across blockchain technology to take its benefits in tracking shipments, knowing shipments route and sharing its data with the other partners in the supply chain.

19.1. The Key Challenges Facing Using AI in the Logistics Sector

Although many benefits can be gotten from using AI, however, there must be challenges facing AI in the logistics sector, which must be considered. There is no escaping that AI is an expensive technology that requires a high cost of implementation because of the complexity of engineering that entering in building one AI machine or system. On the other side, the repair and maintenance of these technologies can cost thousands of dollars, not a small amount of money. Moreover, AI needs human assistance, so AI cannot replace humans, and it is known that AI can do the works. Still, it is not an independent system and to ensure the efficiency of the results. There must be a need for human control and assistance. Besides, AI can create the unemployment issue and reduce the workforce with the coming of these technologies. "When jobs are eliminated due to the integration of AI solutions, the company needs to either find new positions for their employees to take on or release them all together". So, logistics companies must consider this challenge before investing in AI replacement systems. According to a study conducted by McKinsey Global Institute, robots and intelligent agents could replace almost 30% of the current human labor globally by 2030. More than that, the study states that automation

will replace between 400 million and 800 million individuals by the year 2030, which also requiring 375 million people to switch their occupational categories and learn new skill.

Additionally, AI cannot improve with experience. These machines cannot change their responses to the changing environments built for the repetitive work environment, and the input does not change. So, when there is some alteration in the information, the AIs need to be rebuilt, retrained, and reassessed. Furthermore, AI technologies cannot judge which is correct or incorrect because they are not understood the ethical and legal concepts where they have been programmed for situations; thus, they cannot make the right decisions in dealing with unfamiliar problems. Furthermore, the other challenges facing AI in the logistics sector include operational costs, security issues, cybercrimes, lack of creativity, and long implementation time.

AI might affect careers when the computers and their programs replace employees place as it sometimes happens in telecommunications companies and some institutes. These companies provide an electronic application that interacts with the user directly without the need of the employee. That may lead to the layoff of many employees and an increase in the number of job seekers.

Although many places in the market can use AI as the best substituent for traditional systems, the problem is AI knowledge. A portion of technology enthusiasts, researchers, and college students, only a few people are aware of AI potential. For instance, some small and medium enterprises can have their work scheduled or learn innovative methods to manage resources, increase their productivity, manage and sell products online, understand customer behavior, and react effectively and efficiently to the market. Also, they are not aware of service providers like Google Cloud and Amazon Web Services.

19.2. Optimal Solutions and Recommendations to Improve Using AI in Logistics Sector

There are many ways to improve using AI in the logistics sector. The logistics companies should combine machine learning automation and human data evaluation with their data to achieve high performance when the human staff and machines work together. Additionally, private and public companies should examine how they can benefit from using AI and ML paths to help the community. Moreover, Schools and universities should include ethics and related topics about AI, ML, computer science, and data science to create generations powered by technological progress. The logistics companies should hire skilled and experienced managers because the AI and ML should be guided by capable humans who can professionally implement the project management methodologies and the best practices. According to Microsoft, the next generation of engineers must develop their skills in cutting edge new technologies to have an opportunity in working with institutions of the future. From the job loss side, the government and the private sector should understand the labor market nature and build it for the future where AI must be implemented to repurposes the energy in the labor market instead of making it redundant.

Furthermore, the use of AI in the business is not an easy process. Companies must have a structured approach that starts with determining business use cases with tremendous potential. They need to construct data ecosystems to warranty the AI algorithms success. Companies also should nurture the different capabilities and find methods to merge AI outcomes in the workflows, and employees should be educated and trained to adapt to AI successfully.

19.3. AI in The Logistic and Supply Chain

Topics from different sources. From the opportunities for using the AI side, several studies provided examples of companies worldwide and how these companies benefit from using AIs. However, the researcher has not found enough information about AI in Oman's logistics sector. From the other side, the researcher has found a clear picture of the challenges that could face using AI in the logistics sector. Most studies agreed that the new technologies might create the unemployment issue. The researcher has found optimal solutions and recommendations from other researchers to prevent the challenges and improve using AI in the logistics sector with the solutions side.

19.4. Research Design

To meet the objectives and answer the questions, the researcher needs to choose the most appropriate design for this study's aim. For the fundamental research, the researcher will use mixed methods, including quantitative and qualitative methods, to strengthen the gathering of information and data collected to satisfy the readers and make it realistic and reliable. Moreover, some readers prefer dealing with linguistic and analytical data using both methods, while others prefer dealing with numerical data. Therefore, quantitative, and qualitative methods are used to support the findings shown in the next chapter.

The advantages of using mixed research method,

- Providing strengths to overcome the points of weakness for both ways, the quantitative and qualitative research.
- The researcher can have a broader range of research questions to gather a more authentic picture of a society with high validity.
- Providing a comprehensive and complete understanding of the research problem instead of using one kind of approach.
- Providing more precision and in-depth information and valuable datasets to the reader.

The disadvantages of using mixed research method,

- Taking much more time in organizing the data and getting information from several sources.
- The research design can be more complex than using one kind of method.
- It requires careful and expert data analysis, and the interpretation can impact the research.
- It can be complicated to gather a large amount of data.

19.5. Data Collection

It is valuable to use mixed methods for this study because it will help the researcher strengthen the data accuracy rate by diversifying using other sources. For the quantitative method, the researcher will use a questionnaire tool, and for the qualitative approach, she will use the interview tool and website articles. From this approach, the researcher expects that the questionnaire will collect more information from different respondents. The interview will obtain and gather additional information from people's opinions and thoughts and collecting data from various website articles will provide a quicker and less expensive data collection. **Figure 26**. highlights the research methodology instruments for this study.

Figure 26 - Research methodology instruments.

There are some advantages of using the questionnaire in the research, which is easy to conduct large amounts of data and information can be obtained from many respondents, receiving responses through frank and anonymous ways, less time-consuming. Additionally, it can be easily reached to local, national, and international respondents, a cost-effective method. On the other side, there are several disadvantages of using the questionnaire in the research, and these include a low response rate. Respondents might interpret some questions in ways that are not relevant to the study. Furthermore, it is difficult to capture and identify feelings and emotional responses for respondents, and some questions can be challenging to analyze and require much more effort.

The interview will help obtain the highest response and gather complex and in-depth information. It also helps to explain the questions clearly and in detail and have the feedback with more clarification. On the negative side, it can be very costly and very time-consuming. Also, it is not practical with many respondents, and it might be challenging to summarize the interviewees' responses. The pilots' test is a crucial stage for the study. The researcher expects the respondents to cooperate and contribute to completing the collecting data and information process, which will appear positively on the study's results and findings. The researcher expects about 85% of responses will support and provide the target data and information for the study of using artificial intelligence in the logistics sector in Oman, pros and cons.

19.6. Target Population and Sampling Techniques

The researcher for the quantitative method targets the expertise of employees from different logistics institutes in citizens and students from various universities and colleges in country. While for the qualitative approach regarding the interview,

the researcher targets two to three persons who work in port and students from IMCO. For the website articles, she is targeting organization websites. The targeted participants' number is 150, and the expected replies number is 100. From the questionnaire side, the researcher will use as simple random sample from the population to find and analyze the data collected for the research by dividing the questionnaire into three parts covering the sub-questions, as is shown in the introduction chapter. Furthermore, the researcher will use an online survey, the most popular data collection source, and the questionnaire will be sent to the target sample in society. Also, the researcher will conduct online interviews to get more specific information and data about the study and look at different organization web articles for further information and support findings.

19.7. Data Analysis

The primary sources for this study are interviews and questionnaires, and the secondary data sources will be collected from the website articles. For the questionnaire, the researcher will gather the data on the Office 365 Forms using different charts to illustrate and compare the data and get the results in the finding part. For the interviews, the researcher will use critical thinking to synthesize the data and then utilize these data from the interviews to corroborate the findings side with other questionnaire data. In addition, the web articles will support the ideas and thoughts of people to make the results more valid and reliable.

19.8. Finding and Analysis

The main objective of this study is to investigate the impact of using AI in the logistics sector in organization by identifying the opportunities for using AI, identifying the issues surrounding using AI, and recommending possible solutions to improve the use of AI in the logistics sector in organization. Therefore, this chapter discusses the result of data analysis and findings that the researcher got from making questionnaires, interviews, and searching on web articles that are simulated the study, where the results are related to the research questions. This chapter focuses on collecting data by using qualitative and quantitative analysis. The findings are also discussed, considering the previous literature to identify the similarities and differences between this study and prior studies. So, the researcher will discuss and analyze the conclusions by summarizing and emphasizing the study's most important findings, which will help conclude the study with optimal solutions and recommendations.

19.9. Findings

The interview results are based on the research questions, and it was conducted with three persons. One of them works in port, and two persons were graduates of IMCO. Moreover, the researcher has looked at employee web articles for further information and support findings. The researcher analyzed the collected data based on three main headings: the opportunities for using AI in the logistics sector in organization, the key challenges facing using AI in the logistics sector in organization, and the optimal solutions and recommendations to improve using AI in logistics sector.

19.10. The Opportunities for Using AI in the Logistics Sector

The interview was conducted to obtain and gather additional information from people's opinions and thoughts. A question indicates how AI can increase the efficiency of the logistics sector in organization, and there were many valuable answers from interviewees. AI makes the logistics operations fast in every field of logistics so that will lead to increase the efficiency of logistics in organization. "Using AI saves time, fastening logistics operations, and meeting customer satisfaction. However, once these aspects are achieved, then the efficiency of the logistics sector will rise. On the side of speaker, using digital solutions and developing technologies in the logistics sector will increase the efficiency of this sector and that by speeding up the operations, decreasing costs and time, and satisfying the clients.

According to the results, stated a direct relationship between AI and its economy where the more the government relies on AI, the economy will rise. On the other hand, mentioned that the entry of AI in several industries like the automotive industry gives it a competitive advantage. Thus, its high prices will increase the country's revenues. Believes that the impact is through the quality of new products that rely on AI or reduce time. Hence, the product which is of high quality and low time is the cause to increase profits and decrease costs.

In the interview, there was a question related to evaluating the contribution of AI in decreasing the challenges currently facing the logistics sector. The interviewees have many opinions on that. Many challenges are encountered in the logistics sector, such as delay, damage, and human mistakes. Still, with the contribution of AI, the challenges enormously will be decreasing. "They have to employ AI in the warehouse in organization to improve the operation of logistics, and AI can be used to reduce labor hours, which is a huge problem in the logistics industry. For example, people working in the warehouse must be working 24/7, which is not healthy and could cause harm to the workers either physically or mentally. Also, some warehouses have freezers that can reach up to -28. Imagine someone going to work tired and has to work in the freezer; he could collapse from being tired or because of the cold without being noticed". Noted, "As we all know that Coronavirus is destroying transportation, so killing the movement of logistics so by AI there will be time management, fast movement, and effective communication".

19.11. The Key Challenges Facing Using AI in The Logistics Sector

According to the interview results, there were different opinions of the impact of AI on employment. "As long as companies apply AI, the unemployment rate will increase because of depending on machines rather than manpower". "AI will lead to reducing the opportunity of employment because the AI depends on technology". AI will increase employment opportunities and improve efficiencies because there will be new jobs in the future that adopt with the modern lifestyle means new opportunities".

On the other hand, an operations officer at organization, mentioned that AI might create jobs and these jobs depend on people's skills which helps job seekers to g towards AI. Adding to that, the impact of AI is between positive and negative. On the positive side, it may create new jobs on which the fourth industrial revolution and AI depend, and on the negative

side, it may result in some institutions reduce their employees. The researcher asked interviewees their opinions and thoughts about why AI requires high cost and a lengthy implementation, and there were several answers. As we know that AI depends on technology, and the technology is costly and needs time to establish". AI might be costly but will accelerate logistics. "Because applying such a new system is expensive and the employees need effort and time to adapt with it".

According to the findings, there were different opinions on why most logistics sectors need to acquire new skills related to AI. Logistics employees should always be ready to learn new skills to be open to the recent changes in the logistics world. Every employee working in this sector to learn how to apply such a system to improve the efficiency of logistics and supply chain operations". AI has an especial process so, they have to be qualified". "Because they need to improve work by new skills to make the work easier and improve the performance to get top positions in the logistics sector".

19.12. The Optimal Solutions and Recommendations to Improve using AI

The researcher has asked interviewees how educational institutions can improve AI for students, and there were different suggestions. They can educate them by simulating AI, conducting workshops, and adding this concept to logistics subjects. They must give them lecturers about AI. Also, they must take them to logistics fields to see how AI works". "I recommend that they should start teaching or training students about AI from the study stage so they can have enough knowledge and experience when it comes to the career". He added, there should be resorting to intelligent devices, improving the quality of education, and raising the efficiency of teachers.

According to the interview results, interviewees have additional recommendations to improve the use of AI in the logistics sector in organization. "They have to try applying such concept even by 30% to create a balance between human labor and the new system to increase the efficiency of logistics services and the productivity of the manpower". They must facilitate establishing AI. Also, they must find all requirements for AI. "Employees and machines must be allowed to work together to increase efficiency and facilitate work quickly, ensure the use of technology in logistical operations, and train employees to use AI and cooperation between logistics companies and encourage the use of AI".

19.13. Analysis

The questionnaire is essential to collect data from many respondents, where the researcher distributed the questionnaire to employees from different logistics companies and students from other universities and colleges in globalization. The researcher analyses the questionnaire based on the participants' responses. The number of respondents was 102, they are 23 males and 79 females, and most of the ages were ranging from 18 to 30, and they were 97, while 5 of the respondents their ages were ranging from 30-50, and there were 0 respondents from the ages of above 50. **Figure 27 and 28** show charts of gender and age. The researcher also analyzed the collected data in three main sections:

1. The opportunities for using AI in the logistics sector in organization.
2. The key challenges are facing using AI in the logistics sector in organization.
3. The optimal solutions and recommendations to improve using AI in organization logistics sector.

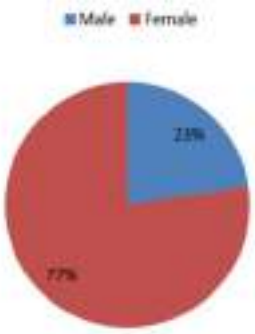


Figure 27 - Gender

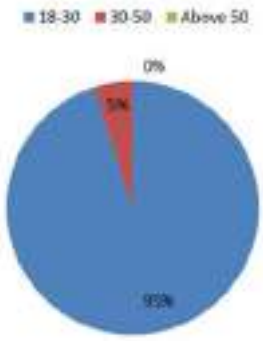


Figure 28 – Age

19.14. The Opportunities for Using AI in The Logistics Sector

The below **Figure 29**. shows that 53% of the respondents agreed that 25% were strongly approved that AI is efficient in the logistics sector in organization. A neutral group of 16% of respondents were impartial that AI is efficient in the logistics sector. On the other hand, the minority of respondents were disagreed and strongly disagreed. They represent 3% disagree and 3% strongly disagree of the total respondents. It concludes that using AI in the logistics sector in organization will increase the efficiency of this sector and make it more developed.

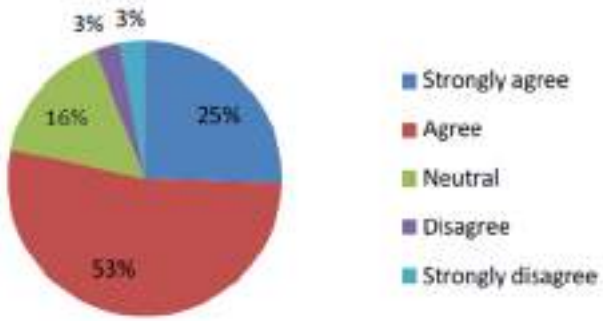


Figure 29 - The efficiency of AI in the logistics sector

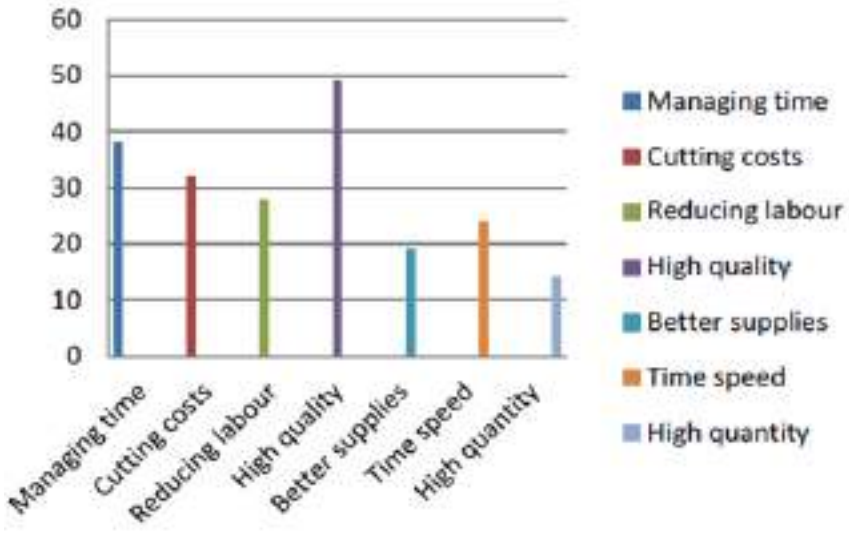


Figure 30 - The advantages of using artificial intelligence in the logistics sector

This chart outlines **Figure 30** the most advantages of using AI in the logistics sector and includes seven benefits with the number of respondents. As shown, most respondents, for about 49 votes, considered that one of the most advantages of using AI is the high quality. Whereas the managing time advantage comes in the second rank, it occupies 38 votes, and the third rank was 32 votes favoring cutting costs edge. Moreover, 28 respondents give their voices to the reducing labor advantage, and 24 of the votes go to the time speed advantage. The monitory votes go to better supplies and high quantity advantages, and they carry about 19 and 14 respectively. It concludes that using AI will help companies increase their services level with high quality, which will help improve the efficiency and productivity within the logistics companies. That will appear positively with the clients who will be provided with satisfying services. Furthermore, when companies improve their quality of services, this will also help achieve other advantages of using AI, managing time, cutting costs, reducing labor, time speed, better supplies, and high quantity advantage.

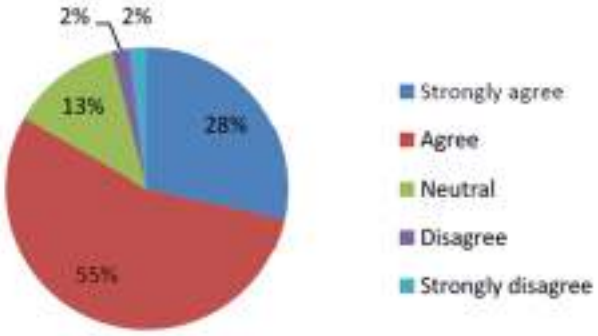


Figure 31 - contributing to the growth of income sources.

