INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 15, Issue 2, (2025) E-ISSN: 2222-6990

Machine Learning in Logistic: Scoping Review

[1]Muhammad Hamdi Che Hassan, [2]Lokhman Hakim Osman
[1,2]Faculty of Economics and Management, Universiti Kebangsaan Malaysia
Email: [1]p119828@siswa.ukm.edu.my, [2]lokhman@ukm.edu.my

To Link this Article: http://dx.doi.org/10.6007/IJARBSS/v15-i2/24645 DOI:10.6007/IJARBSS/v15-i2/24645

Published Date: 10 February 2025

Abstract
Background: Data has become a critical factor in the success of companies, particularly in logistic Machine learning a key area within artificial intelligence, is increasingly supplementing traditional analytical approaches. Machine learning may rapidly modify logistics management to accommodate varying client expectations, thus improving operational responsiveness. This adaptability is essential in contemporary dynamic market contexts, when conventional solutions may fail due to their rigid characteristics. **Methodology:** This scoping review utilized two databases, Web of Science (WOS) and Scopus, to explore the characteristics of the published scientific literature on this topic and to uncover emerging themes associated with Machine Learning in logistic. **Result:** This study identified nine main themes, and twenty-two sub-themes related to the application of Machine Learning in logistics. Machine Learning is frequently utilized in inter-company logistics to improve efficiency with suppliers and consumers, manage internal operations, identify weaknesses, and implement corrective actions swiftly. **Conclusion:** Machine learning algorithms can predict risks in supply chain networks by analysing historical data and identifying potential disruptions. This predictive capability allows organizations to take proactive measures to mitigate risks, thereby minimizing financial losses and operational failures. This opens opportunities for future research, examine the challenges and potential benefits of use machine learning for small and medium-sized firms (SMEs), particularly in providing logistic service.
Keywords: Machine Learning, Supply Chain Management, Logistics, Transportation

Introduction

Machine learning has emerged as a disruptive force in logistics, greatly boosting several elements of supply chain management, transportation, and operational efficiency. The incorporation of machine learning methodologies into logistics operations enhances decision making, predictive analytics, and risk management, resulting in optimised performance and decreased expenses. Traditional logistic regression has been fundamental in predictive modelling, particularly in medical and social sciences, due to its interpretability and user-friendliness. Nonetheless, its constraints become evident when addressing high dimensional datasets or when the interrelations among variables are nonlinear. Machine learning models surpassed classical logistic regression in forecasting in-hospital mortality after acute myocardial infarction, underscoring the added usefulness of Machine learning methodologies in clinical environments (Khera et al., 2019). Logistic regression is susceptible to missing data, which may lead to biases, while machine learning algorithms can manage these inconsistencies more adeptly (CAI, 2024).

Machine learning methods are especially beneficial when the number of variables surpasses the number of observations, a frequent occurrence in contemporary datasets (Levy & O'Malley, 2020). This is essential in logistics, where the intricacy of supply chains and the magnitude of data might surpass conventional statistical techniques. Logistics supply chain optimisation further corroborates this, demonstrating that machine learning's data processing capabilities are crucial for fulfilling the requirements of efficiency and precision in logistics management (Zhang & Hu 2024). In logistics, machine learning has been utilised to enhance operations such as demand forecasting and inventory management. Machine learning may rapidly modify logistics management to accommodate varying client expectations, thus improving operational responsiveness (Dong et al., 2022). This adaptability is essential in contemporary dynamic market contexts, when conventional solutions may fail due to their rigid characteristics.

Machine learning has proven to be particularly competent at coping with massive volumes of data and recognising patterns in the data. This attribute allows machine learning to render dependable conclusions beyond human capability. Moreover, Machine learning techniques help users to deal with quickly changing environments and discontinuous information. Consequently, machine learning is a valuable resource for logistics (Ni et al., 2020). Validate this assumption and highlight the potential of advanced data analytics and Machine learning in logistic and organisations can especially gain from machine learning in the domains of planning and delivery.

Data analytics and Machine learning are becoming increasingly relevant, especially in the logistic context (Kersten et al., 2020). Global supply chains and logistical operations are becoming more complicated, requiring innovative technologies to improve efficiency, accuracy, and decision-making. In this field, machine learning has revolutionised demand forecasting, route optimisation, inventory management, and risk avoidance. The urgent need to synthesise machine learning research in logistics to understand its current state and limitations prompted this scoping assessment. This study examines how machine learning is changing logistics, reducing costs, and creating more sustainable and resilient supply chains.

To achieve this research goal, the following three research question was derived and answered progressively throughout this article through the analysis of the identified articles in a scoping review. Therefore, the objective of this study is to build a complete mapping of the scope of research that has been done on machine learning. This study will concentrate specifically on logistics. The scoping review will provide a knowledge of the major concept from a fresh perspective, which will open the door for further consideration of the concept through additional consideration. The objective is to provide a comprehensive understanding of the significant impact of machine learning in logistic regression on the competitive landscape of supply chain management, aimed at offering pertinent insights to practitioners, policymakers, and researchers. Alongside the segment that functions as an introduction. This article is organised as follows: Section 2 outlines the recommended scoping review methodology, whilst Section 3 presents the findings. Section 4 presents the discourse, recommendations, and conclusion.

Methodology

This empirical study is a scoping review utilising a systematic literature sorting process to outline the current and developing literature on a certain topic or issue (Anderson et al., 2008). It entails, among other responsibilities, locating, selecting, and summarising pertinent research to deliver a succinct overview. Scoping reviews are frequently performed to delineate essential concepts, identify gaps in the literature, and uncover promising research avenues. Scoping reviews contrast with systematic reviews by encompassing broad research fields and a variety of study types, emphasising breadth over depth of analysis (Che Hassan & Osman, 2024). Arksey and O'Malley (2005) defined five stages for the scoping review methodology, which are as follows:

(1) Formulating the research question: In this study must describe its purpose and objectives. The review must delineate the principal research topic and any ancillary enquiries that will direct the review procedure. Consequently, the focus on exploring the optimal techniques to enhance machine learning in logistical situations has been undertaken. The preliminary research questions are essential for guiding the targeted investigation within the extensive body of literature pertaining to certain topics. Firstly, What the impact machine learning in logistic? Second, What the main themes and sub-themes in this study? And third, what are the main roles of Machine learning in logistic, and how could they contribute to the success of logistic supply chain management and future research directions?

