



Modern AI in Green Logistics: Smart Systems for Sustainability and Carbon Reduction

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ABSTRACT

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Article History:

Submitted: 05-02-2025

Accepted: 02-03-2025

Published: 08-03-2025

Keywords

AI-driven logistics, big data analytics, carbon footprint reduction, green supply chain, intelligent transportation, machine learning.

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Green AI has emerged as a new powerful tool of logistics in this present modern world which has helped optimize supply chain operations and at the same time the emission of greenhouse gases had also been reduced. More, artificial intelligence systems such as integrated intelligent predictive analytics, the IoT Approach, application of optimal routes, and automated warehouses are making a positive contribution to sustainability through the efficiency reduction of fuel consumption, optimal inventory, and management of transportation networks. This paper review is based on the topic of AI and the way it is being employed in green logistics, particularly in the reduction of environmental footprint, optimization of resources and setting up of environmentally friendly last one kilometer conveying solutions. In this regard, it also provides faces of the most successful companies that have been adopting sustainable AI-facilitated initiatives. There are certain challenges that organization face while adopting AI in logistics some of which are the high cost of the implementation, data security, skills of the workers, and compatibility with legacy systems. With a focus on corporate social responsibility as well as the effective management of resources at the government level for sustainable supply chain, Artificial Intelligence technology will have a big part to play in the development of new and efficient transport system.





INTRODUCTION

Companies in the supply chain and logistics industry have benefitted from the venture into the artificial intelligence age. Over the last several years, the implementation of smart systems with the help of artificial intelligence is increasing since enterprises are moving towards sustainable practices in their logistics operations. It is owed to the concerns raised regarding the environment, strict measures proffered by regulating authorities, and the high demand for sustainable supply chain management [1]. Green logistics is the reduction of the negative environmental impact whilst keeping an organization's operational effectiveness, and in this process, AI is beginning to be applied.

Since fuel and power are crucial to the operations within logistics, it plays a significant role within the current global emissions of carbon. In traditional logistics models, numerous issues like route optimization, fuel consumption and wastage and so forth exist [2]. The incorporation of artificial intelligence technologies into logistics and supply chain leads to the optimization of its operations by lowering fuel consumption and, therefore minimizes the emission of greenhouse gases. These systems include the use of artificial intelligence, advanced statistical models, the immediate processing of data, and the automation of business processes in order to increase productivity and profitability [3].

In this part, the most notable area where AI's impact on green logistics has been observed is in route planning and managing fleets. Extensive data processing based on traffic flow, weather information, and other factors that contribute to fuel consumption helps to identify the most efficient routes for deliveries. This helps in making the usage of fuel as low as possible and also comfortably curtails emissions of carbon. Further, by using AI, the large set of data gathered through vehicle performance can be used to schedule the proper time for the maintenance thus reducing breakdowns and increasing the durability of logistics fleets [4]. Another of the major areas where AI is said to help in sustainability is in the warehouse and inventory management. Lightings and temperatures can be automatically controlled, and storage spaces are effectively utilized and minimized on wastage through the use of such systems. Automated robots together with AI in the supply of warehouses decrease the need for human intervention as well as energy consumption. Additionally, AI optimizes demand forecasting, which in turns mitigates overstock, too much inventory, trying to reduce emission thereby bringing down the carbon footprint of supply networks [5].





Beyond operational efficiency, AI supports sustainable decision-making through data-driven insights. They will be able to read through environmental reports, monitor levels of carbon emissions, and even introduce environmentally friendly measures through recommendation from the machine. To a certain extent, AI enables sustainable implementation of renewable energy resources in the company's logistics processes, thus contributing to the goal of achieving carbon neutrality. This review aims at discussing how artificial intelligence in modern green logistics helps to achieve the reduction of carbon footprint [6]. This paper discusses strengths, weaknesses, and opportunities of AI in making logistics sustainable. The realism is that as the adoption of AI increases in industries, the logistics industries is at the frontline on the innovation to sustainable supply chain.

UNDERSTANDING GREEN LOGISTICS

Green logistics is a management term that seeks to reduce the adverse effect of supply chain activities, transportation and other logistics activities in an organization without compromising efficiency and effectiveness. With the emerging issues on environmental conservation, global warming and availability of resources reaching agenda, industries are being compelled to adopt green supply chain practices. Organizations are undertaking such changes due to CSR, legal requirements, and for meeting the needs of the customers who have become more conscious of environmental impacts [7].

Green logistics can be defined as implementing measures with the aim of making the logistics activities more environmentally friendly. They cover features such as efficient energy use in the means of transportation, the utilization of limited resources, the reduction of carbon dioxide emission and the environmentally friendly packaging [8]. It is ensured that economic progress is aligned with sustainable dimensions where it is possible for companies to draw profits by running their business sustainably. Measures that need to be put in place in order to reduce the emission of greenhouse gases in transportation and warehousing [9].