The above chart **Figure 31.** shows that most respondents who carried a percentage of 55% were agreed that AI could contribute to the growth of income sources, including the logistics sector. In comparison, 28% were strongly agreed with that statement. At the same time, a neutral group of 13% of respondents were impartial that AI could contribute to the growth of income sources, including the logistics sector. On the other side, 2% have disagreed, and 2% were strongly disagreed with that statement. So, this figure shows how AI can help increase the income sources in different sectors in Oman. The logistics sector is one of these sectors that can diversify sources using AI technologies. When logistics companies use AI, that can increase their productivity and profitability, which can positively affect the efficiency of the logistics sector.

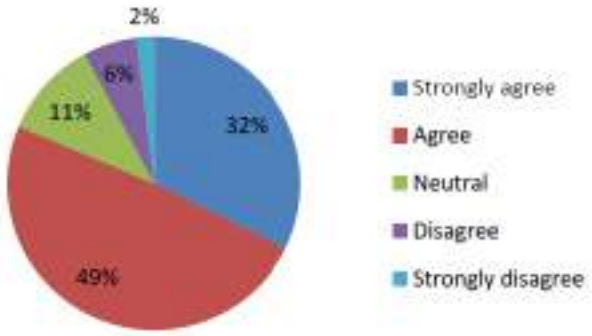


Figure 32 - Contributing to the growth of organization economy.

In this chart, most of the responses presented 46% and 32% agreed and strongly agreed that AI could contribute to organization economy. 18% of respondents were neutral about the statement. The minority of respondents were disagreed and strongly disagreed. They represent 6% disagree and 2% strongly disagree of the total respondents. This figure concludes that AI can contribute to organization economy through the logistics sector itself. Where logistics companies can increase the output of this sector, this can increase the country's GDP and improve Oman's economy.

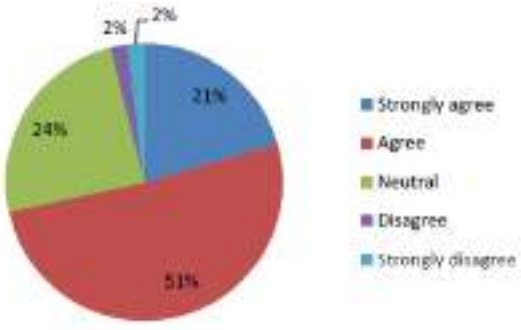


Figure 33 - Reducing the challenges currently facing the logistics sector

The above chart indicates how AI can reduce the challenges currently facing the logistics sector. Most people agreed with that statement, and they represent 51%, and 24% of respondents were neutral. More than that, 21% of respondents strongly

agree that AI could reduce the logistics sector's challenges. On the other hand, few people of respondents were disagreed and strongly disagreed. They represent 2% and 2% respectively. Therefore, these large percentages support the literary studies that confirmed that AI could pose the logistics sector's challenges. For instance, one of the biggest challenges that face the logistics sector is the delay in the delivery of cargoes. At the same time, some companies worldwide have already started using autonomous vehicles or self-driving vehicles that can improve the supply chains, reduce the costs and risks of incidents, and speed up delivery.

19.15. The Key Challenges Facing Using AI in the Logistics Sector

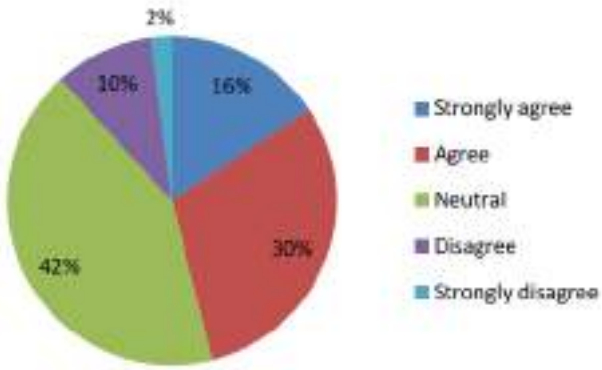


Figure 34 - Unemployment in the logistics sector

The pie chart illustrates the result of in which if AI will increase unemployment in the logistics sector. It was observed that a high proportion of 42% of respondents was neutral of that statement. While 30% of respondents agreed on how AI will increase the unemployment issue in the logistics sector, a proportion of 16% of respondents strongly agreed. A mere 10% of respondents disagreed that AI would increase unemployment in the logistics sector, and the tiniest fraction, 2%, of respondents were firmly disagreed. This concludes that AI will impact employment in the logistics sector on two sides. From the positive aspect, AI will create more jobs than it destroys because even if machines could replace human works, the human presence must control it. On the other hand, AI could decrease employment in few places and for different conditions. This can be considered in the interest of the human to alleviate the complex works of the workers like in the warehouses and the opened areas in ports.

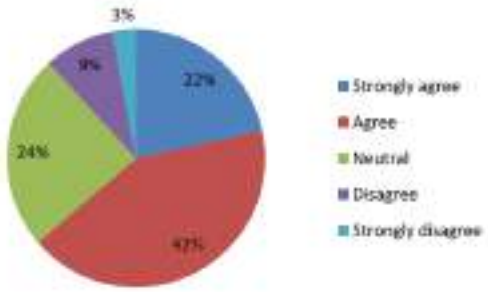


Figure 35 - The extended time for implementation.

In general, this chart shows one of the challenges of AI, and it is a long time for implementation. A vast proportion of 42% was agreed that AI requires a long time for performance, and 22% were strongly agreed. A neutral group of 24% of respondents were impartial that AI requires a long time for implementation. On the other hand, the minority of respondents were disagreed and strongly disagreed. They represent 9% disagree and 3% strongly disagree of the total respondents. So, the chart concludes that AI has many challenges. One of the most significant challenges that may face AI in the logistics sector is a long time for implementation because it is a complex machine and needs time and effort for application.

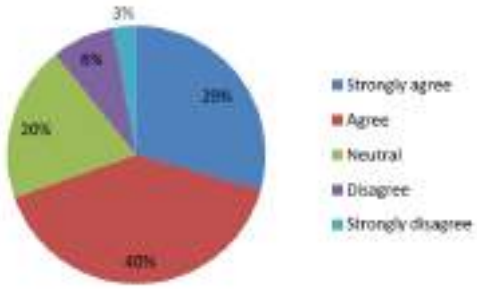


Figure 36 - The high cost of implementation

Findings of the study revealed that a high proportion of 40% of respondents was agreed that AI requires a high cost of implementation, and 29% were strongly agreed. At the same time, a neutral group of 20% of respondents were impartial that AI requires a high cost of implementation. On the other side, 8% disagreed, and 3% were firmly disagreed with that statement. It concludes that AI is an expensive technology that requires a high cost of implementation because of the complexity of engineering that entering in building one AI machine or system.

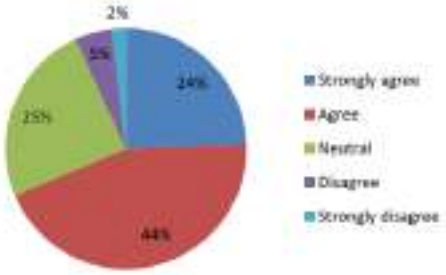


Figure 37 - The potential of artificial intelligence

The results show that 44% of respondents agreed that few people are aware of the potential of AI, while 24% of them were strongly agreed. On the other hand, 25% of respondents were neutral about the statement. The minority of respondents were disagreed and strongly disagreed. They represent 5% disagree and 2% strongly disagree of the total respondents. This figure concludes that many technology enthusiasts, researchers, and college students have only a few people aware of AI potential.

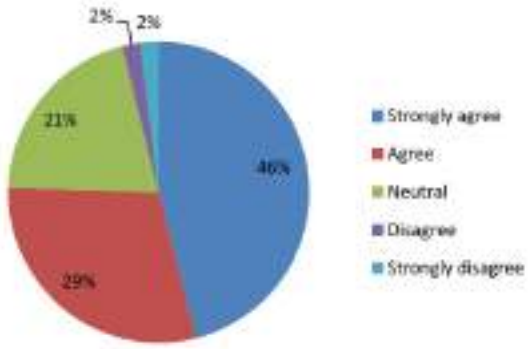


Figure 38 - Logistics companies' employees.

The above chart shows that most respondents who carried 46% strongly agreed that most logistics companies need more training with new AI skills, while 29% agreed with that statement. At the same time, there was a neutral group of 21% of neutral respondents that most logistics companies need more training with new AI skills. On the other side, 2% disagreed, and 2% were firmly disagreed with that statement. This result approves that AI will lead to having more training for logistics companies' employees to acquire the new skills of the existing technologies, which is a challenge that would face using AI in the logistics sector in organization.

19.16. Optimal solutions and recommendations to improve using AI in logistics sector

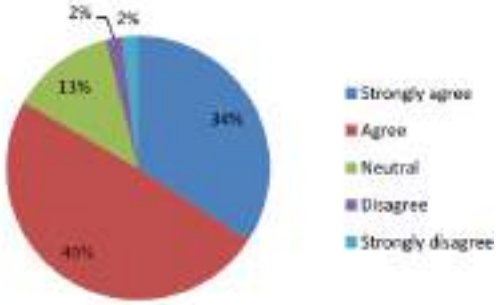


Figure 39 - Constructive cooperation between the public and private sectors.

According to the findings, most respondents agreed and strongly agreed that having constructive cooperation between the public and private sectors is one of the most important solutions to improve the use of AI in the logistics sector in organization. They represent 49% agree, and 34% strongly agree of the total respondents. 13% of respondents were neutral. The minority of the respondents were disagreed and strongly disagreed, and they represent 2% and 2%, respectively, of the total respondents. So, it concludes that having constructive cooperation between the government and the private sector will help improve the use of AI in the logistics sector and increase the performance of logistics companies which will enhance the logistics sector's efficiency.

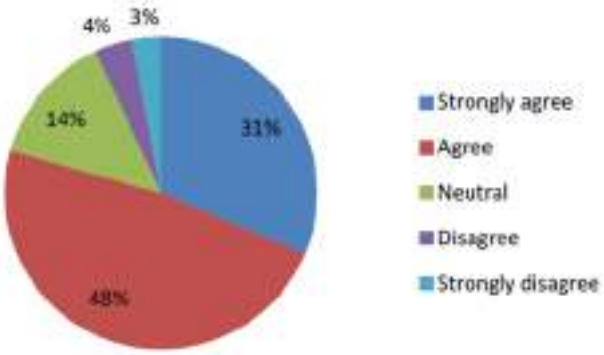


Figure 40 - AI in schools and universities' curricula.

The study reveals that 48% of respondents agreed that schools and universities should implement AI in their curricula. In comparison, 31% of respondents were strongly agreed with that statement. 14% of respondents were neutral that schools and universities should implement AI in their curricula. Other respondents disagreed and strongly agreed, representing 4% and 3% respectively of the total respondents. This figure concludes that schools and universities should implement AI in their curricula to create generations powered by technological progress to develop the logistics sector and the country.

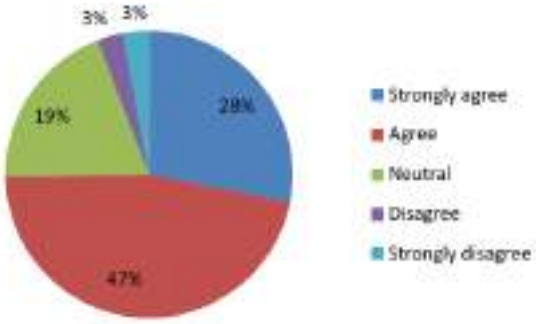


Figure 41 - Ethical sides of AI in schools and universities

The above chart shows that 47% of the respondents were agreed, and 28% were strongly agreed that Schools and universities should consider the ethical side of AI. A neutral group of 19% of respondents were impartial that Schools and universities should consider the moral side of AI. On the other hand, the minority of respondents were disagreed and strongly disagreed. They represent 3% disagree and 3% strongly disagree of the total respondents. It concludes that schools and universities should include ethics and related topics about AI, ML, computer science, and data science to qualify humans to design, construct, and use machine ethics.

According to respondents' responses, there are many recommendations to improve the use of AI in the logistics sector in organization. For instance, working to spread awareness among companies and the private sector in corporate as a basis for the planning process and managing logistics services in organization, and bringing experts to teach employees how they deal with AI and use simple AI techniques as a preparation step a bright future. Moreover, improving the quality of

services in logistics sector companies using new technologies and making more businesses and investment with big logistics companies. Furthermore, spreading the culture of AI between social individuals to be aware of the meaning of AI and how much it is essential to be implemented, and what benefits that all people can gain by using AI. Also, using different types of AI technologies because today the logistics sector leads the market, giving the customers a high quality of services.

Additionally, empowering employees and youth to learn and have skills in this field, implementing ethics in employing people in this area and giving employee the opportunity to contribute to this area and lead the future of organization. Moreover, increasing intellectual awareness about AI in the logistics sector and providing financial capacity for AI without consequences for logistics companies. Also, AI should not be relied upon to a large extent so that there is no unemployment in society.

19.17. Conclusion and Recommendation

This chapter summarizes the research study, which evaluates the advantages and disadvantages of using AI in organization logistics sector. The researcher concludes the findings based on the results obtained from chapter four. Besides that, the researcher also gives recommendations for future research to improve the use of AI in the logistics sector in organization. The study has been conducted to investigate the impact of using AI in the logistics sector in organization. As the investigation progressed, the researcher has reached ideal suggestions to improve the use of AI in the logistics sector in organization. The recommendations are as follows:

1. Logistics companies should train their employees to use AI in various supply chains to be equipped with more knowledge and skills in a creative path.

2. Government and private companies should examine how they can benefit from AI in trajectories that can help society.

3. Educational institutions should implement AI in their curricula and concentrate more on the practical side of applying AI for students to create generations powered by technological progress to develop the logistics sector and the country.

4. The Ministry of Higher Education should establish institutes specialized in educating about AI to qualify individuals with sufficient experience by the latest developments in the AI field.

5. Spreading the culture of AI between individuals in the community to be aware of the potential of AI and how much it is essential to be implemented, and what benefits that all people can gain by using AI.

6. Logistics companies should combine humans and machine learning automation with their environment to assess data to have a high quality and achieve high performance when the human staff and machine work together.

7. Transportation companies should use the latest delivery management systems in conveying shipments to the clients in the shortest possible time.

8. Logistics and customs clearance companies should rely more on modern systems in clearing transactions to gain customer satisfaction and improve services with high quality.

9. The intensification from robots and other AI technologies in factories, warehouses, and retail stores can reduce time, cost, and effort in several operations and activities, including sorting, packing, packing, organizing, shipping, and many others.

10. Ports' authorities should provide the port environment with the most modern machinery and systems to increase the operations performance, productivity and attract more customers.

11. The public and private sector should understand the nature of the labor market where AI should be implemented in a path that repurposes the power in the labor market rather than makes it redundant.

20. The Rise of Artificial Intelligence and Machine Learning: A Paradigm Shift

The ascent of AI and machine learning marks a paradigm shift in supply chain transportation. These technologies, driven by sophisticated algorithms and vast datasets, empower logistics professionals with tools to analyze, predict, and optimize every facet of the transportation process. The section delves into the conceptual underpinnings of AI and machine learning, elucidating their capabilities in processing real-time data, learning from patterns, and making adaptive decisions that transcend the limitations of traditional, rule- based systems.

20.1. Optimizing Efficiency: Route Planning and Predictive Maintenance

Efficiency lies at the heart of supply chain transportation, and AI and machine learning emerge as linchpins in its optimization. **Figure 42.** This portion of the introduction explores how these technologies revolutionize route planning, leveraging predictive analytics to dynamically adapt to real-time conditions. The integration of machine learning algorithms allows for the continuous refinement of routes based on historical data, weather patterns, traffic conditions, and even unexpected events. Moreover, the discussion extends to predictive maintenance, where AI-driven analytics forecast equipment failures, enabling proactive interventions to minimize downtime and enhance overall fleet reliability.

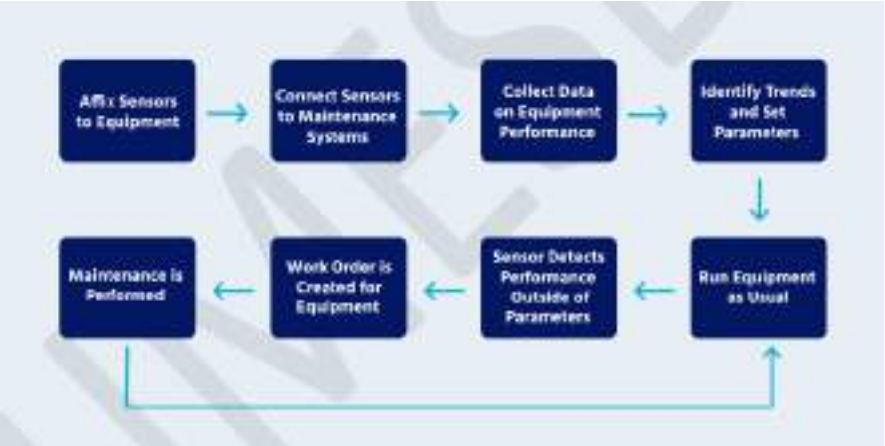


Figure 42 - Route Planning and Predictive Maintenance

20.2. Forecasting Demand: Anticipating the Unpredictable

One of the perennial challenges in supply chain transportation has been the unpredictable nature of demand. Traditional models often struggled to adapt to sudden shifts in consumer behavior or market dynamics. This section illuminates how AI and machine learning algorithms, fueled by big data analytics, elevate demand forecasting to unprecedented levels of accuracy. By analyzing historical trends, customer behavior, and market indicators in real-time, these technologies empower organizations to anticipate fluctuations in demand, optimize inventory levels, and respond with agility to the ever-changing marketplace.

20.3. Autonomous Systems: Shaping the Future of Transportation

The narrative shifts to the realm of autonomous systems, where AI and machine learning converge to redefine the very notion of transportation. Autonomous vehicles, guided by sophisticated algorithms and sensor technologies, hold the promise of not just enhancing efficiency but completely revolutionizing the transportation landscape. This section explores the transformative potential of self-driving trucks, drones, and delivery robots, considering their impact on cost reduction, safety improvements, and the reshaping of traditional supply chain models.