(2) ***Finding relevant studies:*** Formulate a comprehensive search strategy to identify and uncover studies relevant to the objectives. This involves scrutinising, among other sources, online databases, grey literature, and supplementary information. The search terms and the inclusion-exclusion criteria must be explicitly delineated. Fundamental themes and search terms were identified to collect content relevant to social entrepreneurship pedagogy and methodologies, as detailed in Table 1. The parameters of the review of search terminology. In this scoping review will use two academic databases specifically Web of Science (WoS) and Scopus, are employed for relevant information.

(3) ***Selecting Studies***: Identify papers that fulfil the review's objectives by using inclusion and exclusion criteria. Thereafter, established clear inclusion and exclusion criteria for the works to be examined in this empirical study. Initially, only research papers were chosen, as most studies predominantly emphasise findings. Furthermore, research articles provide the principal source of analytical evidence. This study omits book series, book chapters, systematic reviews, review articles, meta-analyses, and meta-syntheses from its scope. The selected items were published in English between 2020 and 2024. Only empirical papers from the past five years were deemed eligible for inclusion, emphasising the necessity of focussing on contemporary research that exhibits both quality and relevance, especially for scoping reviews (Kraus et al. 2020). To prevent unnecessary or lengthy studies, papers from the fields of computing, decision science, engineering, psychology, energy, or medical were excluded (Table 2).

(4) Charting the data: This stage allows for the acquisition of essential information from other studies by employing a consistent charting form. Microsoft Excel was utilised to generate graphical representations of the data for thematic and comparative analysis. A detailed table was created to summarise findings and address research issues, including the author's name, publication year, main themes, and sub-themes. (Charting Form in Table 3).

(5) ***Collating, summarizing, and disclosing the results***: To comprehend the application of machine learning in logistics and the growing topics addressed in this context, a synthesis of prevalent themes and discoveries from the literature was compiled. Additional crucial information documented included the location of each study, the year of publication, and other details relevant to the study objectives.

Table 1
The Search Strings

Database search string	
WOS	TS= "Machine learning " AND “Supply chain management " AND "Logistics" AND "Transportation"
SCOPUS	TITLE-ABS-KEY ((" Machine learning ") AND (" Supply chain management ") AND ("Logistics") AND (" Transportation”))

Table 2
The inclusion and exclusion criteria

Criterion	Eligibility	Exclusion
literature type	research articles	book series, book, chapter in book
Language	English	non-English
Timeline	2020-2024	<2020
Subject area	Business, Management and Accounting, Social Sciences, Economics, Econometrics and Finance	Computer Science, Decision Sciences, Engineering, Psychology, Energy, Medicine

Findings

In the course of this scoping review, a total of 105 publications were discovered through the use of database searches that were carried out on Scopus and WoS. As a result of the removal of their titles and abstracts, as well as the exclusion of four publications from the initial hit due to their classification (systematic review, review article, and meta-analysis article), there were only four hundred and one papers remained. It was necessary to take this action in order to ensure that there was no repetitive work. Immediately after this, a comprehensive review of all 91 papers was carried out. At this point, it was necessary to eliminate 69 of the articles from consideration because they did not relate to the subject matter of this study. In conclusion, it was discovered that just 22 of the papers were pertinent and met the objectives that were intended for this study. This was carried out in accordance with the recommendations that were given by Moher et al., (2015) during the examination of the reporting items that were included in the systematic reviews (Figure 1).

It was determined that the selection of papers was based on a number of different considerations, and it was restricted to empirical research that had been published in journal articles within a period of five years. Before the journal was reviewed, the conference proceedings were not included since there was a lack of systematisation and openness due to traditional evaluations, which were most likely influenced by the author subjectivity (Hodgkinson, Ford, 2014). This was the reason why the conference proceedings were not included.

By selecting high-quality publications that have been published during the last five years for the purpose of conducting a scoping review, this study intends to improve the journal source. According to the findings, the methodology that was utilised was a combination of qualitative and quantitative research. in accordance with the parameters that were presented earlier. In Table 3, summaries of the twenty-two articles of current research that were chosen for inclusion in the scoping review.