Energy methods which should be used include the use of efficient vehicles, renewable resources of energy, and energy conservation devices. Reducing the use of plastics, increasing the usage of biodegradable packing and designing package in the most efficient way possible. Promoting sustainable development by engaging suppliers and parties that you work closely with in a supply





chain. Designing proper mechanisms for managing and encouraging product returns, recycling, and disposal for the purpose of minimizing wastage [10].

Sustainability has recently become one of the distinct and visibly functional priorities in many supply chains as more companies have increasingly embraced its role in their target. As we know that green logistics have a number of opportunities associated with it, at the same time, green logistics implementation come with a number of issues [11].

High Initial Costs: Green products including electric cars and energy are an example of devices that require long-term investments to be made in order for them to become popular [12].

Lack of pure infrastructure: There is no adequate infrastructure to support the sustainability of such transportation methods, for instance, charging stations for electrical trucks or infrastructures for recycling [13].

Challenges of Global Supply Chain: Management of sustainability issues in supply chain across the borders remains a major challenge because of issues such as different regulations that have been set, economic factors and logistics [14].

Challenges of Green logistics: There is a challenge in making companies incorporate logical and cost effective solutions in the supply chain without having to reduce the efficiency of the company financially [15].

Green logistics is a complex concept that is highly dependent upon the use of new technology. The integration of artificial intelligence in routers the ability to track in real-time the performance of the vehicles and make use of predictive analytics in order to cut down on fuel usage and enhance efficiency. Also, smart sensors in the IoT improve the energy consumption of vehicles and warehouses, as well as, block chain technologies for supply chain sustainability [16]. Having gone through the analysis of the paper, one can conclude that green logistics is not just a choice for organizations that plan to stay relevant in the long run. Through embracing modern technologies, firms can ensure economic development in the business and environmental conservation so that sustainable logistics and supply chain improvement becomes the practice in the future [17].



ARTIFICIAL INTELLIGENCE IN MODERN LOGISTICS

Artificial Intelligence (AI) transforms logistics operations through smart data-based solutions that help us run our supply chain better and more efficiently at lower costs while making our operations more sustainable. Human-based decision-making in past logistics systems produced problems with performance that harmed customers and degraded the environment. AI processing power helps logistics operators form insights from big data and reduces environmental impact through smarter decisions [18].

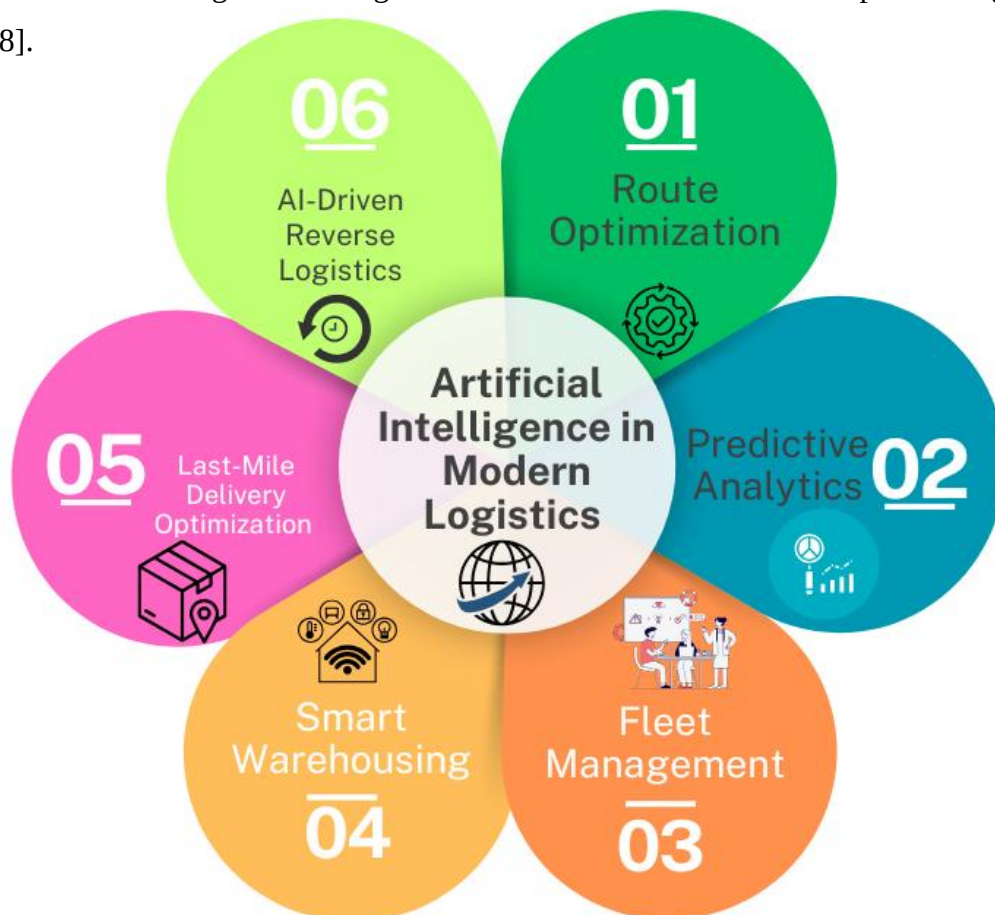


Figure: 1 showing AI in modern logistics

Overview of AI Applications in Logistics: Businesses add AI technology to multiple areas within their logistics operations such as transport and storage processes along with demand predictions and customer assistance [19]. These AI practices function as our main system applications:

- AI systems with traffic, weather and fuel data analyze delivery routes to choose the best paths that save fuel and reduce pollution.