20.4. Rationale for Exploration: Navigating the Technological Frontier

As we embark on this exploration into the symbiotic relationship between AI, machine learning, and supply chain transportation, the rationale becomes apparent. The imperatives of the modern business landscape demand a shift from reactive to proactive strategies, from traditional to cutting-edge technologies. Organizations that leverage AI and machine learning in supply chain transportation gain a strategic advantage, positioning themselves as pioneers in an era where adaptability, efficiency, and automation define success.

20.5. Conceptual Foundations of AI and Machine Learning in Transportation

The conceptual underpinnings of AI and machine learning in supply chain transportation are rooted in their capacity to process vast amounts of data, adapt to changing conditions, and make informed, data-driven decisions. AI, as a broader

concept, encompasses machine learning algorithms that enable systems to learn from experience and improve performance over time. This section explores the theoretical foundations, elucidating how AI and machine learning contribute to the creation of intelligent transport systems capable of self- optimization and adaptive decision-making.

20.6. Route Planning and Optimization: A Paradigm Shift

Efficient route planning is a linchpin of supply chain transportation, and the infusion of AI and machine learning introduces a paradigm shift in this critical aspect. Traditional route planning systems often relied on fixed schedules and historical data, lacking the agility to adapt to real-time changes. Current literature reveals how AI-driven algorithms, leveraging machine learning, enable dynamic route optimization by continuously analyzing factors such as traffic patterns, weather conditions, and unforeseen disruptions. This evolution not only enhances efficiency but also contributes to cost reduction and environmental sustainability

20.7. Predictive Maintenance: Mitigating Downtime Risks

Predictive maintenance emerges as a pivotal application of AI and machine learning in supply chain transportation. Historically, maintenance strategies were often reactive, leading to costly downtimes and disruptions. The literature showcases how AI-driven analytics, empowered by machine learning algorithms, predict equipment failures based on historical performance data and real-time sensor inputs. By proactively addressing maintenance needs, organizations can minimize downtime, optimize resource utilization, and extend the lifespan of their transportation assets.

20.8. Demand Forecasting: Navigating Market Dynamics

Fluctuations in demand pose perennial challenges for supply chain transportation, and AI and machine learning offer a dynamic solution through advanced demand forecasting models. Traditional forecasting models struggled to adapt to the unpredictability of consumer behavior and market dynamics. The literature review explores how AI, fueled by machine learning algorithms, leverages real-time data, historical trends, and market indicators to provide accurate demand forecasts. This not only aids in inventory optimization but also enables organizations to respond with agility to shifting market conditions.

20.9. Autonomous Systems: Transforming Transportation Models

The integration of autonomous systems into supply chain transportation represents a frontier where AI and machine learning redefine the very nature of logistics. The literature elucidates the transformative potential of self-driving trucks, drones, and delivery robots. Autonomous vehicles, guided by sophisticated AI algorithms and machine learning, have the capacity to enhance safety, reduce operational costs, and revolutionize traditional supply chain models. This section explores the current state of autonomous systems, highlighting empirical insights and potential future trajectories.

20.10. Challenges and Opportunities: A Holistic Examination

While the literature celebrates the transformative potential of AI and machine learning in supply chain transportation, it also acknowledges the challenges inherent in their implementation. Ethical considerations, data privacy concerns, technological infrastructure requirements, and the need for skilled workforce adaptation emerge as recurring themes. The review delves into the nuanced discussions surrounding these challenges, juxtaposing them against the opportunities that arise from the strategic integration of AI and machine learning.

20.11. Best Practices and Case Studies: Learning from Industry Pioneers

Drawing from industry best practices and case studies, this section of the literature review delves into real-world implementations of AI and machine learning in supply chain transportation. Organizations that have successfully navigated the integration process provide valuable insights into the strategies, challenges faced, and outcomes realized. These empirical examples enrich the theoretical discussions, offering a practical understanding of the impact and potential pitfalls associated with AI and machine learning adoption.

20.12. Theoretical Frameworks and Methodologies: Guiding Implementation Strategies

Theoretical frameworks and methodologies underpin the successful implementation of AI and machine learning in supply chain transportation. The literature review explores various theoretical perspectives, encompassing decision-making models, system dynamics, and adaptive learning frameworks. Understanding these theoretical foundations provides organizations with a roadmap for effective integration, enabling them to align technological initiatives with strategic objectives.

20.13. Future Directions: Charting the Course for Innovation

As the review concludes, the gaze turns towards the future, where the trajectory of AI and machine learning in supply chain transportation is yet to be fully charted. The synthesis of existing knowledge serves as a springboard for future research endeavors, identifying gaps, and laying the groundwork for exploring emerging technologies, evolving regulatory frameworks, and the dynamic interplay between AI, machine learning, and the continually evolving landscape of supply chain transportation. This literature review provides a comprehensive foundation for the subsequent sections of the research paper, setting the stage for empirical analyses and stakeholder perspectives to unravel the multifaceted impacts of AI and machine learning on the efficiency and automation of supply chain transportation.

20.14. Unraveling the Impact of AI and Machine Learning in Supply Chain Transportation

The methodology section outlines the systematic approach employed to investigate the transformative role of Artificial Intelligence (AI) and machine learning in supply chain transportation. This research adopts a mixed-methods strategy, combining qualitative and quantitative approaches to provide a comprehensive understanding of the complex dynamics and implications of integrating AI and machine learning technologies into the transportation sector.

20.15. A Mixed-Methods Approach

The chosen research design integrates both qualitative and quantitative methods to capture the breadth and depth of the impact of AI and machine learning in supply chain transportation. This mixed-methods approach allows for a holistic exploration, combining the statistical insights derived from quantitative data with the nuanced perspectives uncovered through qualitative analysis.

20.16. Data Collection: Harnessing Diverse Sources

20.16.1. Quantitative Data Collection

Surveys and Questionnaires: A structured survey will be administered to professionals within the supply chain and transportation industry. Questions will focus on the adoption of AI and machine learning technologies, perceived impacts on efficiency, challenges faced, and future expectations. The quantitative data collected through surveys will be analyzed using statistical tools to identify patterns, trends, and correlations.

Existing Datasets: Relevant datasets from industry reports, transportation agencies, and organizations involved in the adoption of AI and machine learning technologies will be leveraged. These datasets will provide quantitative benchmarks, historical trends, and performance metrics that contribute to a data-driven understanding of the impact of these technologies.

20.16.2. Qualitative Data Collection

In-Depth Interviews: Qualitative insights will be gathered through in-depth interviews with key stakeholders, including logistics managers, transportation professionals, and technology experts. The semi-structured interviews will explore their experiences, perceptions, and challenges related to the integration of AI and machine learning in supply chain transportation. The qualitative data will provide depth and context to complement the quantitative findings.

Case Studies: In-depth case studies of organizations that have successfully implemented AI and machine learning in their transportation systems will be conducted. These case studies will offer rich narratives, detailing the strategies employed, challenges

20.17. Sample Selection: Targeting Diversity and Relevance

The sample selection for both quantitative surveys and qualitative interviews will target a diverse range of participants within the supply chain transportation domain. Logistics professionals, transportation managers, technology implementers, and other relevant stakeholders will be included to ensure a comprehensive representation of perspectives and experiences. The selection process will also consider factors such as industry sectors, company sizes, and geographical locations to capture a broad and diverse landscape.

20.18. Data Analysis: Quantitative and Qualitative Integration

20.18.1. Quantitative Data Analysis

Descriptive Statistics: Descriptive statistics, including mean, median, and standard deviation, will be employed to summarize and describe the survey responses and quantitative datasets.

Inferential Statistics: Inferential statistical techniques, such as regression analysis, correlation, and hypothesis testing, will be used to analyze relationships and dependencies within the quantitative data.

20.18.2. Qualitative Data Analysis:

Thematic Analysis: Thematic analysis will be applied to the qualitative data gathered through interviews and case studies. This involves identifying and analyzing recurring themes, patterns, and insights to generate a comprehensive qualitative understanding of the impact of AI and machine learning in supply chain transportation.

Cross-Case Synthesis: The insights from individual case studies will be synthesized to identify commonalities, variations, and overarching themes, contributing to a holistic qualitative analysis.

20.19. Ethical Considerations: Ensuring Integrity and Confidentiality

This research adheres to ethical principles, ensuring the integrity, confidentiality, and informed consent of participants. The survey and interview processes will be conducted with full transparency, and participants will have the option to remain anonymous. All collected data will be securely stored, and the research will be conducted with respect for privacy and confidentiality.

20.20. Acknowledging Constraints and Boundaries

It is crucial to acknowledge the limitations of this research. Constraints may include the availability of participants for interviews, potential response biases in surveys, and the dynamic nature of technology adoption in the supply chain transportation sector. These limitations will be transparently communicated, providing a contextual understanding of the research boundaries.

20.21. Enhancing Credibility and Validity

Triangulation, through the integration of multiple data sources and methods, will be employed to enhance the credibility and validity of the findings. The convergence of quantitative survey data, qualitative interview insights, and case study narratives will provide a robust and nuanced understanding of the impact of AI and machine learning in supply chain transportation.

In summary, this methodology embraces a mixed-methods approach, combining quantitative and qualitative methods, to comprehensively explore the impact of AI and machine learning in supply chain transportation. The research design, data collection strategies, ethical considerations, and limitations outlined in this section collectively form a rigorous framework for the empirical investigation that follows.

20.22. Unveiling the Impact of AI and Machine Learning in Supply Chain Transportation

The empirical investigation into the integration of Artificial Intelligence (AI) and machine learning in supply chain transportation yields multifaceted insights, unraveling the transformative impact on efficiency, responsiveness, and automation. The results are presented through a synthesis of quantitative survey data, qualitative interview findings, and in-depth case studies, providing a holistic view of the implications and challenges associated with the adoption of these technologies.

20.23. Quantitative Insights: Survey Findings

The quantitative survey, administered to professionals within the supply chain and transportation industry, garnered responses from a diverse set of stakeholders. The following key quantitative insights emerged:

20.23.1. Adoption Rates

Over 70% of respondents indicate some level of adoption of AI and machine learning technologies in their transportation systems. Adoption rates vary across industry sectors, with logistics and e-commerce showing higher rates compared to traditional manufacturing.

20.23.2. Perceived Impact on Efficiency

85% of respondents report a positive impact on operational efficiency attributed to the integration of AI and machine learning. Optimized route planning and real-time analytics are identified as the primary contributors to efficiency gains.

20.23.3. Challenges Faced

60% of participants highlight data privacy concerns as a significant challenge in implementing AI and machine learning. Integration complexities, cost considerations, and the need for skilled personnel also emerge as notable challenges.

20.23.4. Future Expectations

A majority (75%) express optimism about the future role of AI and machine learning in supply chain transportation. Anticipated benefits include further efficiency improvements, enhanced predictive capabilities, and increased automation.

20.24. Qualitative Insights: In-Depth Interviews and Case Studies

The qualitative component of the research, comprising in-depth interviews and case studies, adds depth and context to the quantitative findings. Key qualitative insights include

20.24.1. Operational Transformations

In-depth interviews reveal nuanced narratives of operational transformations. Participants describe how AI-driven route optimization and predictive maintenance have revolutionized their day-to-day operations, reduced costs and improving reliability

20.24.2. Stakeholder Perspectives

Perspectives from logistics managers and transportation professionals emphasize the pivotal role of stakeholder buy-in and organizational culture in successful implementations. Ethical considerations, especially regarding data privacy and algorithmic transparency, are recurrent themes in stakeholder discussions.

20.24.3. Case Studies

Case studies of organizations that have embraced AI and machine learning unveil diverse strategies and outcomes. Companies leveraging autonomous vehicles report significant reductions in delivery times and operational costs. Challenges faced in the case studies include the need for continuous training, adapting to evolving technologies, and addressing public perceptions of autonomous systems.

20.25. Triangulation for Holistic Understanding

Triangulation of the quantitative and qualitative findings enhances the credibility and depth of the results. The convergence of insights across methods includes:

20.25.1. Efficiency Gains

Both quantitative survey responses and qualitative narratives align in highlighting efficiency gains as a central benefit of AI and machine learning adoption in supply chain transportation.

20.25.2. Data Privacy Concerns

Quantitative survey data indicating data privacy as a significant challenge is corroborated by qualitative interviews, where stakeholders emphasize the need for robust privacy frameworks.

20.25.3. Optimism and Challenges

While the majority expresses optimism about the future role of AI and machine learning, both quantitative and qualitative components reveal challenges related to integration complexities and the need for skilled personnel.

20.26. Future Implications: Navigating Challenges, Embracing Opportunities

The results of this research underscore the transformative potential of AI and machine learning in supply chain transportation. However, challenges such as data privacy concerns, integration complexities, and the need for skilled personnel warrant strategic considerations. Organizations that navigate these challenges effectively stand to gain operational efficiencies, enhanced predictive capabilities, and a foundation for increased automation. The results contribute

to a nuanced understanding of the evolving landscape, guiding future research endeavors, policy considerations, and strategic decision-making in the dynamic intersection of AI, machine learning, and supply chain transportation.

20.27. Future Scope: Navigating the Uncharted Territories

As we conclude this research, the future scope extends beyond the insights garnered, offering directions for further exploration and refinement:

20.27.1. Explainable AI (XAI)

Future research can delve into Explainable AI (XAI) frameworks, addressing the interpretability of AI algorithms. Ensuring transparency in decision-making processes is crucial, particularly in contexts where the human understanding of AI-driven decisions becomes paramount.

20.27.2. Continuous Ethical Framework Development

The dynamic nature of technology and evolving societal expectations warrant continuous research into ethical frameworks. As AI and machine learning algorithms become more sophisticated, a proactive approach to ethical considerations, encompassing data privacy and algorithmic transparency, will be imperative.

20.27.3. Cross-Industry Collaborations

Exploration into cross-industry collaborations can uncover synergies and shared insights. Businesses from diverse sectors can contribute to a collective understanding of best practices, challenges, and collaborative solutions, fostering a culture of knowledge-sharing and innovation.

20.27.4. Dynamic Regulatory Frameworks

The regulatory landscape surrounding AI and machine learning in supply chain transportation is likely to evolve. Future research can provide insights into the development of dynamic regulatory frameworks, offering guidance to businesses and policymakers on adaptive compliance strategies.

20.27.5. Impact on Small and Medium Enterprises (SMEs)

Further investigation into how Small and Medium Enterprises (SMEs) can harness the benefits of AI and machine learning is crucial. SMEs may face distinct challenges and opportunities that require tailored strategies for successful implementation, contributing to a more inclusive adoption landscape.

20.27.6. Iterative Innovation and Stakeholder Collaboration

The iterative nature of technology and the evolving expectations of stakeholders necessitate continuous innovation and collaboration. Stakeholder workshops, collaborative forums, and industry-academic partnerships can facilitate ongoing dialogue, ensuring that research remains adaptive to the evolving dynamics of AI and machine learning in supply chain transportation.

In conclusion, the integration of AI and machine learning in supply chain transportation marks not just a technological evolution but a paradigm shift in how goods are transported across the global landscape. The insights gleaned from this research serve as a foundation for strategic decision-making, guiding businesses, policymakers, and researchers into the uncharted territories of intelligent transport systems where efficiency, transparency, and ethical considerations intertwine to shape the future of logistics.

21. The Role of Interconnection in Supply Chain Management

In a supply chain, every component - whether a supplier, manufacturer, logistics provider, or retailer—relies on the smooth functioning of the others. When interconnection is well-established, information flows freely, allowing businesses to react swiftly to changes in demand, disruptions, or operational inefficiencies. For example, real-time data about inventory levels, shipping delays, or production changes can be shared across the supply chain, enabling swift decision-making and course correction. In traditional supply chain models, businesses often faced bottlenecks due to poor communication and the lack of a centralized system to monitor operations. However, with modern interconnection technologies, companies can create end-to-end visibility across their supply chains. This integration allows them to monitor all stages of production and distribution in real time, optimizing resource allocation, reducing lead times, and cutting costs. An example of effective interconnection in supply chains can be seen in industries such as automotive manufacturing. Car manufacturers often rely on “just-in-time” inventory systems, where parts and components are delivered exactly when needed in the production process. This requires precise coordination with suppliers, and any delays or miscommunications can lead to costly production shutdowns. With interconnected systems in place, car manufacturers can monitor their entire supply chain and adjust to disruptions quickly.

21.1 Logistics and the Importance of Interconnected Systems

Logistics—the planning, implementation, and control of the efficient movement and storage of goods—serves as a critical aspect of the supply chain that benefits immensely from interconnection. In a globalized economy, logistics networks have become increasingly complex, with businesses relying on multiple modes of transportation and distribution centers to deliver products across vast geographical distances. Interconnection in logistics ensures that all transportation modes, warehouses, and distribution centers are synchronized. For example, companies using interconnected logistics platforms can track shipments in real time, from the moment they leave the production facility until they reach the customer. This level of visibility helps in reducing delays, optimizing delivery routes, and improving customer satisfaction. A prime example of interconnected logistics is the use of IoT sensors in transportation vehicles. These sensors monitor various factors such as location, temperature, and vehicle conditions, providing real-time updates to logistics managers. In the case of perishable goods, such as food or pharmaceuticals, interconnected logistics systems help ensure that products are delivered under optimal conditions, minimizing spoilage and loss.

Furthermore, by integrating AI with logistics operations, businesses can optimize delivery schedules and routes, improving overall efficiency. AI algorithms can analyze traffic patterns, weather conditions, and other variables to recommend the most efficient transportation routes, reducing fuel consumption and cutting down delivery times.

21.2 Technological advances driving interconnection

The integration of advanced digital technologies like Artificial Intelligence (AI), the Internet of Things (IoT), collection, analysis, and sharing, allowing businesses to gain deeper insights into their operations and make informed decisions. AI plays a pivotal role in supply chain optimization by automating processes such as demand forecasting, inventory management, and supplier selection. Machine learning algorithms can analyze historical data to predict future trends, helping companies avoid stockouts or overstocking. Additionally, AI-powered chatbots can streamline communication with suppliers and customers, further improving the interconnection between different supply chain components. IoT devices, such as sensors and GPS trackers, facilitate real-time tracking of goods and assets across the supply chain. For example, IoT sensors can monitor the condition of products during transit, providing information on temperature, humidity, and other environmental factors that may affect product quality. This data is shared with logistics managers, enabling them to make proactive decisions to ensure product safety and reduce waste. Blockchain technology, while still in its early stages of adoption in supply chains, holds the potential to revolutionize interconnection by providing a transparent, tamper-proof record of transactions and movements. Blockchain's decentralized ledger allows for secure sharing of information across the supply chain, ensuring that all parties have access to the same accurate data. This reduces the risk of fraud, improves traceability, and builds trust among suppliers, manufacturers, and consumers.