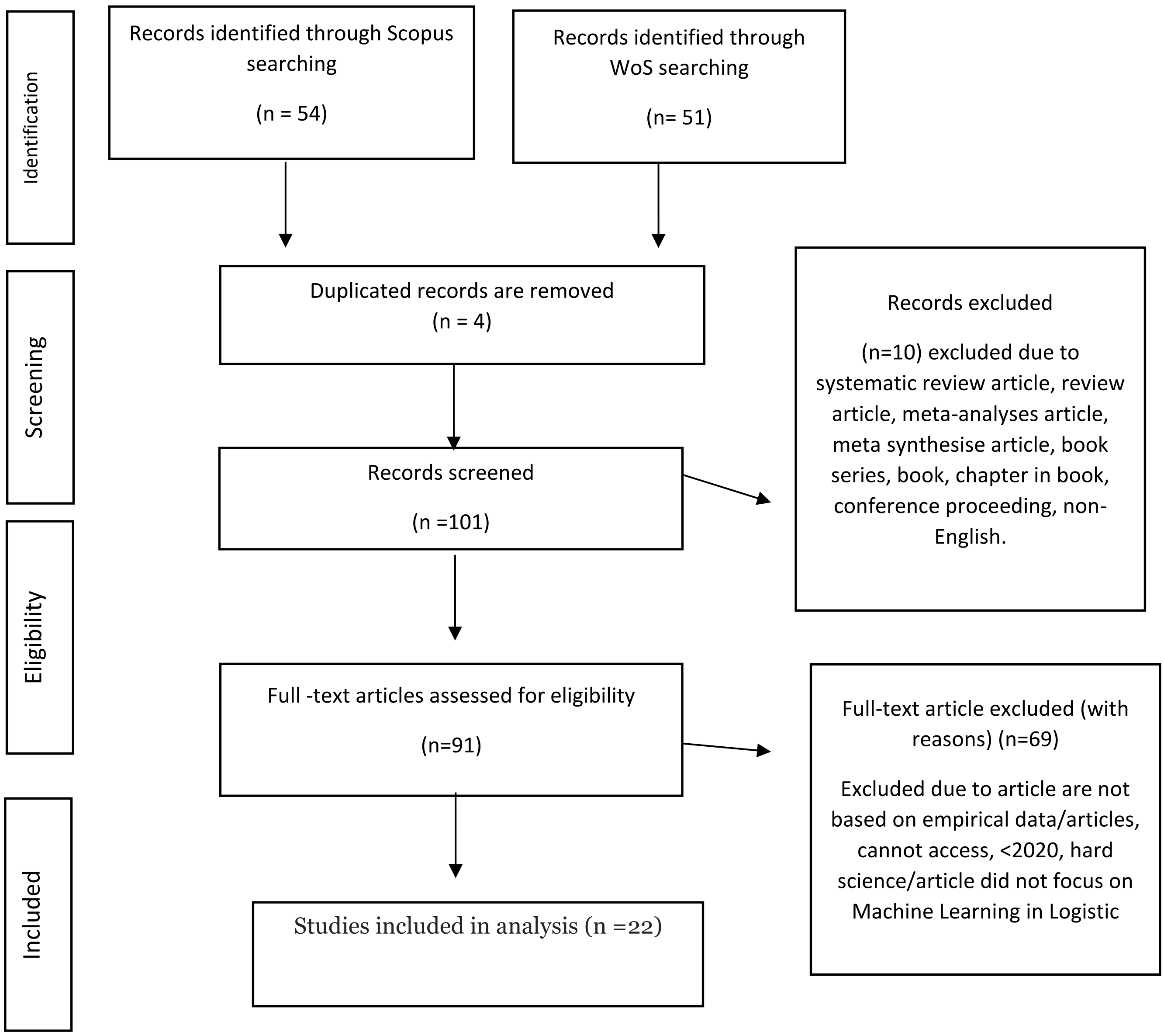

Fig 1: Flow diagram of research selection process using Preferred Reporting Items for Systematic Reviews (PRISMA)

Table 3
Data Charting Form

No	Author & Year	Impact	Sub-themes	Theme
1	(Karimi-Mamaghan et al., 2020)	the benefits of aggregating commodities at hub facilities, which allows for the exploitation of scale economies. This can lead to more efficient transportation solutions, as larger carriers can be utilized on hub-to-hub connections, ultimately reducing costs and improving service efficiency	Cost Reduction	Route Optimization
2	(Lu et. al., 2020)	Machine Learning is widely used in manufacturing and supply chains to improve quality control. Computer vision and deep learning models are employed to detect defects in products, while predictive maintenance algorithms reduce downtime by forecasting equipment failures. Recent research highlights the use of Machine Learning for real-time quality monitoring in production lines.	Defect Classification	Trend and Issue Identification
3	(Brintrup et. al., 2020)	Machine Learning models are increasingly applied to identify and mitigate risks such as supplier disruptions, geopolitical uncertainties, and natural disasters. Techniques like anomaly detection and natural language processing (NLP) are used to analyse unstructured data from news, social media, and weather reports to predict potential disruptions (Ivanov et al., 2020	Resilience planning	Trend and Issue Identification
4	(Kinra et al., 2020)	The finding demonstrates that textual data, such as newspaper articles and tweets, can provide valuable insights into public opinion regarding driverless cars. This approach allows policymakers to capture sentiments and concerns that traditional survey methods might miss, thereby enriching their understanding of public attitudes.	Sentiment Analysis	Customer-Centric Logistics
5	(Sun et al. 2021)	The finding highlights the challenges posed by larger instances in scheduling problems. Machine learning techniques, particularly those focused on scalability, can be employed to handle complex scheduling scenarios more effectively, enabling the development of robust solutions that can adapt to increasing problem sizes.	Complexity Handling	Resilience
6	(Changjian et al., 2021)	The study revealed significant deviations in drivers' awareness of fuel-saving factors, highlighting that certain factor, such as engine speed and idling conditions, were underestimated. This insight can guide future machine learning models to focus on these critical areas, improving their predictive accuracy and relevance in real-world applications	Energy Efficiency	Route Optimization

7	(Nitsche et. al., 2021)	Machine Learning facilitates collaboration among supply chain partners by enabling shared data platforms and collaborative planning. Techniques like federated learning allow organizations to train Machine Learning models on shared data without compromising privacy. Recent studies explore the use of Machine Learning in vendor-managed inventory (VMI) systems to improve coordination and reduce bullwhip effects	Vendor-managed inventory (VMI)	Supplier Performance
8	(Shan et al., 2021)	Digital twins, powered by Machine Learning, create virtual replicas of physical supply chains to simulate scenarios and predict outcomes. This technology is used for real-time monitoring, predictive maintenance, and optimizing supply chain operations. Recent research highlights the integration of Machine Learning with digital twins to improve decision-making and reduce risks	Simulation	Enhanced Forecasting
9	(Arunmozhi, 2022)	technology can minimize the reliance on intermediaries in supply chain processes. This leads to better control and efficiency, allowing stakeholders to share real-time data effectively. By integrating AI and blockchain, improves product traceability and transaction transparency. This is crucial for maintaining trust among stakeholders and ensuring compliance with regulations	Stakeholder Trust	Trust and Compliance
10	(Valero et al., 2022)	using machine learning algorithms, can significantly enhance the accuracy of arrival time predictions for container ships. This improvement can help port authorities and shipping companies better manage schedules and resources.	accuracy	Route Optimization
11	(Romagnoli et al., 2023)	Adopting a combination of sustainable practices and digital technologies can significantly enhance the functionality of Enhancement of Circular Supply Chains (CSC). This is crucial for firms aiming to improve their operational efficiency and sustainability efforts	Operational management	Network optimization
12	(Zhang et. al., 2023)	With increasing regulatory pressure and consumer demand for sustainability, Machine Learning is being used to optimize supply chains for lower carbon emissions.	Carbon emission tracking	Green Logistics
13	Duan et. al., (2024)	The integration of blockchain and Machine Learning is expected to deepen, enabling greater transparency and security in supply chains Machine Learning can analyse blockchain data for fraud detection and compliance monitoring.	Fraud detection	Trust and Compliance