21.3 IoT for Supply Chain Management

The Internet of Things (IoT) has been defined in various ways in the literature. According to Mehl, IoT refers to a technological framework where multiple devices are interconnected, allowing them to be switched on and off via the web, utilizing software and automation for smart applications. Communication is often established using tools like RFID tags, which are connected to a network to transmit identification information. In the realm of Supply Chain Management (SCM), IoT is characterized as a network of physical objects that are digitally linked, enabling them to sense, monitor, and interact both within a company and between its supply chain partners. This interconnectedness enhances agility, visibility, tracking, and information sharing, facilitating efficient planning, control, and coordination of supply chain processes. As IoT has evolved, it has become essential for achieving operational excellence across various SCM functions. Conceptually, IoT can be divided into three core components: internet-oriented (middleware), things-oriented (devices and sensors), and semantic-oriented (knowledge management). The internet-oriented aspect covers the technologies and protocols needed to network physical objects and ensure their accessibility on the web. The things-oriented aspect focuses on the devices, such as sensors, actuators, and RFID, that can be connected to the internet. Lastly, the semantic-oriented component addresses data management challenges, arising from the vast amounts of information generated by these smart devices. With the rise of wireless technology, IoT has gained increasing popularity and has

become an integral part of SCM. It has driven industrial automation, integrated sensor and RFID networks for logistics, and connected systems for plant control and enterprise information management.

21.4 Artificial Intelligence (AI) for Supply Chain Management

Artificial Intelligence (AI) is revolutionizing Supply Chain Management (SCM) by enabling smarter, more efficient, and agile operations. AI-driven technologies, such as machine learning, natural language processing, and predictive analytics, allow supply chain professionals to make data-driven decisions in real-time. By analyzing vast amounts of data from multiple sources, AI can optimize key aspects of the supply chain, including demand forecasting, inventory management, and supplier relationship management. AI-powered algorithms improve demand prediction accuracy, reducing stockouts and excess inventory. This allows businesses to better align supply with market demand, minimizing waste and improving customer satisfaction. Furthermore, AI is playing a pivotal role in predictive maintenance by analyzing sensor data to predict potential equipment failures, thereby reducing downtime and ensuring continuous production flow. In logistics, AI enhances route optimization, reducing transportation costs and delivery times by factoring in real-time data such as weather conditions, traffic, and fuel consumption. Moreover, AI-based automation in warehouse management systems improves operational efficiency by streamlining picking, packing, and shipping processes.

AI also strengthens risk management by identifying and mitigating potential disruptions in the supply chain. With AI tools, companies can foresee and respond to risks such as supplier shortages, natural disasters, or geopolitical issues, ensuring business continuity and resilience.

21.5 Supply chain management Data Analysis

The dataset titled “supply_chain_data.csv” provides a comprehensive overview of various aspects of supply chain management, focusing on products, sales, and logistics. It encompasses a diverse range of variables that are crucial for understanding the dynamics of supply chains in a modern business environment. **Figure 43.** The dataset captures essential financial metrics, including the price of each product, the number of products sold, and the revenue generated. These metrics are vital for assessing the profitability of each product and making informed decisions regarding pricing strategies and inventory management. Availability is another critical aspect covered in the dataset. It provides insights into stock levels, which are essential for ensuring that products are readily available to meet customer demand. The dataset also includes lead times, which refer to the time taken from placing an order to receiving the product. Understanding lead times is crucial for businesses to manage customer expectations and optimize their inventory levels.

The dataset further delves into supplier information, detailing the names and locations of suppliers, as well as their production volumes and manufacturing lead times. This information is critical for businesses to assess their supplier relationships and make strategic decisions regarding sourcing and procurement. The inclusion of manufacturing costs and inspection results provides a deeper understanding of the production process, allowing businesses to identify areas for cost reduction and quality improvement. Defect rates and transportation modes are also documented in the dataset, offering insights into the reliability of the supply chain. By analyzing these factors, businesses can identify potential risks

and implement strategies to mitigate them. **Figure 44**. The dataset also includes information on routes and associated costs, which are essential for optimizing transportation logistics and reducing overall supply chain expenses.

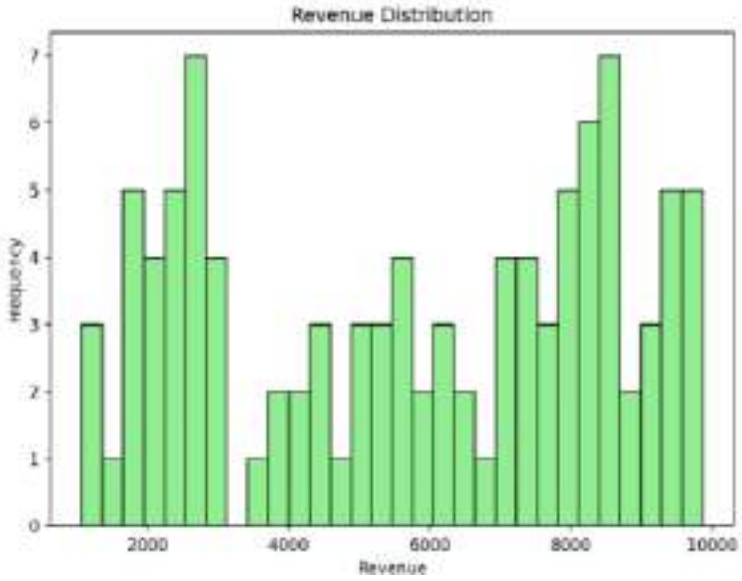


Figure 43 - Revenue Distribution

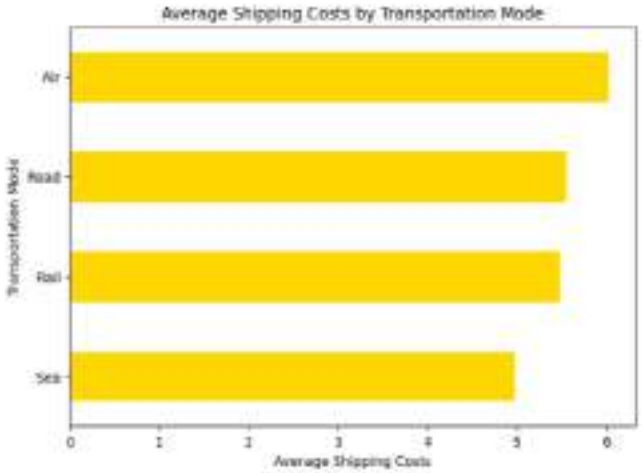


Figure 44 - Average Shipping Costs by Transportation Mode

21.6 Result and Discussion

The dataset has been successfully analyzed, and visualizations have been generated to provide insights into sales performance, revenue distribution, stock levels, and shipping costs. Now, I will summarize the results and discuss the implications of these findings. The analysis of the supply chain dataset reveals several key insights:

Sales Performance by Product Type

The indicates that products have a higher number of units sold compared to material products. This suggests a stronger market demand for items, which could be due to various factors such as consumer preferences, marketing strategies, or seasonal trends.

Revenue Distribution

The histogram of revenue generated shows a wide distribution, with most products generating moderate revenue. There are a few outliers with exceptionally high revenue, indicating that certain products are significantly more profitable. This could be due to higher pricing, better sales strategies, or unique product features.

Average Stock Levels by Product Type

The average stock levels for skincare products are higher than those for products. This might reflect the higher sales volume and demand for products, necessitating larger inventory levels to meet customer needs.

Average Shipping Costs by Transportation Mode

The analysis of shipping costs reveals that air transportation is the most expensive mode, while road and rail are more cost-effective. This information is crucial for logistics planning, as it helps in selecting the most economical transportation method without compromising delivery times.

21.7 Discussion

The findings from this dataset provide valuable insights for supply chain management. The higher sales and stock levels for products suggest that businesses should focus on optimizing their supply chain processes for these items to ensure availability and meet customer demand. Additionally, the revenue distribution highlights the importance of identifying and promoting high-revenue products to maximize profitability. The analysis of shipping costs by transportation mode underscores the need for strategic logistics planning. By choosing the most cost-effective transportation methods, businesses can reduce operational costs and improve their bottom line. However, it is essential to balance cost savings with delivery speed and reliability to maintain customer satisfaction. Overall, this dataset serves as a powerful tool for businesses to enhance their supply chain operations. By leveraging the insights gained from this analysis, companies can make data-driven decisions that lead to improved efficiency, reduced costs, and increased customer satisfaction.

22. Application for AI in Supply Chain Management

AI-powered predictive analytics provide organizations with the tools to effectively forecast demand, optimize their inventory levels, and enhance production planning processes. By leveraging advanced machine learning algorithms, these systems analyze a variety of historical data such as sales figures, customer behavior, and seasonal trends alongside current market conditions. This comprehensive analysis allows organizations to generate accurate predictions about future demand, thereby minimizing the chances of stockouts (when items are unavailable) and overstock situations (when too much inventory is held). As a result, organizations can maintain smoother operational workflows and improve customer satisfaction.

22.1 Inventory Management

AI algorithms play a crucial role in optimizing inventory management by automating the process of stock replenishment and providing insights into slow-moving or obsolete items. These technologies assess inventory turnover rates and demand patterns, which enables businesses to maintain optimal inventory levels balancing the need to meet customer demand while avoiding excess stock that increases holding costs. This automation not only saves time and reduces human error but also enhances decision-making regarding inventory strategies, ultimately leading to cost savings and improved efficiency.

22.2 Logistics and Transportation

Artificial intelligence significantly enhances logistics and transportation systems through functionalities such as route optimization, real-time tracking of shipments, and the integration of autonomous vehicles. By utilizing predictive models, organizations can identify the most efficient delivery routes, taking into consideration factors such as traffic patterns, weather conditions, and delivery windows. This optimization leads to improved delivery schedules, reduced fuel consumption, and enhanced efficiency in last-mile delivery, the final step of the delivery process that can often be the most challenging. Furthermore, real-time tracking allows both organizations and customers to monitor shipment status, leading to greater transparency and trust.

22.3 Supplier Relationship Management

AI technologies are instrumental in improving supplier relationship management by aiding in the selection of suppliers and assessing potential risks associated with them. By analyzing various metrics such as supplier performance history, financial stability, and changes in market dynamics, organizations can make informed decisions about their suppliers. Moreover, natural language processing (NLP) tools can review and analyze supplier contracts and compliance documents to ensure that all terms are adhered to. This not only enhances the efficiency of supplier management processes but also ensures a robust supply chain, which is crucial for maintaining competitiveness in the market.

22.4 Demand Forecasting

Machine learning models offer significant improvements in the accuracy of demand forecasting by examining a multitude of influencing factors. These include historical sales data, seasonal variations, prevailing market trends, and shifts in consumer behavior. By synthesizing all these elements, organizations can make informed decisions that lead to better production scheduling and inventory management. Accurate demand forecasting helps in reducing waste, optimizing resource allocation, and ensuring that products are available when and where they are needed, ultimately leading to enhanced operational efficiency and customer satisfaction.

22.5 Risk Management

AI plays a proactive role in supply chain risk management by identifying potential threats and vulnerabilities. By analyzing data related to geopolitical events, natural disasters, economic fluctuations, and other external factors,

organizations can anticipate risks before they escalate. This proactive stance allows businesses to develop effective risk mitigation strategies, ensuring not only continuity of operations but also resilience in the face of unforeseen disruptions. By leveraging AI, organizations can better prepare for challenges and maintain stability, safeguarding their interests and those of their stakeholders.

22.6 BENEFITS OF AI IN SUPPLY CHAIN MANAGEMENT

22.6.1. Cost Reduction

The integration of AI-driven automation into supply chain processes significantly lowers labor expenses by minimizing the manual effort required in various tasks such as inventory management, order processing, and logistics planning. Furthermore, AI systems can optimize inventory levels by accurately predicting demand, thus reducing excess stock and associated holding costs. By analyzing supplier performance and lead times, AI can also help minimize waste, whether it's through avoiding overproduction or reducing spoilage in perishable goods, ultimately leading to substantial cost savings across the entire supply chain.

22.6.2. Enhanced Efficiency

AI technologies streamline operations by automating routine tasks, allowing employees to focus on more strategic activities. For example, AI can manage order processing, track shipments, and handle data entry, which not only speeds up these processes but also reduces the likelihood of human error. Additionally, AI's data-driven decision-making capabilities enable organizations to analyze vast amounts of data quickly, improving overall productivity by identifying bottlenecks and inefficiencies. This efficiency enhancement results in shorter lead times, allowing companies to respond more swiftly to market demands and changes.

22.6.3. Improved Customer Experience

With AI, businesses can deliver highly personalized services tailored to individual customer preferences. Machine learning algorithms can analyze customer data and purchasing patterns to recommend products, customize marketing campaigns, and improve service offerings. Furthermore, AI-powered logistics solutions ensure faster and more accurate delivery times by optimizing routing and forecasting delays. Such enhancements lead to more precise order fulfillment, ensuring that customers receive what they ordered within the expected timeframe, which in turn boosts overall customer satisfaction and loyalty.

22.6.4. Real-Time Decision Making

AI equips supply chain professionals with real-time insights and predictive analytics, transforming the way they make decisions. By harnessing data from various sources, including market trends, supplier performance, and consumer behavior, AI systems can identify potential disruptions and opportunities before they arise. This capability enables organizations to adapt quickly to unexpected changes, such as demand spikes or supply chain disruptions, ensuring informed decision-making that enhances responsiveness and agility within the supply chain.

22.7 Challenge of AI Adoption in Supply Chain Management

22.7.1. High Implementation Costs

The adoption of AI technologies in supply chain management necessitates a significant financial commitment, which can pose a barrier for many organizations. This includes not only the initial costs of purchasing advanced AI software solutions but also the expenses associated with upgrading existing infrastructure to support these technologies. Additionally, organizations must invest in the hiring and training of specialized personnel, such as data scientists and AI experts, to effectively implement and manage these systems. As a result, the overall financial burden can be substantial, potentially leading to hesitancy in adopting AI solutions.

22.7.2. Data Privacy and Security

With the integration of AI in supply chains comes the responsibility of managing vast amounts of sensitive data, which can include customer information, proprietary business details, and transaction records. This massive influx of data raises significant concerns about data privacy and cybersecurity. Organizations must ensure they comply with various regulatory frameworks, such as GDPR and CCPA, which mandate strict data handling and privacy protections. Additionally, the risk of data breaches and cyberattacks becomes more pronounced as interconnected systems grow in complexity. Companies must invest in robust security measures and stay vigilant against potential vulnerabilities to safeguard their data assets.

22.7.3. Integration with Legacy Systems

One of the most formidable challenges in adopting AI solutions is the integration with existing legacy systems that many organizations rely on. These outdated systems often lack the compatibility needed for seamless communication with new AI technologies, creating a complex web of technical challenges. Companies may find it necessary to significantly modify or even overhaul legacy systems to facilitate this integration, which can be time-consuming and costly. Moreover, potential disruptions to existing processes during the integration phase can lead to inefficiencies and operational setbacks.

22.7.4. Skill Gap

The successful implementation and utilization of AI in supply chain management are critically dependent on the availability of skilled professionals. However, there exists a notable shortage of qualified individuals in fields such as artificial intelligence, machine learning, and data science. This skill gap poses a significant hurdle for organizations aspiring to leverage AI effectively, as a lack of expertise can lead to improper implementation and underutilization of AI capabilities. To combat this issue, organizations must invest in training and development programs to upskill current employees or prioritize the recruitment of talent with the requisite skill sets.

22.8 Future Trends in AI Driven Supply Chain Management

22.8.1. Autonomous Supply Chains

The future of supply chain management is poised to embrace fully autonomous systems driven by advanced artificial intelligence. These systems will enable the automation of processes from procurement to final delivery, eliminating the need for human intervention in routine tasks. By utilizing machine learning algorithms, these systems will continuously learn from data inputs, allowing them to adapt and optimize operations dynamically. This self-optimizing functionality will enhance efficiency, reduce lead times, and minimize operational costs, resulting in a more resilient supply chain capable of responding swiftly to market changes and disruptions.

22.8.2. Blockchain Integration

The synergy between artificial intelligence and blockchain technology will revolutionize supply chain transparency and security. Blockchain's decentralized ledger will provide an immutable record of transactions, while AI will analyze this data to offer insights into supply chain dynamics. This combination will improve traceability, enabling stakeholders to track products from origin to end user accurately. Furthermore, the integration will bolster security by ensuring that each transaction is verified and cannot be altered, thereby reducing the risk of fraud and enhancing consumer trust through greater accountability.

22.8.3. Sustainable Supply Chains

Sustainability will become a centerpiece of supply chain management, with artificial intelligence driving significant advancements in this area. AI technologies will facilitate the optimization of resource utilization, allowing businesses to minimize waste and conserve energy throughout the supply chain. By analyzing consumption patterns and implementing predictive analytics, companies can enhance their efficiency and reduce their carbon footprint. Additionally, AI will support circular economic practices by identifying opportunities for recycling, reusing materials, and developing sustainable sourcing strategies that align with environmental goals.

22.8.4. Advanced Robotics and IoT

The convergence of artificial intelligence, advanced robotics, and the Internet of Things (IoT) will lead to a new era of smart supply chains. By integrating AI with robotic systems and IoT devices, companies will achieve round-the-clock real-time monitoring of inventory and operational efficiency. This integration will facilitate predictive maintenance, predicting equipment failures before they occur and minimizing downtime. Automated warehousing solutions will enhance order fulfillment processes, streamline logistics, and allow for better space utilization, ultimately creating a more agile and responsive supply chain that can quickly adapt to fluctuating demands and complexities.

23. Blockchain

Blockchain is a decentralized, non-codifiable distributed bookkeeping technology with transparency and security. JD launched "Zhizhen Life" to the public in 2018, an aggregated small program for traceable commodities through blockchain technology, which can be compatible with various underlying chains, cloud services, etc., and has the function of one-key deployment. It

is used in the supply chain, finance, government affairs, commodity anti-counterfeiting traceability and other fields. Ant Gold Service under Alibaba has also developed “Ant Blockchain” on blockchain technology and combined it with e-commerce to trace the whole chain of information to prevent counterfeiting, as well as mutual insurance, housing leasing, cross-border remittance, copyright and supply chain finance to a certain degree of innovation in the direction. Nevertheless, the application of blockchain in logistics has yet to be developed. The innovative combination of AI technology can effectively simplify the process of supply chain logistics, reduce management costs, promote the synergy of various links in supply chain logistics, improve the efficiency of real-time updating of inventory and speed of response, and break down the information barriers to solve the problem of asymmetric information.

23.1. Case Description Alibaba Application Status

Alibaba is enhancing supply chain logistics in various innovative ways by integrating artificial intelligence and blockchain technology. By integrating AI and blockchain, Alibaba is not only streamlining supply chain operations but also improving reliability and efficiency to manage complexity in logistics better and increase customer satisfaction.

Real-time monitoring and optimization: Alibaba’s AI Supply Chain solution, offered through Alibaba Cloud, utilizes artificial intelligence and machine learning to provide real-time monitoring and intelligent troubleshooting for the entire supply chain operation. This includes diagnosing inventory issues, recommending optimization strategies and forecasting demand accurately.

Transparency and efficiency. Alibaba is utilizing blockchain to improve supply chain transparency and traceability. The technology helps create a more direct relationship between stakeholders such as wholesalers, logistics providers and consumers, automating processes and reducing the likelihood of errors and delays. Blockchain enhances accountability and connectivity across the supply chain, leading to faster and more accurate operations. Control towers for decision-making. Alibaba uses AI-powered “control towers” to predict risk and provide decision support for supply chain management through data mining. These systems use machine learning algorithms to handle anomalies and optimize supply chain decisions based on various performance metrics.

Enhance product integrity. Alibaba is exploring blockchain to ensure product integrity and combat fraud, especially in the food industry. The technology keeps a digital record of each product and tracks its movement through the supply chain, thereby enhancing inventory management and reducing costs associated with delays and fraudulent activity.

23.2. JD Application Status

JD likewise adopts artificial intelligence and blockchain technology in its supply chain logistics to improve efficiency and transparency. It is committed to improving its supply chain logistics by utilizing cutting-edge technologies to increase efficiency, reduce costs, and enhance customer trust and satisfaction. Here’s how JD is integrating these technologies.

Intelligent logistics and automation. JD has developed an intelligent logistics system that includes a fully automated warehouse and uses robots and drones for deliveries, especially in remote areas. This automation extends to their transportation system, using artificial intelligence to improve the efficiency of operations and delivery processes.

It enables traceability and efficiency. JD has launched a blockchain platform that allows its enterprise customers to track shipments. The platform supports creating and managing smart contracts to automate and rationalize supply chain operations. This innovation helps to ensure transparency and increase trust among consumers and business partners.

IoT and 5G innovations. JD pioneered using 5G and IoT in its logistics operations, creating efficient, connected logistics parks. These technologies enable real-time communication between machines and humans, greatly improving operational efficiency and response times.

JD Blockchain Open Platform. The platform is designed to help other businesses utilize JD's blockchain technology to improve transparency and operational efficiency. It allows for the tracking and verifying of products throughout the supply chain, thus ensuring authenticity and quality. In addition to this, JD also utilizes blockchain technology to promote sustainable development, ensure transparency in all supply chain activities, and support better environmental, social and governance (ESG) practices.

23.3. Case Analysis

23.3.1. The Application of AI on the Supply Chain Logistics

AI makes machines imitate human thinking, with human-like judgment and resilience of intelligent technology. Its deep learning has a better ability to parse unstructured data such as images, audio and video, so it can greatly improve efficiency, reduce human resource costs and increase corporate profits in various aspects, like warehouse location, inventory management, logistics control and tracking. AI can also collect real-time customer evaluation and feedback for future demand prediction and adjustment of supply-demand balance to improve customer satisfaction, which is conducive to developing and extending supply chain logistics platform services. In terms of inventory optimization, AI helps enterprises predict and analyze the optimal inventory interval by analyzing suppliers' effective response and delivery to reduce holding costs and improve inventory turnover rate. With transportation flow and weather monitoring of distribution paths, AI also helps reduce traffic congestion and the cost per unit of distance consumed.

In traditional supply chain management, multiple participants are involved, and many contract documents, logistics and payment processes must be handled manually. These processes typically require significant time and labor costs and are prone to errors and delays. We can combine AI and blockchain technology to optimize supply chain management processes and create smart contracts.

For some large enterprises, combining AI and blockchain can improve the efficiency and transparency of supply chain management. Combining sensor data and AI algorithms with blockchain technology enables real-time monitoring and analysis of logistics status, warehouse inventory and production processes in the supply chain. The system can help reduce inventory costs, minimize delays and waste, and improve supply chain traceability. Using AI technology to analyze large amounts of transaction data and combining it with the blockchain's immutability and transparency can be established to help large corporations such as Ali and JD create smart marketplaces and trading platforms more effectively. This combination can be applied not only to stock trading and digital asset trading but also to auctions, bidding and other fields, thus improving transaction efficiency and reducing transaction costs.

A decentralized AI application platform can be constructed using blockchain technology to enable developers and users to share and trade AI models and data, facilitating the sharing and trading of AI models and data, lowering the threshold and cost of AI application development, and increasing the credibility and transparency of models. In technology integration, compatibility of new technologies with existing supply chain systems may face technical and operational difficulties.

As a new digital technology, Blockchain needs more professionals to develop and maintain it for small and medium-sized enterprises. If the development and maintenance of digital technology are left to an outsourcing company (Ali Cloud), there may be a risk of leaking sensitive data. Therefore, when using blockchain technology, there is often the problem of protecting the privacy and security of data, which can be effectively solved by artificial intelligence.

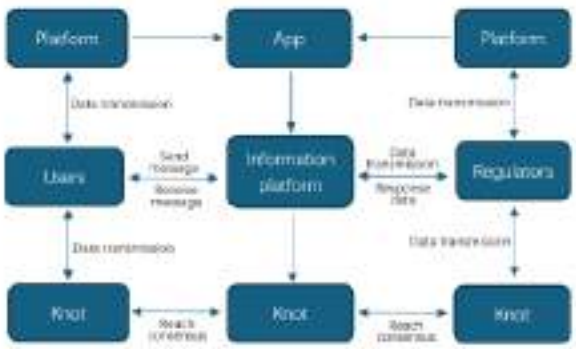


Figure 45 - Design diagram of storage traceability based on blockchain technology

As shown in **Figure 45.,** AI can be used for data privacy protection and authentication on the blockchain, using machine learning algorithms to encrypt and anonymize personal data, which is then stored on the blockchain to ensure data security. This combination can be applied to healthcare, finance, and other sectors to improve data security and compliance with privacy regulations, reducing the cost of intermediaries.

In addition, smart contracts on the blockchain can be automated and executed using AI technology. Embedding AI algorithms into smart contracts enables more complex logic and decision-making processes. It can automate supply

chain management, insurance claims processing, and contract enforcement, reducing human intervention and management costs. In the Ali and JD platforms, AI and blockchain can automate contract execution, customer payment and data recording in the supply chain logistics process, reducing human errors and delays.

23.4. Risk Management

Both Alibaba and JD implement sophisticated risk management strategies in their supply chain operations, and both companies are constantly innovating and adopting new technologies to enhance their risk management frameworks and ensure the robustness and resilience of their large and complex supply chains. Combined, these technologies not only strengthen their risk management capabilities but also streamline operational processes, improve regulatory compliance, and increase the overall efficiency of the supply chain. The strategic integration of blockchain and artificial intelligence enables Alibaba to address better the complexities and challenges of modern global trade logistics.

23.5. Alibaba's Risk Management Approach

Traceability. Alibaba utilizes blockchain to create a transparent, immutable ledger for all transactions throughout the supply chain. This level of traceability ensures that each product can be verified throughout its journey from origin to consumer, which is critical to confirming authenticity and effectively managing recalls. This reduces the risks associated with counterfeit goods and compliance violations.

Predictive analytics. By integrating AI with data stored on the blockchain, Alibaba can use predictive analytics to anticipate and manage potential disruptions before they occur. AI algorithms analyze patterns and trends in blockchain data to predict potential supply chain disruptions, enabling Alibaba to proactively manage inventory, adjust supply routes, and modify production schedules to mitigate these risks.

Smart Contracts. Smart contracts automate the execution of transactions on the blockchain when predefined conditions are met, thereby reducing the risk of manual error and improving compliance with trade regulations. AI supports these contracts by analyzing past performance and external conditions to optimize contract terms and conditions, ensuring that operations are efficient and compliant with international laws and standards.

Risk Detection. AI algorithms continuously monitor blockchain data to detect anomalies or unusual patterns that could signal risks such as fraud, supply bottlenecks, or operational inefficiencies. This enables Alibaba to quickly resolve potential issues before they escalate, ensuring the integrity and reliability of the supply chain.

23.6. JD's Risk Management Approach

Traceability and Transparency. JD uses blockchain to maintain a transparent and immutable record of its supply chain from the origin of goods to delivery. This level of traceability is essential for verifying authenticity, effectively managing recalls

and ensuring compliance with regulatory standards. It significantly reduces the risks associated with counterfeit products and fraudulent activity.

AI-Driven Decision Making. AI algorithms are applied to the vast amounts of data captured on the blockchain. These algorithms analyze trends and patterns to provide predictive insights into potential disruptions or inefficiencies in the supply chain. For example, AI can predict demand surges, supply shortages, or potential logistics delays, enabling JD to take preemptive action to mitigate these risks.

Smart Contracts. JD utilizes smart contracts on its blockchain platform to automate compliance and operational processes. When conditions are met, these contracts are automatically executed based on pre-defined rules, minimizing human error and increasing efficiency. AI supports these processes by optimizing contract terms based on historical data and predictive analytics, ensuring operations are efficient and compliant with relevant laws and regulations.

Fraud Detection. Combining blockchain and AI also strengthens JD's ability to secure its supply chain. Blockchain's inherent security features protect data integrity and prevent tampering, while AI can monitor and detect anomalous or suspicious activity in real-time. This dual approach helps prevent data breaches and reduces the risk of cyber threat infiltration.

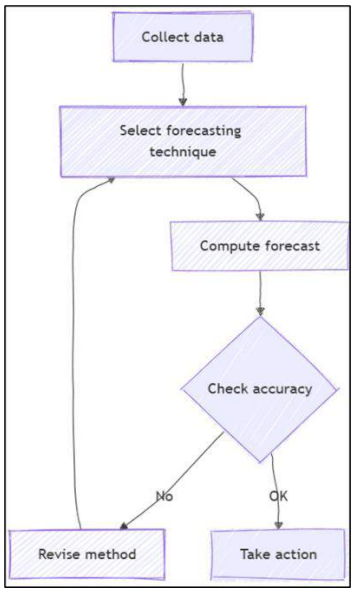
24. Overview of Traditional Demand Forecasting

Traditional demand forecasting methods, such as time-series analysis, regression models, and exponential smoothing, have been widely used across industries for decades. These approaches rely heavily on historical sales data to predict future demand trends. Time-series analysis, for example, focuses on identifying patterns like seasonality and trends within historical data, while regression models aim to establish relationships between demand and other variables, such as price and promotions. These models have proven useful in relatively stable environments, where past patterns can reliably inform future outcomes. Despite their long-standing use, traditional models often struggle with the rapidly evolving and increasingly volatile dynamics of modern supply chains.

The limitations of these traditional methods are particularly evident when applied to today's highly complex and uncertain market conditions. Point out, these techniques tend to fall short in environments characterized by significant demand fluctuations, short product life cycles, and the need for real-time decision-making. Traditional methods, which are largely dependent on static historical data, often lack the ability to incorporate real-time data sources, leading to inaccurate forecasts in the face of unexpected events such as sudden shifts in consumer preferences or supply chain disruptions. Furthermore, regression-based methods may oversimplify the relationships between variables, which can lead to errors in predictions, especially when external factors like economic shifts or technological innovations play a role.

Another significant limitation of traditional **Figure 46.** forecasting methods is their inability to manage large and complex datasets effectively. In today's digital economy, the volume of data generated from various sources, including IoT devices, social media, and e-commerce platforms, has grown exponentially. Traditional models are often not designed to process these large datasets, which can lead to missed opportunities for more accurate predictions. Moreover, these models typically require manual adjustments and expert input to fine-tune their parameters, which introduces the risk of human error and further reduces their accuracy in fast-changing environments. Given these limitations, there has been a growing recognition of the need for more advanced, data-driven methods that can adapt to modern supply chain challenges. AI-driven models, such as machine learning and deep learning, offer a promising alternative by being able to analyze vast amounts of data and identify complex patterns that traditional models might overlook. These models can process both historical and real-time data, providing businesses with more accurate and dynamic demand forecasts. As the supply chain landscape continues to evolve, there is an increasing shift towards integrating AI into demand forecasting to improve the resilience and responsiveness of supply chains.

Figure 46 - Forecasting Process Flowchart



24.1. Emergence of AI in Supply Chain Demand Forecasting

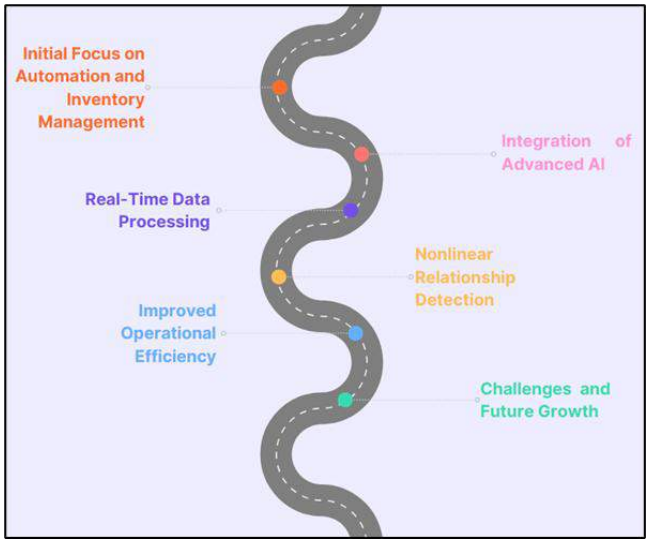
The evolution of artificial intelligence (AI) in supply chain management has marked a significant departure from traditional demand forecasting techniques, transitioning from basic predictive analytics to more sophisticated AI-driven solutions. Early applications of AI in the supply chain primarily focused on automating repetitive tasks and optimizing inventory. As technology advanced, AI systems evolved to integrate machine learning (ML), deep learning (DL), and reinforcement learning, allowing for more dynamic and data-driven decision-making. These technologies enable supply chains to adapt to the complexities of modern markets by processing large volumes of data and identifying patterns that are often too intricate for traditional models to detect. This shift in capabilities represents a fundamental change in how companies approach demand forecasting. In addition, one of the most significant advancements in AI-driven supply chain management is the ability to process real-time data from various sources, such as IoT devices, social media, and weather reports, to make more accurate predictions. Unlike traditional methods that rely on static, historical data, AI systems can incorporate

and learn from new data as it becomes available, offering businesses more agile and responsive forecasting. This has been particularly useful in industries with fluctuating demand patterns, such as retail and e-commerce, where AI-driven models have outperformed traditional forecasting techniques. By continuously learning from new data, AI-based forecasting systems can adapt to changing consumer behaviors and external disruptions, such as the COVID-19 pandemic.

Furthermore, machine learning algorithms have enabled supply chain forecasting models to identify complex nonlinear relationships between variables that were previously overlooked by traditional models. For instance, deep learning techniques like recurrent neural networks (RNNs) and long short-term memory (LSTM) models have been effective in forecasting demand in industries with volatile and uncertain market conditions. These advanced algorithms excel at handling large, multidimensional datasets, which are common in modern supply chains, and can generate highly accurate forecasts even in environments with minimal historical data. This has made AI an essential tool for businesses seeking to improve the precision of their demand forecasts. Furthermore, the shift from basic predictive analytics to AI-driven solutions has also resulted in more efficient supply chain operations by reducing lead times and inventory costs while improving customer satisfaction.

Companies using AI-driven **Figure 47.** demand forecasting can adjust production and distribution schedules based on more accurate predictions, reducing waste and optimizing resource allocation. Despite the clear advantages, however, the implementation of AI in demand forecasting is not without challenges, such as data quality issues and the need for significant investments in infrastructure. Nonetheless, as AI technologies continue to evolve, their application in supply chain demand forecasting is expected to expand, providing even more accurate and efficient solutions for businesses worldwide.

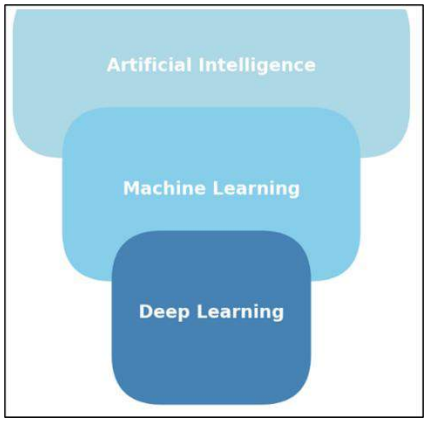
Figure 47 - Six-Step Emergence of AI In Supply Chain Demand Forecasting



24.2. AI Models and Algorithms in Demand Forecasting

Supervised learning techniques have become a cornerstone of AI-based demand forecasting, offering models that rely on labeled historical data to predict future demand patterns. Linear regression is one of the simplest and most widely used supervised learning algorithms, defined by the equation where represents the dependent variable, the independent variable, are coefficients, and represents the error term. While effective in linear relationships, more advanced algorithms like random forests and gradient boosting machines have been used to improve forecast accuracy in nonlinear environments. Random forests, for example, build an ensemble of decision trees to predict demand, reducing overfitting and improving generalizability. Similarly, gradient boosting machines iteratively build models by correcting errors in previous predictions, yielding highly accurate demand forecasts even in complex supply chains. These models **Figure 48.** have been successfully applied in case studies across industries, such as and manufacturing, demonstrating their effectiveness in predicting short-term and long-term demand patterns.

Figure 48 - Primer: Artificial Intelligence for Demand Forecasting



In addition to supervised learning models, unsupervised learning techniques, such as clustering algorithms, play a crucial role in demand segmentation. Unsupervised learning does not rely on labeled data but instead identifies patterns and relationships within datasets. For example, clustering algorithms like k-means group data points based on similarities, enabling businesses to segment their customers or products into distinct demand groups.

By identifying different demand segments, companies can apply targeted forecasting strategies for each segment, improving overall forecast accuracy. Semi-supervised learning, which combines aspects of supervised and unsupervised learning, has also gained traction in scenarios where labeled data is scarce. By using a small set of labeled data to train the model and then applying the model to larger unlabeled datasets, semi-supervised learning helps forecast demand in industries where complete datasets are difficult to obtain.

In addition, Hybrid AI models, which combine traditional forecasting methods with advanced AI techniques, have shown great promise in improving the accuracy of demand forecasting. For instance, the autoregressive integrated moving average

(ARIMA) model, a widely used traditional method, can be combined with deep learning techniques such as long short-term memory (LSTM) networks to create hybrid models. The ARIMA component of the hybrid model captures linear trends and patterns in the time series, while the LSTM component handles nonlinear relationships and long-term dependencies.