14	(Pasupulet et al., 2024)	By leveraging advanced Machine Learning algorithms, the research demonstrates a 12% improvement in lead time efficiency and an 8% reduction in replenishment errors. This indicates that organizations can make more informed and timely decisions, ultimately leading to better service delivery and customer satisfaction	Operational waste	Customer centric logistics
15	(Rezki & Mansouri 2024)	By utilizing various machine learning algorithms, the study demonstrates the ability to predict delivery delays and assess supplier performance effectively. This predictive capability is crucial for supply chain managers to anticipate issues before they escalate, thereby improving operational efficiency	Risk mitigation	Supplier performance
16	(Teshome et al., 2024)	Technologies that can improve the efficiency of T&L systems while minimizing environmental impacts. For instance, the adoption of electric vehicles and drones can enhance service delivery in remote areas, contributing to economic growth and improving the quality of life for local communities	Enhanced service	Green logistics
17	(Song et al., 2024)	By implementing machine learning for customer-driven logistics operations, online sellers and logistics companies can differentiate themselves in a competitive market and allowing customers to select their preferred delivery time (morning, afternoon, or evening). This flexibility can lead to increased customer satisfaction and potentially higher ratings for sellers, as some customers are willing to pay for this service	Smart scheduling algorithms	Customer centric logistics
18	(Bhattacharya et al., 2024)	The application of machine learning in Closed-Loop Supply Chains allows for the identification of patterns and trends within data, which can lead to improved forecasting and inventory management. This emphasizes that the complexity and volume of data in modern supply chains necessitate advanced analytical techniques like machine learning to optimize logistics and inventory management processes	Dynamic inventory	Enhanced forecasting
19	(Fareed et al., 2024)	Technologies to improve their green manufacturing capabilities and overall sustainability. Adaptation of advanced technologies can significantly enhance the environmental, economic, and social sustainability of multimodal logistics systems. This is crucial for addressing the pressing challenges of climate change and resource scarcity.	Sustainability	Green Logistics

20	(Fatorachian & Kazemi 2024)	The integration of advanced AI technologies with fault-tolerant control and cybersecurity measures is crucial for improving the reliability and security of transportation systems. This approach helps in managing both physical malfunctions and cyber threats effectively, ensuring that systems can withstand disruptions	Cybersecurity	Resilience
21	(Dinh et al., 2024)	Using advanced Machine Learning algorithms like xgboost, Decision Trees (DT), and Random Forest (RF) to forecast ship waiting times and turnaround durations. This capability allows port authorities to better anticipate and manage vessel traffic, leading to more efficient operations and help port authorities optimize resource allocation and reduce congestion. This proactive management of vessel traffic can significantly decrease turnaround times, enhancing the overall efficiency of port operations	Efficiency	Network optimization
22	(Polo-Triana et al., 2024)	Machine learning can be combined with traditional and emerging technologies is a key contribution. This integration is shown to lead to significant advances in decision-making processes, improving efficiency in complex environments such as inventory management and logistics	Decision making	Network optimization

Impact of Machine Learning in Logistic

This section will answer the research question “What the impact machine learning in logistic?” The impact of machine learning on logistics is profound and multifaceted, reshaping traditional processes and enhancing operational efficiencies (Ye et al., 2020). As logistics operations become increasingly complex due to the exponential growth of data and the intricacies of supply chains, machine learning emerges as a pivotal technology that can optimize various aspects of logistics management (Zhang et al., 2024).

One of the primary applications of Machine learning significantly transforms logistics by refining decision-making, integrating with both conventional and novel technologies, and augmenting efficiency throughout intricate supply chain operations. Advanced machine learning algorithms, like XGBoost, Decision Trees, and Random Forests, have shown effective in accurately forecasting ship waiting periods, arrival timetables, and turnaround durations. These features allow port authorities to optimise resource distribution, mitigate congestion, and improve operational efficiency. Forecasting tools powered by machine learning assist in detecting delivery delays, evaluating supplier performance, and reducing replenishment errors, hence enhancing lead time efficiency and customer satisfaction.

The integration of AI with blockchain improves supply chain transparency and trust, facilitating real-time data sharing and enhanced product traceability, while diminishing reliance on middlemen. Machine learning enhances circular and closed-loop supply chains by recognising data patterns, optimising inventory management, and promoting sustainable practices. This is crucial for tackling environmental issues, as technologies such as electric vehicles and drones reduce emissions while improving service delivery, particularly in rural regions.

The implementation of machine learning in logistics enhances operational resilience and agility while also bolstering security via fault-tolerant control systems and robust cybersecurity protocols. Moreover, its utilisation in client-centric logistics operations, such as providing flexible delivery alternatives, allows firms to distinguish themselves in competitive markets, enhancing consumer happiness. Organisations can optimise transportation costs and minimise inefficiencies by consolidating goods at hubs to leverage economies of scale and use sophisticated analytical methods. Machine learning enables companies to synchronise operational strategies with digital capabilities, strengthening response to market fluctuations while improving economic, social, and environmental sustainability in logistics systems.

The scoping review generated sub-themes and themes to answer the second research question. There were nine major themes which were then divided into twenty-two sub-themes. The first theme, Network Optimization (decision-making, efficiency, and operational management). Focuses on decision-making, efficiency, and operational management. Machine learning aids 5G resource allocation, while efficiency cuts costs and energy in IoT networks. Cloud computing enhances monitoring and failure recovery, collectively boosting performance and flexibility. The second theme, Resilience (Complexity Handling Cybersecurity). Handles complexity and cybersecurity. Redundancy and adaptive algorithms strengthen systems like smart grids under stress, while AI-driven solutions ensure real-time threat detection and robust security. The third theme, Green Logistics (Enhanced Service, Carbon emission tracking, Sustainability). Emphasizes enhanced service, carbon emission tracking, and sustainability. Initiatives include electric vehicles, optimized delivery routes, IoT-enabled carbon monitoring, renewable energy use, waste reduction, and circular economy practices. The fourth theme, Enhanced Forecasting (Dynamic inventory, Simulation). Utilizes dynamic inventory and simulation models to respond to demand changes in real-time, prevent stock issues, and optimize business strategies for efficiency. The fifth theme, Customer-Centric Logistics (Smart Scheduling Algorithms, operational waste, Sentiment Analysis). Leverages smart scheduling, operational waste reduction, and sentiment analysis to enhance customer satisfaction through optimized delivery routes, personalized services, and greener operations. The sixth theme, Supplier Performance (Risk Mitigation, Vendor-managed inventory). Improves reliability through risk mitigation and vendor-managed inventory, reducing delays, enhancing accuracy, and strengthening supply chain resilience. The seventh theme, Trust and Compliance (Fraud detection, Stakeholder Trust). Uses AI and blockchain for fraud detection, while transparency, ethical sourcing, and effective communication foster stakeholder confidence and long-term relationships. The eighth theme, Route Optimization (Accuracy, Energy Efficiency, Cost Reduction). Employs real-time data and algorithms to enhance accuracy, energy efficiency, and cost reduction, optimizing routes to minimize delays, fuel use, and expenses. The ninth theme, Trend and Issue Identification (Defect Classification, Resilience planning). Applies AI and data analytics for defect classification and resilience planning to address risks, ensuring quality and continuity during disruptions.