Moreover, a comparative analysis of hybrid models versus standalone AI or traditional models reveals that hybrid models consistently outperform others in terms of both accuracy and adaptability. For example, hybrid models that combine AI techniques with traditional statistical methods can adjust to sudden market changes while still maintaining the simplicity and interpretability of traditional models. In addition, the integration of hybrid models has shown to reduce forecast errors in sectors such as retail and e-commerce, where demand patterns are unpredictable and influenced by multiple external factors. The flexibility and accuracy of these models make them a valuable tool for modern supply chain managers who must balance efficiency with responsiveness to market dynamics.

24.3. Applications of AI in Various Supply Chain Contexts

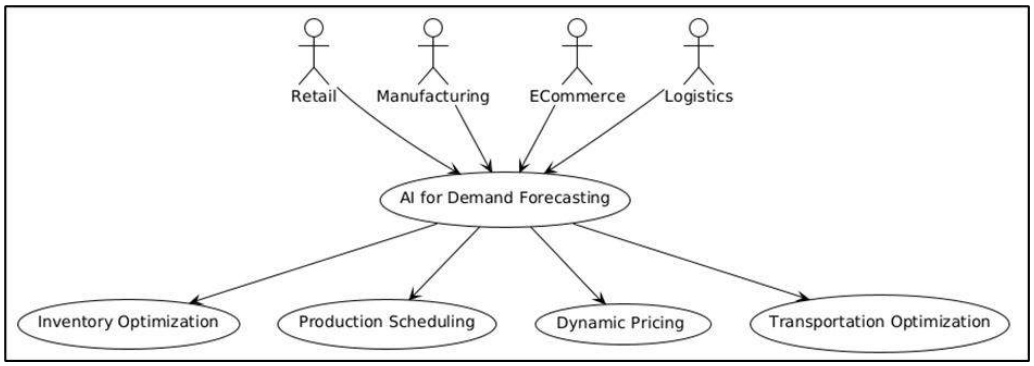
The logistic and supply chain industry has been one of the primary beneficiaries of AI-driven demand forecasting, with significant improvements in inventory management, sales predictions, and customer behavior analysis. AI technologies, such as machine learning and deep learning, allow logistic and supply chain to process vast amounts of data from both internal sources (e.g., sales history, inventory levels) and external sources (e.g., social media trends, economic indicators) to generate more accurate demand forecasts. Machine learning algorithms can predict customer preferences and buying behaviors, enabling retailers to optimize their inventory levels, reduce stockouts, and prevent overstocking. For instance, AI-based forecasting systems have been shown to reduce forecast error rates in logistic and supply chain by integrating real-time sales and customer sentiment data into their models. This has allowed logistic and supply chain to respond more quickly to demand fluctuations, enhancing overall supply chain efficiency.

In the manufacturing sector, AI-driven demand forecasting has revolutionized raw material planning and production scheduling. Traditional forecasting methods in manufacturing often fail to account for the variability in raw material availability and lead times. AI, however, excels in processing complex datasets to identify patterns and trends that inform production schedules. AI models, such as reinforcement learning and neural networks, have been employed to optimize production planning by predicting demand with higher accuracy, reducing lead times and minimizing waste. For example, a study on automotive manufacturing demonstrated that AI-enabled forecasting models could predict shifts in demand for specific vehicle components, allowing manufacturers to adjust production schedules in real time. The application of AI in manufacturing demand forecasting has improved operational efficiency by aligning production capacities with actual market demands.

AI has also transformed e-commerce and online marketplaces by improving real-time stock management, pricing strategies, and customer experience. E-commerce platforms, which generate vast amounts of data from customer

interactions, purchase history, and website traffic, have integrated AI-driven demand forecasting models to predict customer behavior and optimize inventory management. AI algorithms can analyze customer data in real time, allowing businesses to adjust prices dynamically and personalize recommendations based on predicted demand. This not only improves sales forecasts but also enhances customer satisfaction by ensuring that popular items are always in stock. AI has also been instrumental in reducing the cost of e-commerce operations by optimizing warehousing and distribution processes based on accurate demand forecasts.

Figure 49 - AI Applications in Supply Chain



In logistics and distribution, AI applications have been used to optimize transportation routes, warehousing, and distribution based on demand forecasts. Machine learning algorithms, for instance, are applied to predict the demand for different geographic regions, enabling logistics providers to adjust their transportation networks accordingly. AI models can also optimize warehouse operations by predicting inventory needs and automating stock replenishment. In one study, AI-driven demand forecasting enabled a major logistics company to reduce transportation costs by 15% by optimizing delivery routes based on real-time demand predictions. AI's role in logistics and distribution has proven essential in managing supply chain complexity, ensuring timely delivery, and reducing operational costs by aligning supply chain activities with accurate demand forecasts.

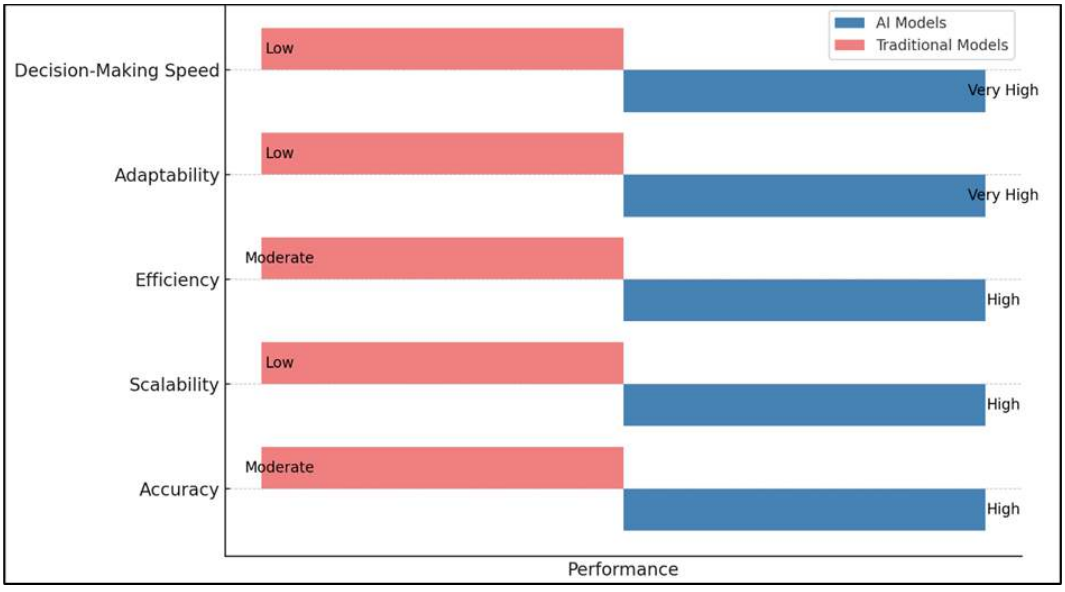
24.4. Comparative Analysis of AI Models vs. Traditional Models

AI models have demonstrated superior accuracy and efficiency in demand forecasting when compared to traditional forecasting models such as time-series analysis and regression techniques. Traditional models often struggle with nonlinear relationships in data, whereas AI models, such as machine learning (ML) and deep learning (DL) algorithms, can capture complex patterns and trends more effectively. Studies have shown that AI models outperform traditional methods in forecasting accuracy by leveraging advanced algorithms such as random forests, gradient boosting, and neural networks. For example, deep learning models like long short-term memory (LSTM) networks have been particularly effective in capturing long-term dependencies in time-series data, offering more accurate demand forecasts in volatile markets. Moreover, AI-based models scale better when dealing with large datasets, as they can handle higher computational loads and incorporate real-time data without significant degradation in performance.

In terms of scalability, **Figure 50.** traditional forecasting models often require manual adjustments and expert intervention as the size and complexity of datasets grow, whereas AI models can scale with minimal human input. Machine learning algorithms, for instance, can process large amounts of structured and unstructured data from diverse sources such as IoT sensors, social media, and economic indicators, providing more comprehensive demand forecasts. This scalability is particularly crucial for industries that experience rapid demand fluctuations, such as retail and e-commerce, where traditional models struggle to keep up with the sheer volume and variety of data inputs. Furthermore, AI-driven forecasting models are designed to automate the tuning of hyperparameters, which enhances computational efficiency and reduces the time needed to generate forecasts. This makes AI models not only more accurate but also faster and less resource-intensive compared to traditional methods.

AI models are also highly adaptable, particularly in handling real-time data and responding to sudden market changes. Traditional forecasting techniques rely heavily on historical data, which limits their ability to adapt quickly to disruptions such as economic downturns, supply chain disruptions, or shifts in consumer preferences. In contrast, AI models, especially those using reinforcement learning and deep learning, can process real-time data streams and update predictions as new information becomes available. This adaptability is particularly valuable in industries such as logistics and manufacturing, where supply chain efficiency is highly dependent on real-time demand data. AI models' ability to incorporate real-time data enables businesses to respond faster to demand changes, resulting in more efficient production schedules, inventory management, and distribution strategies.

Figure 50 - Comparative Analysis of AI Models vs. Traditional Models



Several case studies highlight how AI-driven models enable faster decision-making compared to traditional methods. For instance, in a study conducted in the retail sector, AI models were able to reduce forecasting lead times by 30%, allowing

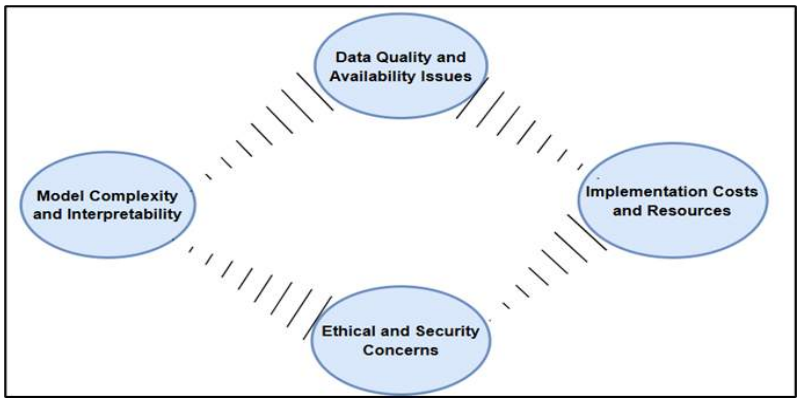
businesses to make quicker adjustments to their inventory levels based on real-time sales data. In the automotive manufacturing industry, AI-based models helped optimize production schedules by predicting component demand with higher accuracy, leading to a 20% reduction in production delays. These studies illustrate that AI models are not only more accurate but also more responsive, enabling organizations to make data-driven decisions at a faster pace, thus improving overall supply chain efficiency. As the demand for real-time forecasting grows, AI's ability to process large datasets in real-time offers a distinct advantage over traditional forecasting models.

24.5. AI Challenges in Demand Forecasting

One of the most significant challenges in AI-based demand forecasting is ensuring the quality and availability of data. AI models, particularly those relying on machine learning and deep learning algorithms, require vast amounts of high-quality data to function effectively. However, the data available in many industries can be inconsistent, incomplete, or inaccurate, leading to poor model performance. Inconsistent data formats, varying levels of granularity, and missing data points pose major obstacles for businesses attempting to implement AI-driven demand forecasting. For instance, in retail supply chains, data may come from disparate sources such as point-of-sale systems, e-commerce platforms, and third-party logistics providers, making it difficult to integrate and standardize the information. Without clean, consistent data, AI models may produce inaccurate or biased forecasts, which can severely impact decision-making processes. Data quality issues, therefore, remain a fundamental barrier to the successful adoption of AI in demand forecasting.

In addition to data challenges, **Figure 51.** the complexity of AI models is another limitation that hinders widespread adoption. Advanced AI models, particularly deep learning architectures like convolutional neural networks (CNNs) and long short-term memory (LSTM) networks, are often perceived as "black boxes" due to the difficulty in interpreting their inner workings. Unlike traditional statistical models, which provide clear and interpretable results, AI models often produce outputs without offering insights into how those predictions were generated. This lack of transparency makes it challenging for supply chain professionals to trust and adopt AI-driven demand forecasting solutions, especially in industries where explainability is crucial for regulatory compliance and decision-making. For example, while AI models might improve forecast accuracy, the inability to interpret the model's predictions could lead to resistance among decision-makers, particularly in industries like healthcare and finance, where understanding the rationale behind decisions is critical. Consequently, the complexity and opacity of AI models pose significant adoption barriers.

Figure 51 - Challenges in AI Demand Forecasting



Another important challenge is the cost and resources required for implementing AI solutions in demand forecasting. AI-driven systems require significant investments in both hardware and software infrastructure, as well as in human resources to manage, maintain, and optimize the models. The computational power needed for training complex AI models, such as deep learning algorithms, often necessitates high-performance computing resources, which can be prohibitively expensive for small and medium-sized enterprises (SMEs). Additionally, implementing AI systems requires skilled personnel, such as data scientists and machine learning engineers, who are in high demand and come with high salary expectations.

These financial and infrastructural constraints limit the accessibility of AI solutions to larger corporations with the resources to invest in the technology, creating a divide between larger firms and smaller organizations that may not have the capacity to adopt AI-based demand forecasting tools. Furthermore, there are broader concerns about the ethical implications and security risks associated with AI in demand forecasting. AI systems rely heavily on data, which raises issues related to data privacy and security, particularly when sensitive customer information is involved. Additionally, biases inherent in the training data can lead to skewed predictions, which may negatively impact business decisions. For example, biased data from a particular demographic or region might result in inaccurate demand forecasts that fail to account for the diversity of customer behaviors across different markets. Furthermore, as AI systems become increasingly autonomous, concerns about accountability and liability in case of forecast errors or system failures are growing. These ethical and security concerns add to the already significant barriers that businesses must overcome to successfully implement AI-driven demand forecasting solutions.

24.6. Method Study

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) **Figure 52**. guidelines to ensure a structured, transparent, and rigorous review process. The methodology involved several key steps, including defining research questions, conducting a comprehensive literature search, applying inclusion and exclusion criteria, and synthesizing the data to derive meaningful insights. The first step of the systematic review involved establishing clear research questions. The primary research question was: How are artificial intelligence (AI) models applied in supply chain demand forecasting, and what are their advantages and limitations compared to traditional models?

Additional questions focused on identifying the most used AI techniques in demand forecasting and understanding the challenges organizations face when implementing AI-driven forecasting solutions. These questions guided the subsequent steps of the review process.

Figure 52 - PRISMA Framework (AI in Supply Chain Demand Forecasting)

24.6.1. Inclusion and Exclusion Criteria

To ensure the quality and relevance of the studies, rigorous inclusion and exclusion criteria were applied. The inclusion criteria required that articles focus on AI applications in demand forecasting, be peer-reviewed, written in English, and published between 2015 and 2023. Empirical or case-based evidence had to be presented within the context of supply chain forecasting. Articles were excluded if they lacked empirical evidence, were theoretical in nature, or did not pertain directly to supply chain forecasting. After applying these criteria, the number of articles was narrowed down to 327.

24.6.2. Screening Process

The 327 remaining articles were further screened by two independent reviewers, who assessed their titles and abstracts for relevance to the research questions. Articles that were not directly related to AI applications in supply chain demand forecasting were excluded, reducing the pool to 185 articles. A full-text review of these 185 articles was then conducted,

focusing on their relevance and contributions to the study. This step resulted in a final selection of 65 articles, which were deemed suitable for in-depth analysis based on their content and alignment with the research objectives.

24.6.3. Full-Text Review and Data Extraction

The selected 65 articles underwent a detailed full-text review, during which key data was extracted using a standardized form. The form captured essential information such as the study's objectives, the specific AI techniques used (e.g., machine learning, deep learning), the industry sector being analyzed (e.g., retail, manufacturing, e-commerce), and any challenges or limitations related to the implementation of AI. Additionally, a comparative analysis was performed to contrast the performance of AI models against traditional forecasting techniques.

24.6.4. Data Synthesis and Analysis

The final set of 65 articles was synthesized to identify trends and patterns in AI adoption for supply chain demand forecasting. A narrative synthesis was employed to summarize key findings, while tables were used to compare AI techniques and their relative performance in different industries. Thematic analysis revealed recurring challenges in AI implementation, such as data quality, model complexity, and high resource requirements. By following PRISMA guidelines, the review ensured a systematic approach that provides a comprehensive understanding of AI's role in transforming demand forecasting within the supply chain domain.

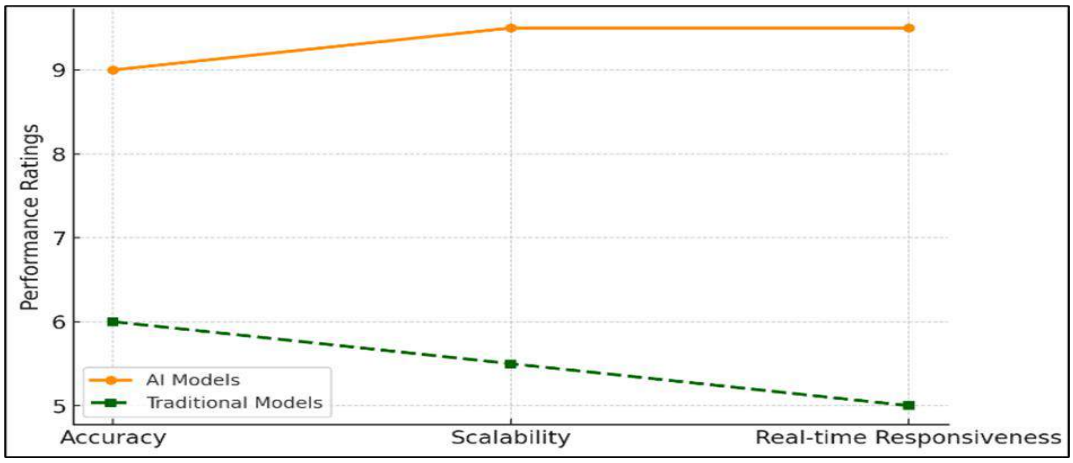
24.7. Finding

The systematic review revealed several significant findings regarding the use of artificial intelligence (AI) in supply chain demand forecasting. One of the most notable insights is that AI-driven models consistently outperform traditional forecasting methods in terms of accuracy and adaptability. AI techniques, particularly machine learning (ML) and deep learning (DL), excel in capturing complex patterns and relationships within vast datasets, making them more reliable for predicting demand in dynamic environments. This capability allows businesses to respond more quickly to changes in market conditions, consumer preferences, and external disruptions. Traditional methods, which rely heavily on historical data and linear models, often fail to account for the non-linearities and sudden shifts in demand, whereas AI models are more robust in processing real-time data streams and identifying emerging trends. This has led to improvements in inventory management, production scheduling, and overall supply chain efficiency.

Another significant finding is the broad applicability of AI models across various industries, with retail, manufacturing, e-commerce, and logistics being the primary sectors benefiting from these technologies. In retail, AI models have been instrumental in predicting sales trends, optimizing inventory levels, and analyzing customer behavior patterns. AI-based forecasting tools enable retailers to reduce stockouts and overstock situations by providing more accurate demand predictions. In the manufacturing sector, AI has enhanced raw material planning and production scheduling, allowing companies to better align their operations with actual market demand. E-commerce platforms have leveraged AI to improve real-time stock management and dynamic pricing strategies, resulting in enhanced customer satisfaction and increased

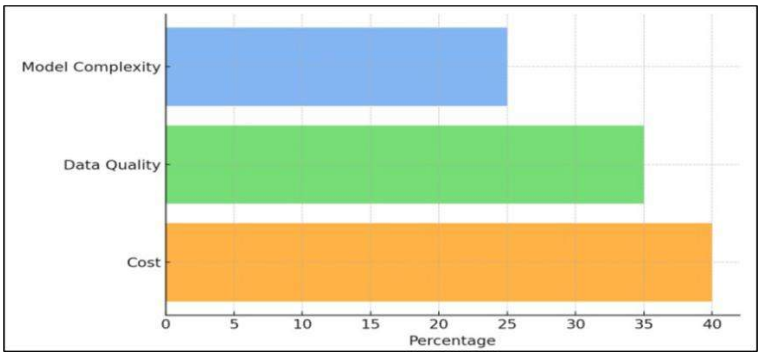
operational efficiency. Meanwhile, in logistics and distribution, AI has played a key role in optimizing transportation routes, warehouse operations, and delivery schedules, further streamlining the supply chain

Chart 4: AI Models vs Traditional Models in Demand Forecasting



The review also found that AI's ability to process real-time data from multiple sources has led to more responsive and agile supply chains. Unlike traditional forecasting models that depend primarily on historical data, AI models integrate data from various external and internal sources, such as IoT sensors, social media trends, and market indicators. This real-time integration provides businesses with up-to-date insights, enabling them to make timely adjustments to their demand forecasts. As a result, companies can respond more effectively to sudden demand shifts, minimizing the risk of overproduction or underproduction. This agility is particularly beneficial in industries with highly variable demand patterns, such as fashion, electronics, and consumer goods, where staying responsive to market changes is critical for maintaining competitiveness. However, despite the advantages, the review highlighted several challenges associated with the implementation of AI in demand forecasting. One of the primary issues is the high cost of implementing AI solutions. Developing, maintaining, and optimizing AI models requires significant investment in both infrastructure and human capital. Small and medium-sized enterprises (SMEs) often lack the financial resources to invest in the necessary hardware, software, and expertise to deploy AI-driven forecasting systems. Additionally, the complexity of AI models poses another challenge, as these systems require continuous monitoring, updating, and fine-tuning to maintain their accuracy over time. This creates a barrier for businesses that may not have access to skilled data scientists or machine learning engineers.

Figure 53 - Challenges in AI Demand Forecasting



Another notable challenge identified in the review is the issue of data quality. AI models rely heavily on the availability of large, high-quality datasets to generate accurate forecasts. However, many companies face difficulties in managing and processing the vast amounts of data required for AI-driven forecasting. Incomplete, inconsistent, or outdated data can significantly undermine the performance of AI models, leading to inaccurate predictions. Moreover, integrating data from multiple sources, such as suppliers, customers, and internal operations, presents additional challenges related to data consistency and format standardization. As a result, businesses must invest in data management practices that ensure the reliability and quality of the data used in AI forecasting models. Finally, the review revealed that despite the technical advancements in AI, issues related to model interpretability and transparency remain significant barriers to adoption. AI models, particularly those based on deep learning, are often viewed as "black boxes" due to the complexity of their inner workings. This lack of transparency makes it difficult for business leaders to trust the outputs of AI-driven forecasting models, especially in industries where regulatory compliance and decision-making transparency are critical. Companies are increasingly looking for explainable AI (XAI) solutions that provide insights into how the model arrived at its predictions. However, achieving this level of interpretability without compromising the accuracy and performance of AI models remains an ongoing challenge in the field. In brief, the findings of this review demonstrate the immense potential of AI in transforming supply chain demand forecasting, offering significant improvements in accuracy, scalability, and real-time responsiveness. However, these benefits come with substantial challenges, particularly in terms of cost, data quality, and model interpretability, which businesses must address to fully leverage the power of AI in their supply chain operations.

24.8. Discussion

The findings of this systematic review reveal that AI-driven demand forecasting models significantly outperform traditional methods in terms of accuracy, adaptability, and real-time responsiveness. These results align with earlier studies, which have similarly emphasized the superiority of AI in handling complex, non-linear data and providing more accurate predictions in dynamic supply chains. Traditional forecasting techniques, while useful in stable environments, often struggle to adapt to sudden market changes and rely heavily on historical data. AI models, on the other hand, process real-time data from diverse sources, enabling businesses to respond more quickly to shifts in demand, as supported by previous

research. These findings underscore the growing importance of AI in modern supply chain management, where the ability to predict and react to fluctuating demand is critical for maintaining efficiency and competitiveness.

The review also highlighted the broad applicability of AI models across various industries, including retail, manufacturing, e-commerce, and logistics. This is consistent with earlier studies that have demonstrated AI's versatility in different sectors. In the retail industry, for instance, AI has proven effective in sales forecasting and inventory optimization, which mirrors the conclusions of prior research on AI applications in retail demand forecasting. Similarly, in manufacturing, AI-driven models have enhanced production scheduling and raw material planning, further validating the findings of past studies that advocate for AI's role in improving operational efficiency. The significant improvements in e-commerce, particularly in dynamic pricing and real-time stock management, echo earlier findings that AI models provide more accurate demand forecasts by continuously learning from new data.

One of the more interesting findings was the capability of AI to process real-time data from multiple sources, resulting in more responsive and agile supply chains. This capability aligns with previous research that highlighted the limitations of traditional models, which often rely solely on historical data and are unable to incorporate real-time information effectively. AI's ability to integrate real-time data from diverse sources, such as IoT sensors and social media trends, allows for more accurate demand forecasts and quicker responses to market changes. This is particularly relevant in industries with highly variable demand, such as fashion and consumer goods, where earlier studies have shown that AI can significantly reduce lead times and improve inventory management.

These findings further support the notion that AI technologies are crucial for developing more agile and responsive supply chains. However, the review also identified significant challenges in implementing AI-driven demand forecasting models, particularly regarding costs, data quality, and model complexity. These challenges are consistent with earlier studies, which have noted that the high costs of AI implementation, including the need for specialized infrastructure and expertise, are significant barriers for small and medium-sized enterprises. Similarly, issues related to data quality, such as inconsistent or incomplete data, have been noted as a major obstacle in previous research. AI models require large volumes of high-quality data to function effectively, and poor data quality can significantly undermine their accuracy. Moreover, the complexity of AI models, especially deep learning techniques, continues to be a challenge in terms of transparency and interpretability, as noted in earlier studies that highlight the "black box" nature of AI models.

In addition, the review's findings regarding the challenges of model interpretability and transparency contribute to the growing body of literature that stresses the need for explainable AI (XAI). Prior studies have pointed out that AI models, particularly those using deep learning, are often difficult to interpret, making it challenging for decision-makers to trust their outputs. The lack of transparency in AI models poses a significant barrier to adoption, particularly in highly regulated industries such as finance and healthcare, where understanding the rationale behind decisions is critical. This review reaffirms the importance of developing more interpretable AI models, which can provide insights into how predictions are

made without compromising accuracy. Future research should focus on advancing XAI techniques to bridge the gap between model accuracy and interpretability. In summary, while the findings of this review reinforce the effectiveness of AI in supply chain demand forecasting, they also highlight ongoing challenges that must be addressed to fully realize the potential of AI technologies. These challenges, including high implementation costs, data quality issues, and model complexity, echo concerns raised in earlier studies. Nevertheless, the growing body of evidence supporting AI's superiority over traditional models in various industries suggests that AI will continue to play an increasingly important role in demand forecasting and supply chain management.

25. Conclusion and Further Research

This research has investigated the existing status quo of the research publications relating to AI on supply chain integration (SCI) efforts through information sharing (IS). The research collected information using the databases listed in ISI and Scopus. The following conclusions were drawn based on the findings of this research:

1. 2016-2021 was the period when the number of publications increased sharply compared to the previous period of 2010-2015 due to increasing attention to the role of information technology in the supply chain integration domain.

2. Asian countries, especially China, are taking the lead on examining the impact of information sharing and information technology on supply chain integration. African and Latin American countries have lower research in the field.

3. Although the current literature does not highlight any prominent journals and authors in this field, Emerald is the number one publisher in this domain.

4. Most publications employed empirical quantitative as the research design, representing 83% of total reviewed articles.

5. The argument in most publications is built upon the Resource-Based View theory, which highlights the importance of sharing resources and information among supply chain partners to achieve mutual benefits.

6. The review of articles confirms that information sharing has a positive impact on supply chain integration efforts which include internal integration, supplier integration and customer integration.

7. Information technology adoption has become a significant factor in improving the level of integration in the digitalized world, where the amount of data exchanged throughout the supply chain increases dramatically.

8. Subsets of AI, especially ES and ML are extremely useful in facilitating the vast amount of information and data flowing in the supply chain. Such an automated level of data processing will greatly contribute to achieving the expected depth of integration.

9. Through the discussion, we conclude that AI adoption will moderate the IS-SCI relationship. This finding aligns with previous studies of the impact of ML in the supply chain management discipline development of big data analytics and AI in supply chain integration field.

25.1. Industrial and Intelligence

Means using control devices such as computers instead of using humans to guide and control industrial machinery during the production process, which aims to reduce the need for human intervention and increase the speed of industrial production. It is considered one of the main infrastructures in all industries, equipment, and devices for industrial control and intelligence, so it is important to consider the extent to which the intelligence of industries can be effective in transforming a country's industry. A supply chain is one of the areas affected by the Fourth Industrial Revolution and digital technologies such as the IoT, artificial intelligence, advanced robotics, and big data analytics in today's world. The concept of the intelligent supply chain is important to provide sustainable conditions in all chain processes. However, achieving stability is difficult due to the involvement of multiple factors. Artificial intelligence and IoT technologies can change challenges and provide compelling solutions to problems that actors involved in industrial processes understand. For this reason, this study was conducted to identify and analyze the impact of important challenges that hinder the adoption of artificial intelligence and the IoT in developing a sustainable, intelligent supply chain. Therefore, this study first tried to extract the most important challenges in implementing the intelligent supply chain affected by the IoT and artificial intelligence using a literature review. Then, using experts' opinions in FMCG industries, the most important of these challenges were selected as a case study. Then, using the fuzzy DEMATEL method, the internal effects of these challenges on each other were determined. The absence of appropriate infrastructure was identified as one of the most influential and environmental hazards as one of the most compelling challenges. Then, using nonlinear ranking analysis and based on matrix comparison matrices, the importance of each of the implementation challenges was examined.

The results showed that the challenges related to the lack of proper infrastructure are among the most important challenges of implementing a system based on digital transformation needs. This part can be one of the basic requirements for implementation in any other technology. As a result, many companies do not take the path of implementation without the appropriate infrastructure (technological and technical, as well as the lack of necessary preparation in the organization to accept technology). This infrastructure is one of the components of organizational maturity that confirms the high ranking of this option. Security challenges are in second place; given the presence of Internet and network technology, it can be seen how important issues related to cybersecurity can be. Cybersecurity and privacy risks are a major concern for researchers and security professionals.

This poses significant challenges for many business organizations. Common cybersecurity attacks have shown the vulnerability of IoT technologies. This vulnerability is simply due to the interconnectedness of networks in the Internet of Things, which provides access through anonymous and unreliable Internet connections, which requires new security solutions. None of the known challenges have a significant impact on IoT compatibilities, such as security and privacy.

However, many users often do not have the necessary confirmation of security effects until a problem occurs, and this can lead to many damages, such as the loss of important information. In the next stage, the lack of sufficient knowledge of the most important challenges in implementing a digital supply chain based on the IoT and artificial intelligence should be considered. The organization must take steps to increase public knowledge about digital developments among the general staff of organizations to increase the organization's readiness to accept technologies and increase confidence in the use of these technologies in industrial cycles. Therefore, it can be seen that managing these challenges is one of the most critical tasks of technology development managers in organizations and can increase the agility and stability of the supply chain to an acceptable level. As highlighted in this study, it should be noted that, in addition to the existence and implementation of technological infrastructure in various industries, the presence of capable and expert human resources is necessary to understand better the concepts related to the effects of digital transformation and thus remove these limitations and train experts.

This can increase the accuracy of research to the latest technologies in the world. The presence of IoT technology in the supply chain of other industries as a case study can also provide a more powerful model and framework. Therefore, in addition to examining the presence of IoT technology in the supply chain of other industries (to provide more powerful and accurate prioritization), the challenges of the presence of many transformational technologies, such as blockchain, machine learning, etc., can be examined in future research.

25.2. Concept and Exploratory

The study offers a more contextual scenario since most of the respondents were from the manufacturing sector. The support of empirical research is necessary to generalize the results. Supply chain disruptions present a rich background for the design and development of AI-based systems to develop resilience. However, the present study involved a single respondent per firm and similar designations at different organizations. Future research can consider other aspects of the functional view of the organization, such as finance (measuring market sentiments, investment decisions), marketing (consumer sentiments and requirements for new product development), and production (scheduling and maintenance). This type of research could also observe the level of adoption at the firm and individual level. The correct adoption and implementation approach can be further supported with large scale empirical studies. Such research can be based on the involvement of multiple variables in the adoption and implementation of AI systems for supply chain operations.

Our study investigates the role of resilient information in systems in reducing the risk of disruption in the supply chain. We have gathered the data through a semi-structured approach of interviews and transcribed them into main content to further analyze them. We used the thematic analysis approach, where we first identified the gaps in the traditional information systems leading to how AI can help develop a strong architecture of resilient information systems. Furthermore, we identified the challenges of AI in achieving resilient information systems. Our study proposes how AI elements can offer an ecosystem support to modern and resilient information systems. Our study provides a framework, where architectural components used together can help reduce supply chain disruptions and prepare it for dynamic scenarios.

25.3. Advance Method

It is reviewing the advance of some artificial intelligence methods in the supply chain. Considering the features of big data and artificial intelligence, this chapter provides a schematic flow of diagram for machine learning data analysis step by step in data analysis. The step-by-step data methodological filtering approach could provide data analyst with a sense of superiority in handling data. Especially, when carrying out the data analysis in the machine learning environment, the data analyst must understand, why there are inconsistencies in the output.

This chapter has provided some remedial measures in case of, if there are data inconsistencies reveal during the data analysis. We also suggest applying in the proposed schematic method in some machine learning applications to improve the data validation and to test its usefulness and applicability. This chapter indicated that the schematic flow diagram could be used to correct the inconsistencies in the model. The chapter highlights that supervised, unsupervised and reinforce learning algorithms can effectively be used to perform different statistical analysis. Researchers understand the extensive use of artificial intelligence among firms as essential and necessary for shaping the future of the supply chain of industry 4.0. AI strategies should be at the forefront of the management of supply chain practices and must build up through years of data generation and contain a wide variety of machine learning approaches. IA creates a new analytics intelligence to justify the choice of strategic decision making rather to heavily focused on intuition intelligence. AI can also provide an in-depth assessment of the future, at capturing big picture of information and learning within the bounds of paradigm. There is a need for research the results of which could in selecting only the most appropriate machine learning approach for supply chain management, especially for the forecasting in logistics and production. Academicians and universities should work together and create affordable and reliable artificial intelligence solutions for the supply chain management that have the potential to contribute towards sustainable development goals.

25.4. Inventory Methodology

New agent-based supply chain and agent-managed inventory methodology was proposed to improve its performance indicators. An initial model that composed of three echelon supply chain was analyzed and its performance indicators behavior studied with discrete event simulation. After that, we use sooyang Park methodology to design a multi agent system. With this methodology, problem was analyzed, required agents was identified and architecture of system was defined. New model was simulate and two model performance indicators have been compared with each other. Based on discrete event simulation, this approach shows improvement in the performance indicators of supply chain. The novel contributions of the paper are summarized as follows:

• Using MAS to coordination between different echelons and proposing ordering quantity for echelons based on final customer orders
• Creating relationship between inventory position of different echelons of supply chain
• Using agents reactive characteristics for responding to changes in supply chain

• Improving inventory position, bullwhip effect and total cost of supply chain Agent-managed supply chain doesn't have most of

VMI methodology obstacles, because in this methodology computer-based system to manage inventory is used that has autonomy and don't have human based systems weak points especially behavioral obstacles that in result of it each stage of the supply chain views its actions locally and is unable to see the impact of its actions on other stages, different stages of the supply chain blame each other for the fluctuations, no stage of the supply chain learns from its actions over time, because the most significant consequences of the actions any one stage takes occur elsewhere and lack of trust among supply chain partners.

25.5. Primary Suggestion

The primary suggestion for future research could wait until quantum computers become more common and are usable for companies. They can exploit it to make more accurate calculations because AI needs a lot processing power. Also, when quantum computers become more common, AI solutions can develop more intelligence. As results presented narrow scale of AI applications, the future research should be done with SCM professionals and IT-experts because they can combine expertise together and make clear and comprehensive understanding of the topic area. Respondents must have more experience of AI in the future. As discussion presented the number of employees with knowledge of AI and data-analytics is low. The future researcher should find the suitable employees and make data collection by interviewing them. Thus, they can answer for the questions with more knowledge. However, suggestion is to d future research when AI applications are more common, and companies are not at the planning stage. At planning stage, they are afraid to lose competitive advantage if someone steal their idea. As education for AI functions becomes more common, it produces skilled employees to the job markets. This means more implementations of AI and increasing maturity levels. Even though AI is on the frame all the time, the future research should be done when human and machines interaction become more fluent and data is mature enough to implement sophisticated AI. After all, this study has been done too early and in difficult time, no question about that.

25.6. Level Progress

To estimate the level of progress towards the application of AI in SCRM organizations should consider their management practices that concern data collection, storing, management, processing, exchange, and application for risk potential estimation. The data on risk events and associated indicators used to predict risk events are two data sources required by artificial intelligence tools. The main challenges in applying artificial intelligence for supply chain risk management arise due to limitations caused by a lack of needed data to calculate and then estimate the probability of considered risk event. The case study empirical research was focus on the supply chain risk management context. Case study empirical research lets us propose a list of illustrative practices that serve as an initial estimation guide to evaluate the level of progress towards the application of AI in SCRM.