In Table 4, the locations of the studies of the machine learning are shown to indicate their geographical context. The analysis shows that the studies were conducted in 14 countries. Some studies were conducted in multiple countries.

Table 4:
Location f study

Author	Country
(Lu et. al., 2020)	New Zealand
(Nitsche et. al., 2021)	Germany
(Shan et. al., 2021)	Australian
(Zhang et. al., 2023) (Changjian et al., 2021), (Sun et al. 2021)	China
(Kinra et. al., 2020)	Denmark
(Rezki & Mansouri 2024)	Morocco
(Song et al., 2024), (Pasupulet et. al., 2024)	USA
(Arunmozhi, 2022), (Karimi-Mamaghan et. al., 2020)	France
(Fareed et. al., 2024), (Romagnoli et al., 2023), (Teshome et. al., 2024)	Italy
(Bhattacharya et. al., 2024)	India
(Brintrup et. al., 2020)., (Duan et. al., 2024), (Fatorachian & Kazemi 2024)	UK
(Dinh et. al., 2024)	Vietnam
(Valero et. al., 2022)	Spain
(Polo-Triana et. al., 2024)	Colombia

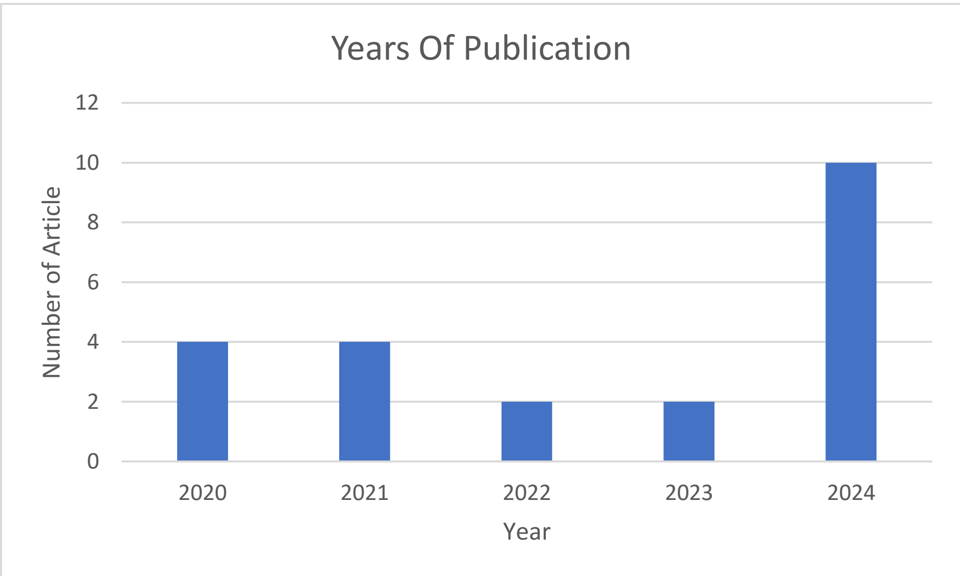

Fig. 2: Number of articles published in Web of Science (WoS) and Scopus
In terms of years of publication, Fig. 2 shows the number of articles published in Web of Science (WoS) and Scopus from 2020 to 2024. A total of four articles were published in 2020 [Kinra et al., 2020, Lu et. al., 2020, Karimi-Mamaghan et al., 2020, Brintrup et. al., 2020] and 2021 total publish is four [Sun et al. 2021, Changjian et al., 2021, Nitsche et. al., 2021, Shan et al., 2021]. Next, two articles were published in 2022 [Arunmozhi et al., 2022, Valero et al.,

2022] followed by two articles published in 2023 [Romagnoli et al., 2023, Zhang et. al., 2023]. Recently, ten articles were published in 2024 [Rezki & Mansouri 2024, Duan et. al., 2024, Pasupulet et al., 2024, Teshome et al., 2024, Song et al., 2024, Bhattacharya et al., 2024, Dinh et al., 2024, Fareed et al., 2024, Fatorachian & Kazemi 2024, Polo-Triana et al., 2024]. The academic disciplines covered by the papers included business, management, and accounting, as well as the social sciences, economics, econometrics, and finance.

Discussion

This section provides an in-depth discussion of the theme, and based on the findings, this study concludes that Machine Learning can significantly enhance logistics performance and sustainability

Improved Customer Service

In term of Customer-Centric Logistics, Machine learning algorithms can examine extensive data produced during the logistics process, allowing organisations to forecast demand, enhance routing, and manage inventory more efficiently. The significance of integrating machine learning and deep learning into intelligent logistics is underscored, as these technologies can deliver comprehensive and efficient solutions for logistics systems through the training of models on aggregated data (Wu & Ge, 2019). This capability enables logistics providers to foresee customer requirements and modify their operations, accordingly, thereby improving the overall customer experience. This aligns with Zafarzadeh et al. (2021), reflecting a global trend in logistics development propelled by advancements in big data, IoT, and other technologies. By automating routine processes, logistics firms may concentrate on more intricate challenges, hence enhancing service quality and customer stratification. The incorporation of machine learning into these automated systems facilitates real-time modifications based on data insights, guaranteeing that logistical operations stay attuned to client requests.

Enhanced Decision Making

Network optimisation has become a crucial method for improving decision-making, operational efficiency, and overall management in the logistics industry. The integration of machine learning in logistics management systems has demonstrated considerable potential in automating decision-making processes. Sun (2023) delineates a logistics management system founded on computational algorithmic models applicable to diverse logistical dimensions, encompassing inventory and transportation planning. Automating these operations enables organisations to attain enhanced operational efficiency and cost reduction, which are essential in the current competitive logistics environment. Beskorovainyi et al. (2022) substantiate this concept by introducing mathematical models that improve decision-making in logistics network optimisation, thereby enabling more informed and efficient operational strategies. The use of machine learning into logistics network optimisation signifies a fundamental change in the management of logistics operations. Machine learning enhances decision-making, automates procedures, optimises resource allocation, and improves risk management, hence providing a comprehensive framework for increasing operational effectiveness and adaptability in logistics.

Improved Delivery Times

Route Optimization in logistics has emerged as a critical area of research, particularly with the advent of machine learning technologies. The logistics industry is increasingly leveraging advanced technologies, including machine learning and data mining, to streamline operations and improve efficiency. For instance, Meng emphasizes that by utilizing data mining technologies, logistics companies can significantly reduce delivery times and fuel consumption, ultimately enhancing customer satisfaction and operational productivity (Meng, 2024). This study is supported by the findings of Wijaya (2023) who notes that artificial intelligence plays a pivotal role in optimizing delivery routes, particularly in the context of the Fourth Industrial Revolution. The application of artificial intelligence in logistics not only improves route efficiency but also aligns with sustainability goals by minimizing environmental impact. A significant aspect of route optimization involves the use of various algorithms to determine the most efficient paths for logistics operations. For instance, genetic algorithms have been highlighted as effective tools for optimizing logistics distribution routes. Research by Judijanto (2023) indicates that genetic algorithms can lead to substantial improvements in route efficiency, thereby reducing costs and enhancing customer satisfaction.

Reduced Logistics Risks

Machine learning in logistics transforms supply networks, improving resilience and efficiency in the face of increased complexity and data volume. Traditional approaches often fail to meet efficiency, precision, and adaptability expectations as logistics operations become increasingly complex. Machine learning optimises logistics system decision-making using massive information, boosting operational resilience (Kozhamkulova et al., 2024). Logistics system resilience includes efficiency and disturbance tolerance. Zhao et al. (2021) simulate logistics companies using reinforcement learning to improve preparedness and reduce operational hazards. This novel approach shows how machine learning can develop agile logistics networks that can adapt to unexpected problems. According to Ferreira's thorough review, AI and machine learning-powered logistics automation leads to resilience improvements (Ferreira & Reis 2023).

Improved Forecasting

The use of machine learning in logistics has transformed operational efficiency and decision-making. Globalisation and e-commerce have made logistics more complex, therefore machine learning technologies can improve supply chain management, predictive analytics, and customer service. A key development in logistics is the implementation of predictive analytics driven by machine learning algorithms. These algorithms can analyse extensive data sets to predict demand, optimise inventory levels, and improve route planning. Wu & Ge (2019). underscore the capability of machine learning and deep learning to deliver comprehensive solutions in intelligent logistics, stressing the significance of data acquisition and training for operational efficacy. The integration of computational logistics and deep learning has demonstrably enhanced decision-making processes in container terminal handling systems (Li & He, 2021). The capacity of machine learning to process and analyse data in real-time enables logistics companies to react promptly to market fluctuations, thus improving their competitive advantage.

Automated Data Analysis

From supplier performance perspective, machine learning can play a pivotal role in supplier evaluation and selection processes. By employing data-driven approaches, organizations can assess supplier performance based on various metrics, including delivery reliability, quality of goods, and responsiveness to changes in demand (Soares et al., 2018). This systematic evaluation process helps organizations to identify high-performing suppliers and foster long-term partnerships, which are essential for achieving competitive advantages in the market (Gallear et al., 2021). Additionally, the use of machine learning in supplier performance assessment can facilitate the identification of potential risks associated with suppliers, allowing organizations to implement risk mitigation strategies proactively (Tukamuhabwa et al., 2021).

Increased Scalability

Green logistics, which incorporates sustainability into logistical operations, has gained considerable momentum in recent years, especially with the emergence of machine learning and data-driven technology. The convergence of these domains not only improves operating efficiency but also promotes environmental sustainability, which is increasingly a vital concern for logistics providers worldwide. Green logistics primarily aims to reduce the environmental effect of logistical operations while preserving service efficiency. It includes diverse strategies such as optimising transportation routes, minimising energy use, and adopting sustainable packaging options. The incorporation of machine learning into these procedures facilitates more advanced data analysis and decision-making processes. Machine learning algorithms can evaluate extensive data concerning transportation routes, weather conditions, and traffic patterns to enhance delivery timetables and minimise fuel use (Mageto, 2022). This feature boosts operating efficiency and substantially reduces greenhouse gas emissions linked to logistics activities.

Faster Response Times

Through a reduction in response times and an improvement in decision-making procedures, the incorporation of machine learning into logistics operations results in a considerable increase in both trust and compliance. When it comes to establishing confidence among stakeholders, the capacity of machine learning to handle enormous datasets in an effective manner and give findings that can be interpreted is essential. It is essential that the interpretability of machine learning models be taken into consideration to cultivate trust in these systems. According to De & Frazzon (2023), it is essential for users to have the ability to explain the aspects that influence model predictions to maintain their confidence and compliance with automated systems. The stakeholders in the logistics industry need to understand how and why certain decisions are made by machine learning algorithms. This is because decisions in this field can have substantial ramifications for the integrity of the supply chain. It is vital to have this expertise to guarantee compliance with the relevant operational norms and regulatory standards.

Automated Processes

The identification of logistics trends and issues employs machine learning to evaluate public sentiment and adjust operations accordingly. The utilisation of data quality and integration is essential in the implementation of machine learning, especially in logistic regression models. The efficacy of machine learning algorithms, such as logistic regression, is significantly dependent on the quality of the data utilised for training and validation. High-quality data guarantees that models may learn precisely from the input attributes, resulting in enhanced predicted performance. In contrast, inadequate data quality can result in deceptive outcomes, overfitting, and ultimately, incorrect forecasts. This problem is summarised by the aphorism "garbage in, garbage out," highlighting that the quality of output is contingent upon the quality of input data (Tran et al., 2021). Data quality comprises multiple factors, such as correctness, completeness, consistency, timeliness, and relevance. Each dimension significantly contributes to the overall efficacy of machine learning models. Accuracy pertains to the degree to which the data aligns with the genuine values, whereas completeness signifies the presence of all requisite data. In logistic regression, absent values or outliers can markedly distort the outcomes, resulting in erroneous inferences regarding the associations between variables (Alsheref & Hassan, 2019). Furthermore, the amalgamation of data from several sources may result in inconsistencies, hence exacerbating the modelling process (Deshmukh et al., 2022).