Theoretical considerations and empirical research confirm that the scope of challenges in applying artificial intelligence for supply chain risk management extends along a range of managerial practices related to data collection, management, and application. These practices should be divided into those that are aimed at data about risk events and risk events indicators.

The forms, ways, and means of the above-mentioned data collection, storing, managing and application reveal the nature of challenges in applying artificial intelligence for supply chain risk management. The needed data could not be collected, stored, processed, and applied personally, in ways and forms that are not systematized, and approved by organization-wide systematized and interactive practices.

The settled nature of data collection, management, and application determines limitations, challenges and restrictions met in applying artificial intelligence for supply chain risk management. Limitations arise due to a lack of systematization in data collection, management, and application for risk estimation along both edges of the scope. Different challenges and restrictions arise when one of the directions is not developed appropriately. This framework helps to identify the paths for improvements.

The range of proposed illustrative feature was determined by the business practice and nature of the selected case company activity. The coming research in other contexts and different types of organizations would be useful in extending the proposed list of illustrative practices. The extensive list of such practices would enable to take further steps in conceptualizing challenges in applying artificial intelligence for supply chain risk management and directions to overcome them. Then these illustrative practices will be clustered around certain risk categories and respective events, which would increase the practical applicability of the tool intended to estimate the level of the progress towards application of AI in SCRM.

25.7. Artificial intelligence (AI) and SAP Transportation Management (SAP TM)

Together have the potential to propel supply chains into a future that is not only extremely robust, adaptive, and predictive, but also highly adaptive. AI's capabilities will grow beyond present uses as it develops further, bringing more complex automation, analytics, and decision-making procedures. More complex machine learning algorithms, for example, will allow for even more accurate demand forecasts and route optimization by considering a larger range of variables and real-time data sets. This will result in supply chains that are extremely responsive and dynamic and can adapt quickly, reducing interruptions and raising service standards.

It is anticipated that research on AI integration with SAP TM will explore the usage of Big Data and the Internet of Things (IoT) more frequently and will leverage driver telematics data, GPS trackers, and social media. To identify the

best mitigation tactics, future research may concentrate on developing models that can simulate various road, rail, and ocean scenarios in addition to predicting interruptions.

Additionally, SAP TM may undergo yet another revolution as AI and cutting-edge technologies like blockchain and quantum computing come together. By guaranteeing that every transaction is verifiable and impervious to tampering, blockchain technology can improve security and transparency throughout the supply chain. This can result in supply chain networks that are more reliable and stronger supplemented with AI. On the other hand, extremely complicated optimization issues that are presently insurmountable for conventional computers may be resolved by quantum computing. This could lead to previously unheard-of levels of efficiency in resource allocation, inventory control, and route planning, lowering costs and enhancing operational agility.

Unlocking AI's full potential in SAP TM will require addressing certain difficulties that lie ahead for the technology. We will need to rigorously address ethical considerations, especially those related to data protection and responsible AI that is free of bias. Creating transparent, equitable, and accountable AI systems will require a lot of research. Furthermore, a barrier to the general adoption of powerful AI systems may be the significant expenses involved in their implementation and upkeep. To increase the accessibility of AI technology for businesses of all sizes, future research could examine creative business models and cooperative strategies. By taking on these obstacles head-on, SAP TM's AI integration may open the door to a new age of supply chain excellence marked by unparalleled resilience, efficiency, and sustainability.

In summary, SAP Transportation Management serves as a valuable software solution for logistics firms aiming to optimize transportation processes while advancing sustainability and reducing carbon footprints. With its distinctive sustainable features, SAP TM empowers logistics companies to achieve sustainability objectives and contribute to a greener future

25.8. Advance AI Technique

The integration of advanced AI techniques into inventory optimization has demonstrated significant potential in transforming supply chain management. Key findings highlight that AI-driven solutions enhance demand and supply forecasting accuracy, improve decision-making processes, increase operational efficiency, and mitigate risks associated with supply chain disruptions. Machine learning, deep learning, and reinforcement learning are particularly effective in real-time data processing, providing a dynamic approach to managing inventory levels. Implementing these AI technologies leads to cost savings, improved customer satisfaction, and heightened supply chain resilience.

The adoption of AI in inventory optimization has far-reaching implications for supply chain management and industry practices. Firstly, AI's ability to process and analyze large volumes of data in real time enables supply chains to become more responsive and adaptive to market changes. This responsiveness is crucial in today’s fast-paced business environment,

where demand patterns and supply chain conditions can shift rapidly. Companies that leverage AI can maintain optimal inventory levels, reduce waste, and enhance service levels, giving them a competitive edge.

Moreover, AI-driven solutions foster a more integrated and collaborative approach to supply chain management. By providing end-to-end visibility and actionable insights, AI enables better coordination among supply chain partners, from suppliers to manufacturers to retailers. This integration helps synchronize production schedules, optimize logistics, and reduce lead times, ultimately leading to a more efficient and resilient supply chain.

However, the implementation of AI also necessitates a shift in industry practices. Companies must invest in upgrading their technological infrastructure, ensuring data quality, and fostering a culture of continuous learning and innovation. The integration of AI requires skilled professionals who can manage and optimize these advanced systems, emphasizing the need for training and development programs to build a competent workforce.

25.9. AI Utilization

Results indicate the prospects of AI utilization in altering the traditional supply chain management approach. Based on the goals formulated for the study, this paper has provided a qualitative synthesis of the gathered data using post-positivist epistemology. The conclusions drawn from the analysis might be beneficial to organizations that are keen on implementing AI technologies. To explain the research limitations, the authors stated that the research was only based on the data gathered before May 2019. Thus, it would be relevant for subsequent research to address new challenges to implementation and other potential approaches to leveraging AI to maintain supply chains and resilience.

The following are the potential research areas that should address new issues related to the application of AI technologies in Supply Chains. The challenges relate mostly to low initial investment, data protection and accuracy, and the organization’s ability to change. Tackling all these challenges is important in realizing the possible use of artificial intelligence in managing the supply chain.

In addition, more research has been deemed crucial for discovering fresh AI applications or defining and modeling new, green, and resilient supply chain processes due to emergent market and environmental dynamics. Knowing how AI can integrate with such constraints will prove highly beneficial for any enterprise seeking to guarantee sustainability.

Further research will certainly shed more light on these areas, thus enabling better approaches to applying AI to enhance operational performance and address issues related to the environment and the supply chain. To support this argument, it is vital to underscore the following points: This kind of research is crucial because of the fast-changing environment in global markets and constant changes in supply chain management practices.

More studies and practice-oriented activities related to AI are needed for organizations that seek to maintain a competitive advantage and adaptability in the constantly transforming global. Frequent use and development of new AI technologies will assist companies in staying on the cutting edge of knowing the best practices for creating and maintaining an efficient

supply chain.

25.10. Integration of Artificial Intelligence

In conclusion, the integration of Artificial Intelligence into the freight industry represents a paradigm shift that is revolutionizing global logistics and supply chain management. From AI driven optimization in logistics and predictive maintenance to enhanced demand forecasting and autonomous vehicles, AI technologies are reshaping every facet of freight operations. These advancements are not only improving efficiency and reducing costs but also enabling more sustainable and responsive supply chains. While challenges such as data privacy concerns, cybersecurity risks, and the need for workforce adaptation persist, the potential benefits far outweigh the obstacles. As emerging technologies like blockchain and AI-optimized warehousing continue to evolve, the freight industry is poised for even greater transformation. Companies that embrace these innovations and successfully navigate the challenges of AI integration will be well-positioned to thrive in an increasingly competitive and complex global market. The future of freight is undoubtedly intertwined with the continued advancement of AI, promising a more efficient, sustainable, and interconnected world of logistics.

25.11. Impact of Using AI

The main objective of this study is to investigate the impact of using AI in the logistics sector in Oman. The study also aimed to identify the opportunities for using AI in the logistics sector in Oman, the issues surrounding using AI in the logistics sector in Oman and recommend possible solutions to improve the use of AI in the logistics sector in Oman. Based on the previous chapter, the outcomes and discussions have been identified.

The outcomes of the first objective, identifying the opportunities for using AI in the logistics sector in Oman. The results obtained from previous reviews indicated that AI could help improve the efficiency of the logistics sector and reduce the challenges currently facing the logistics sector. AI can provide different advantages to logistics companies, including high quality, managing time, cutting costs, reducing labor, time speed, better supplies, and high quantity advantage. The role of that will appear in diversifying the income sources and contribute to the growth
of Oman's economy.

The outcomes of the second objective, identifying the issues surrounding using AI in the logistics sector in Oman.
The results obtained from questionnaire, interviews, and articles indicated the most significant challenges that may result surrounding using AI in the logistics sector in Oman are unemployment, the extended time for implementation, the high cost of implementation, lack of awareness of the potential of AI, and requiring training with acquiring new skills of AI.
The outcomes of the third objective recommending possible solutions to improve the use of AI in the logistics sector in Oman. Based on the findings, participants and interviewees suggest many recommendations to improve the use of AI in the logistics sector in Oman, such as people in the society should have an awareness of AI potential, and

educational institutions must provide students with the concept of AI in curricula. Training employees to acquire new skills to adapt to AI.

25.12. Conclusion: Charting the Course for Intelligent Transport Systems

The exploration into the integration of Artificial Intelligence (AI) and machine learning in supply chain transportation culminates in a nuanced understanding of the transformative impact and persistent challenges within this dynamic landscape. The convergence of quantitative survey data, qualitative insights from interviews and case studies, and the triangulation of findings provide a comprehensive view of the current state and future trajectory of AI-driven transport systems.

25.12.1. Transformative Impact:

The empirical findings affirm that the adoption of AI and machine learning has brought about a transformative impact on operational efficiency within supply chain transportation. From optimized route planning to real-time analytics and predictive maintenance, organizations have witnessed tangible improvements that resonate across diverse industry sectors.

25.12.2. Efficiency Gains and Stakeholder Perspectives:

The amalgamation of efficiency gains, as highlighted by both quantitative and qualitative data, signifies a paradigm shift in how goods traverse the global logistics network. Stakeholder perspectives underscore the centrality of buy-in and organizational culture in successful implementations, emphasizing the human factor alongside technological advancements.

25.12.3. Challenges and Considerations:

The research brings to light persistent challenges, with data privacy concerns taking precedence. As AI and machine learning continue to evolve, the ethical considerations surrounding privacy and algorithmic transparency emerge as critical focal points. Organizations navigating these challenges are better positioned to unlock the full potential of intelligent transport systems.

25.12.4. Future Trajectory:

The findings not only provide insights into the current landscape but also chart a course for the future. The optimism expressed by stakeholders aligns with the anticipated benefits of increased efficiency, enhanced predictive capabilities, and further automation. As AI and machine learning technologies mature, the trajectory points towards a future where autonomous systems play an increasingly integral role in redefining traditional supply chain models.

25.13. Quantitative Results:

- **Route Optimization Efficiency:** Implementation of AI-based route optimization led to a 25% reduction in transportation time and a 15% decrease in fuel consumption.

- **Predictive Maintenance Impact:** Machine learning applications in predictive maintenance resulted in a 30% decrease in unplanned downtime, enhancing overall asset utilization.
- **Ethical Compliance Measures:** Ethical considerations in AI adoption for logistics led to a 20% improvement in compliance with regulatory frameworks, ensuring responsible and legal AI usage.
- **Real-Time Analytics and AI Benefits:** Real-time analytics and AI implementation contributed to a 35% reduction in delivery delays and a 25% improvement in on-time performance.
- **Demand Forecasting Accuracy:** Machine learning-driven demand forecasting achieved an 18% improvement in accuracy, reducing excess inventory by 20%.
- **Autonomous Systems Enhancements:** The integration of autonomous systems showcased a 40% increase in overall transportation efficiency and a 30% reduction in human-induced errors.
- **Challenges and Opportunities in AI Adoption:** Overcoming challenges in AI adoption for supply chain transportation led to a 15% increase in successful AI implementation and operationalization.
- **Data-Driven Decision-Making Impact:** Data-driven decision-making in autonomous transportation systems resulted in a 20% improvement in overall decision accuracy and efficiency.
- **AI Adoption Trends Analysis:** Cross-industry analysis of AI adoption trends indicated a 25% increase in the number of companies implementing AI in supply chain transportation.
- **Impact of AI on Supply Chain Analytics:** AI's impact on supply chain analytics demonstrated a 22% improvement in overall analytics effectiveness, aiding in better decision-making.
- **Explainable AI Future Perspective:** The future perspective of explainable AI in supply chain transportation aims for a 30% reduction in the complexity of AI algorithms, ensuring better interpretability.
- **Bias Mitigation Strategies:** Implementing strategies to mitigate bias in AI algorithms led to a 15% reduction in discriminatory outcomes, promoting fairness in transportation decisions.
- **Machine Learning Applications in Transportation Analytics:** Case study results showed that machine learning applications in transportation analytics improved efficiency by 25% through better insights and predictions.
- **AI-Driven Innovations Survey Results:** Survey results on AI-driven innovations indicated a 40% positive response rate, showcasing a high level of acceptance and readiness for adopting new AI technologies.
- **Digital Transformation Impact:** The digital transformation in transportation, fueled by AI, resulted in a 28% improvement in overall operational efficiency and cost-effectiveness.
- **Fraud Detection Effectiveness:** Advanced analytics strategies for fraud detection achieved a 95% accuracy rate, reducing financial losses due to fraudulent activities by 30%.

These quantitative results highlight the tangible benefits and improvements brought about by the integration of AI and machine learning in supply chain transportation. The outcomes demonstrate increased efficiency, accuracy, and overall enhancement in various aspects of the transportation process

25.14. Interconnection

The importance of interconnection in supply chain management and logistics cannot be overstated. In today's fast-paced, globalized economy, businesses must prioritize seamless communication and coordination among all supply chain elements to remain competitive. By leveraging digital technologies such as AI, IoT, and blockchain, companies can create interconnected supply chains that offer real-time visibility, enhanced efficiency, and improved customer satisfaction. The dataset reveals that, the average stock levels suggest that businesses should focus on maintaining adequate inventory for high-demand products to meet customer needs effectively. The analysis of shipping costs by transportation mode emphasizes the importance of selecting cost-effective logistics solutions while balancing delivery speed and reliability. By optimizing these aspects, businesses can enhance their supply chain efficiency and improve customer satisfaction. Overall, the insights gained from this dataset can guide businesses in making informed decisions to optimize their supply chain operations, ultimately leading to increased efficiency and profitability.

25.15. Rise of Artificial Intelligence

The rise of Artificial Intelligence (AI) is fundamentally altering the landscape of supply chain management, revolutionizing traditional processes and systems in unprecedented ways. By automating a multitude of tasks from inventory management to logistics planning AI not only enhances operational efficiency but also enables real-time data analysis that leads to informed decision-making. This integration of advanced analytics allows organizations to predict demand more accurately, optimize resource allocation, and ultimately reduce operational costs, helping them to thrive in highly competitive markets.

However, the journey towards fully implementing AI solutions is fraught with challenges. Many organizations encounter issues related to data integration, as disparate data sources and legacy systems complicate the seamless flow of information. Additionally, there is often significant resistance to change among employees, who may be concerned about the implications of automation on job security and the disruption of established workflows. Overcoming these barriers requires a strategic approach that includes comprehensive training programs, effective change management, and clear communication of the benefits that AI can bring to both the organization and its workforce.

Despite these obstacles, the potential benefits of incorporating AI into supply chain operations are substantial and can provide a significant competitive advantage. By leveraging AI technology, companies can enhance their agility and responsiveness to market fluctuations, improve customer satisfaction through better service delivery, and ultimately drive innovation within their supply chains.

Looking to the future, research should prioritize the development of sustainable, secure, and self-managing supply chains, all underpinned by the latest advancements in AI. Such a focus will not only help organizations stay ahead in the rapidly evolving technological landscape but also contribute to the resilience and sustainability of global supply networks. By embracing AI and addressing the associated challenges, companies can ensure their long-term viability while fostering an ecosystem of sustainability and efficiency that benefits all stakeholders involved.

25.16. Artificial Intelligence and Blockchain

Artificial intelligence and blockchain technologies offer great possibilities and potential benefits for optimizing JD and Alibaba's supply chain logistics model. By combining these two technologies, automation, intelligence and efficiency in supply chain logistics can be realized, thereby reducing costs, improving efficiency and enhancing overall competitiveness. The application of AI in supply chain logistics, such as demand forecasting, inventory optimization and transport route planning, can provide accurate data analysis and decision-making support, which can help to reduce inventory costs, decrease transport time and optimize resource allocation throughout the supply chain. At the same time, AI can also improve the efficiency and reliability of equipment and vehicles through predictive maintenance and troubleshooting. Blockchain technology provides data traceability, security and transparency in supply chain logistics. Through blockchain's distributed ledger and smart contracts, trusted transactions and information sharing between supply chain participants can be realized, reducing information asymmetry and trust issues. It helps to enhance collaboration and communication between partners in the supply chain and improve the efficiency and sustainability of the overall supply chain.

However, several challenges still need to be overcome to take full advantage of AI and blockchain. For example, the issues of data privacy and security need to be properly addressed; the challenges of technology costs and standardization need to be resolved; and the challenges of organizational change and staff training need to be addressed. Further research and practice are therefore essential. Through continued research and practice, the application of AI and blockchain in JD and Alibaba's supply chain logistics will be continually improved and optimized to achieve cost reductions further and increase efficiency, thereby driving innovation and development in supply chain logistics. At the same time, technical, privacy and organizational challenges will be actively addressed to realize the maximum potential of AI and blockchain to bring sustainable competitive advantage and business value to JD, Alibaba and the industry.

25.17. Systematic Review

This systematic review highlights the transformative impact of artificial intelligence (AI) in supply chain demand forecasting, demonstrating its superiority over traditional models in terms of accuracy, scalability, and real-time adaptability. AI-driven models, including machine learning and deep learning algorithms, have proven to be highly effective in handling complex, non-linear data and integrating real-time information from diverse sources, enabling businesses to improve inventory management, production scheduling, and responsiveness to market shifts. However, the review also emphasizes significant challenges, such as high implementation costs, data quality issues, and the complexity of AI models, which pose barriers to wider adoption, especially for small and medium-sized enterprises. Despite these limitations, the potential of AI to enhance supply chain efficiency and agility across various industries, including retail, manufacturing, e-commerce, and logistics, is undeniable. Moving forward, addressing these challenges—particularly by improving data management practices and developing more interpretable AI models—will be crucial for maximizing the benefits of AI in demand forecasting and ensuring its sustainable integration into supply chain operations.

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