Future Direction of Machine Learning

The future study of machine learning in logistics is poised to revolutionize the industry by enhancing efficiency, accuracy, and real-time decision-making capabilities. As logistics systems become increasingly complex due to the explosive growth of data and the intricacies of supply chains, traditional methods are often inadequate. Machine learning offers powerful data processing and pattern recognition capabilities that can significantly optimize logistics operations (Jomthanachai et al., 2023)

Machine learning in logistics possesses significant promise to tackle uncharted domains and developing difficulties. Machine learning can be utilised in procurement analytics to enhance supplier selection and procurement strategies via predicted risk evaluations and cost-efficiency analyses. Incorporating machine learning models with real-time data streams, such as traffic and weather information, may improve logistics models for route optimisation, facilitating dynamic decision-making and enhancing predictive accuracy. The incorporation of machine learning in reverse logistics presents chances to enhance returns management, minimise waste, and promote sustainability objectives within supply chains. A possible avenue is the utilisation of text analytics in transportation, which, although nascent, could yield profound insights into public sentiment and facilitate informed transportation policies.

Future research may investigate hybrid algorithms that integrate machine learning approaches with sophisticated local search methods, such as Iterated Local Search (ILS), facilitating more flexible and interactive optimisation processes. In parallel, handling the rising cyber-threat scenario is vital. Research may examine advanced persistent threats (APTs) and state-sponsored cyber-attacks, enhancing machine learning-based frameworks for resilient cybersecurity. Implementing cohesive cybersecurity strategies that safeguard both digital and physical logistics systems, including real-time threat detection and adaptive responses, will guarantee system integrity. Moreover, the application of reinforcement learning algorithms that can learn from historical cyber-attacks may result in adaptive and proactive security strategies, thereby strengthening the resilience of logistical operations against emerging threats. Collectively, these pathways underscore the transformative impact of machine learning on the future of logistics and supply chain management.

Implications of the Study

The ramifications of machine learning in logistics are significant, especially as organisations strive to utilise data-driven insights to optimise operational efficiency, minimise costs, and elevate service delivery. The incorporation of machine learning methodologies into logistics operations can profoundly alter conventional procedures, facilitating enhanced predictions and optimised decision-making processes. This transition is shown by the comparative efficacy of machine learning models relative to traditional statistical methods, such as logistic regression, which has been a mainstay in predictive analytics. A primary advantage of machine learning in logistics is its capacity to manage extensive data sets and intricate interrelationships among variables. From the previous study, indicates that machine learning algorithms can surpass logistic regression in numerous predicting tasks, especially when managing high-dimensional data (Cho et al., 2020). This is especially pertinent in logistics, where the interaction of several factors such as demand fluctuations, supply chain interruptions, and consumer preferences can complicate forecasting and inventory management. Machine learning models, such as random forests and gradient boosting machines, exhibit enhanced prediction skills in certain scenarios, enabling organisations to make more educated decisions based on real-time data.

Furthermore, the utilisation of machine learning in logistics beyond simple forecasting. It includes several capabilities such as route optimisation, demand forecasting, and risk assessment. Machine learning approaches can examine previous shipping data to discern patterns and enhance delivery routes, therefore minimising transportation costs and boosting delivery times. Moreover, machine learning capacity to adapt and assimilate new data enables logistics firms to react promptly to fluctuating market conditions, so improving their agility and competitiveness in a constantly changing environment. The impact of machine learning also related to the operational efficiencies achieved via automation. Logistics companies can utilise machine learning algorithms to automate regular processes like inventory management and order processing, thereby liberating human resources for more strategic endeavours. This transition not only improves productivity but also reduces human error, a crucial element in sustaining service quality in logistics operations. The amalgamation of machine learning and Internet of Things (IoT) technology enables real-time oversight of logistics processes, offering enhanced insights into operational efficacy and allowing for proactive control of prospective challenges.

Limitations and Recommendation

The primary limitation of this study is its reliance on only two sources from the Scopus and WoS databases. Although the presence of notable publishers in these databases, the authors acknowledge that the search process may have overlooked relevant studies due to limited access through the institutional portal. Future study may explore alternative databases such as Wiley, ScienceDirect, and ProQuest to compare results. This emphasis prompts a wider discussion in academia, requiring consideration of the incorporation of additional datasets to provide a more holistic view of Machine Learning research. The incorporation of additional databases may increase the number of relevant articles. As suggested by Petrosino et al. (2002), future researchers may employ systematic literature reviews, defined as the identification, integration, and evaluation of all available data from qualitative and quantitative studies to provide empirically derived solutions for research enquiries. Consequently, next research will examine the challenges and potential benefits of use machine learning for small and medium-sized firms (SMEs), particularly in providing logistic service.

Conclusion

The study shows that machine learning in logistics has gained significance in recent years due to a rise in publications. Machine learning is often employed for inter-company logistics to enhance efficiency with suppliers and consumers, as well as to oversee internal processes, pinpoint vulnerabilities, and promptly take corrective actions. A key use of machine learning in logistics is supply chain risk management. Machine learning algorithms can forecast hazards in supply chain networks by examining previous data and detecting possible interruptions. This predictive ability enables organisations to proactively mitigate risks, therefore reducing financial losses and operational failures. The capacity to anticipate hazards and react efficiently is essential in contemporary volatile market conditions, when disruptions may stem from many origins, such as geopolitical occurrences and natural calamities. Nowadays, competitive advantage is not only a primary objective but also a component of sustainability in achievement. Machine learning's promise in logistics also encompasses sustainability initiatives. The amalgamation of machine learning and predictive analytics enables logistics firms to discern prospects for diminishing their carbon footprint through the optimisation of transportation routes and the reduction of fuel use. This corresponds with the increasing focus on sustainable practices in the logistics sector, as organisations strive to reconcile operational efficiency with environmental accountability. The utilisation of machine learning in logistics is diverse, including risk management, transportation optimisation, demand forecasting, and operational efficiency. This study illustrates that machine learning improves decision-making processes and bolsters the resilience and sustainability of logistics operations. As organisations increasingly adopt digital transformation, the significance of machine learning in logistics will surely grow, facilitating more inventive and efficient supply chain solutions.

References

Alsheref, F. K. and Hassan, W. M. (2019). Blood diseases detection using classical machine learning algorithms. *International Journal of Advanced Computer Science and Applications, 10*(7). https://doi.org/10.14569/ijacsa.2019.0100712

Anderson, S., Allen, P., Peckham, S., & Goodwin, N. (2008). Asking the right questions: Scoping studies in the commissioning of research on the organisation and delivery of health services. *Health Research Policy and Systems*, *6*(1), 7. https://doi.org/10.1186/1478-4505-6-7

Arksey H., O'Malley L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19-32. http://doi.org/10.1080/1364557032000119616

Beskorovainyi, V., Kolesnyk, L., & Yevstrat, D. (2022). Formalization of the problem of transport logistics optimization networks at the stage of reengineering. *Innovative Technologies and Scientific Solutions for Industries*, (2 (20)), 5-13. https://doi.org/10.30837/itssi.2022.20.005

Che Hassan M. H., Osman L. H. (2024). The Impact Adoption Blockchain In Food Supply Chain: Scoping Review. *LogForum 20 (3), 323-337,* https://doi.org/10.17270/J.LOG.001063

Cho, B., Kim, K. M., Bilegsaikhan, S., & Suh, Y. J. (2020). Machine learning improves the prediction of febrile neutropenia in korean inpatients undergoing chemotherapy for breast cancer. *Scientific Reports, 10*(1). https://doi.org/10.1038/s41598-020-71927-6

de Oliveira Quadras, D. L., Cavalcante, I., Kück, M., Mendes, L. G., & Frazzon, E. M. (2023). Machine learning applied to logistics decision making improvements to the soybean seed classification process. *Applied Sciences, 13*(19), 10904. https://doi.org/10.3390/app131910904

Deshmukh, H. S., Jadhav, V. S., Deshmukh, S., & Rane, K. K. (2022). Towards applicability of machine learning in quality control – a review. *ECS Transactions, 107*(1), 14729-14737. https://doi.org/10.1149/10701.14729ecst

Ferreira, B. and Reis, J. (2023). A systematic literature review on the application of automation in logistics. *Logistics*, 7(4), 80. https://doi.org/10.3390/logistics7040080

Gallear, D., Ghobadian, A., He, Q., Kumar, V., & Hitt, M. (2020). Relationship between Routines of Supplier Selection and Evaluation, Risk Perception and Propensity to form Buyer–Supplier Partnerships. *Production Planning and Control*, *33*. https://doi.org/10.1080/09537287.2021.1872811

Hodgkinson, G. P., & Ford, J. K. (2014). Narrative, meta-analytic, and systematic reviews: What are the differences and why do they matter?. *Journal of Organizational Behavior, 35*(S1), S1-S5. https://doi.org/10.1002/job.1918

Jomthanachai, S., Wong, W. P., & Khaw, K. W. (2023). An application of machine learning to logistics performance prediction: an economics attribute-based of collective instance. *Computational Economics, 63*(2), 741-792. https://doi.org/10.1007/s10614-023-10358-7

Judijanto, L., Fauzan, T. R., & Fisher, B. (2023). Enhancing logistic efficiency in product distribution through genetic algorithms (gas) for route optimization. *International Journal Software Engineering and Computer Science (IJSECS), 3*(3), 504-510. https://doi.org/10.35870/ijsecs.v3i3.1872

Kozhamkulova, Z., Kuntunova, L., Amanzholova, S., Bizhanova, A., Vorogushina, M., Kuparova, A., … & Nurlybayeva, E. (2024). Development of intellectual decision making system for logistic business process management. *International Journal of Advanced Computer Science and Applications*, 15(1). https://doi.org/10.14569/ijacsa.2024.0150186

Li, B. and He, Y. (2021). A feature-extraction-based lightweight convolutional and recurrent neural networks adaptive computing model for container terminal liner handling volume forecasting. *Discrete Dynamics in Nature and Society*, 2021, 1-17. https://doi.org/10.1155/2021/6721564

Mageto, J. (2022). Current and future trends of information technology and sustainability in logistics outsourcing. *Sustainability, 14*(13), 7641. https://doi.org/10.3390/su14137641

Meng, X. (2024). Research on the development of modern design through data mining technology. *Informatica, 48*(6). https://doi.org/10.31449/inf.v48i6.5241

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L. A., & Group, P.-P. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews, 4*(1), 1. https://doi.org/10.1186/2046-4053-4-1

Soares Aharonovitz, M., Vidal Vieira, J., & Suyama, S. (2018). How logistics performance is affected by supply chain relationships. *The International Journal of Logistics Management*, *29*, 00-00. https://doi.org/10.1108/IJLM-09-2016-0204

Sun, H. (2023). Design logistics management system based on computer algorithm model. *Frontiers in Artificial Intelligence and Applications*. https://doi.org/10.3233/faia230856

Tran, N., Chen, H., Bhuyan, J., & Ding, J. (2022). Data Curation and Quality Evaluation for Machine Learning-Based Cyber Intrusion Detection. *IEEE Access*, *10*, 121900-121923. https://doi.org/10.1109/ACCESS.2022.3211313

Tukamuhabwa, B., Mutebi, H., & Kyomuhendo, R. (2023). Competitive advantage in SMEs: effect of supply chain management practices, logistics capabilities and logistics integration in a developing country. *Journal of Business and Socio-economic Development*, *3*(4), 353-371. https://doi.org/10.1108/JBSED-04-2021-0051

Wijaya, D. R., Athallah, A., Noor'afina, T. N., Telnoni, P. A., & Budiwati, S. D. (2023). Cargo route optimization using shortest path algorithms: runtime and validity comparison. *Journal of Computer Science,* *19*(11), 1369-1379. https://doi.org/10.3844/jcssp.2023.1369.1379

Wu, Y., & Ge, D. (2019). Key Technologies of Warehousing Robot for Intelligent Logistics. Proceedings of the First International Symposium on Management and Social Sciences https://doi.org/10.2991/ismss-19.2019.16

Ye, Y., Xiong, Y., Zhou, Q., Wu, J., Li, X., & Xiao, X. (2020). Comparison of machine learning methods and conventional logistic regressions for predicting gestational diabetes using routine clinical data: a retrospective cohort study. *Journal of Diabetes Research*,1-10. https://doi.org/10.1155/2020/4168340

Zafarzadeh, M., Wiktorsson, M., & Hauge, J. B. (2021). A systematic review on technologies for data-driven production logistics: their role from a holistic and value creation perspective. *Logistics, 5*(2), 24. https://doi.org/10.3390/logistics5020024

Zhang, F. and Hu, J. (2024). Research on logistics supply chain optimization strategy based on machine learning. *International Conference on Smart Transportation and City Engineering (STCE 2023)*, 237. https://doi.org/10.1117/12.3024778