- AI models help find problems in equipment by monitoring vehicles and warehouses which lets teams fix these issues before breakdowns prevent work from happening.
- AI-driven self-driving trucks and drone delivery services decrease the need for fossil fuels by traveling faster than manual delivery systems.
- By using AI-powered robots to manage warehouse operations the system lowers energy needs and runs better than manual systems.
- AI examines market trends and past performance to estimate consumer needs which prevents creating too much product and wasting resources that pollute the environment [20].

Evolution of AI-Driven Supply Chain Management: Logistics companies have progressively developed their AI systems from basic machine help to advanced decision-making platforms. AI helped businesses perform two fundamental tasks at first barcode recognition and automatic stock control management. As tech progress allowed machines to handle more advanced operations such as demand forecasting and pricing optimization [21]. Digital twin technology created by AI shows businesses what happens in their supply chain operations to find ways they can work better. Real-time tracking technology will show all supply chain activities to help companies eliminate performance problems [22].

Benefits of AI in Logistics Operations: Using AI in logistics creates positive outcomes especially through the following advantages:

- Using smart systems and automatic vehicles helps supply chain operators make better delivery routes and use less fuel which decreases environmental pollution.
- Both automated processes and efficiency improvements help AI lower operating expenses as well as staff and vehicle costs.
- Through improved delivery systems AI helps products reach the customer on time and with less movement between locations [23].

Businesses use AI to monitor their sustainability decisions which meet environmental standards worldwide across industries. Modern logistics operates at new levels because AI enhances its performance while also reducing environmental impact. The future growth of AI-driven supply chain





management will help us reach our goal of zero carbon emissions in worldwide trade and delivery operations [24].

SMART SYSTEMS FOR SUSTAINABLE LOGISTICS

Smart technology that uses Artificial Intelligence (AI) and Internet of Things (IoT) systems plus Big Data helps companies run their logistics more productively while saving money and reducing environmental impact. These modern systems help businesses plan better deliveries to save expenses and decrease carbon emissions alongside regular operations. Smart logistics systems use real-time automated data to achieve important environmental aims [25].

Internet of Things (IoT) and Real-Time Tracking: Real-time monitoring becomes possible through IoT solutions which optimize operations throughout green logistics supply chains and transportation activities. IoT sensors in vehicles tracking fuel use combined with telematics send readings about vehicle performance alongside temperature and humidity info from warehouse and shipping container sensors. These practical data points assist in managing fuel better and cutting power usage while keeping perishables from spoiling. AI helps manage vehicle performance and checks driver behavior to provide eco-friendly driving suggestions which decreases vehicle emissions. When businesses use IoT devices they gain complete supply chain insight to find weak points gradually cut delivery times while following green logistics methods [26].

Big Data Analytics for Route and Inventory Optimization: Analytics of Big Data lets logistics businesses make evidence-based choices that enhance performance and environment protection. With AI analytics technology our system analyzes traffic patterns weather forecasts and fuel data to pick the ideal shipping routes which cuts down on fuel waste and pollution. The latest AI methods examine previous market behaviors and customer needs to accurately forecast future customer behavior [27]. By predicting demands correctly this strategy saves resources by stopping unnecessary production rates. The system uses artificial intelligence to arrange storage spaces well and runs orders automatically while improving pack-and-pick processes which saves energy and lowers operational waste [28].





Cloud-based computing helps organizations better use their resources: Cloud platforms help logistics companies utilize real-time data processing to support teamwork and sustainability work. The cloud manages business data to show carbon emissions while guiding supply chain improvements and stops using extra energy. The cloud system with AI tools examines all available data layers to tell companies how to run logistics better and reduce environmental impact. Cloud systems help businesses properly integrate solar, wind, and alternative power systems into their delivery networks to reduce fuel dependency [29]. AI-connected IoT Big Data systems help improve the sustainability and boosted performance of logistics operations. These technologies reduce companies' environmental impact by running warehouses more efficiently and running supply chains better with optimized routes. Smart technology adoption will strengthen its position in building greener and more stable logistics supply chains as the logistics sector grows its digital transformation methods [30].

AI-DRIVEN STRATEGIES FOR CARBON FOOTPRINT REDUCTION

The use of artificial intelligence systems helps companies decrease their environmental impact throughout their logistics and supply chain activities. Artificial intelligence optimizes transportation routes to reduce energy usage which then let's companies decrease greenhouse gases without slowing operations. Sustainable logistics now includes smart controls that make fuel last longer and decrease unnecessary usage while running operations more efficiently. AI supports the largest carbon reduction efforts when it creates more effective delivery routes [31]. These systems review live-streaming information through their AI algorithms to generate results of:





AI-driven strategies for carbon footprint reduction

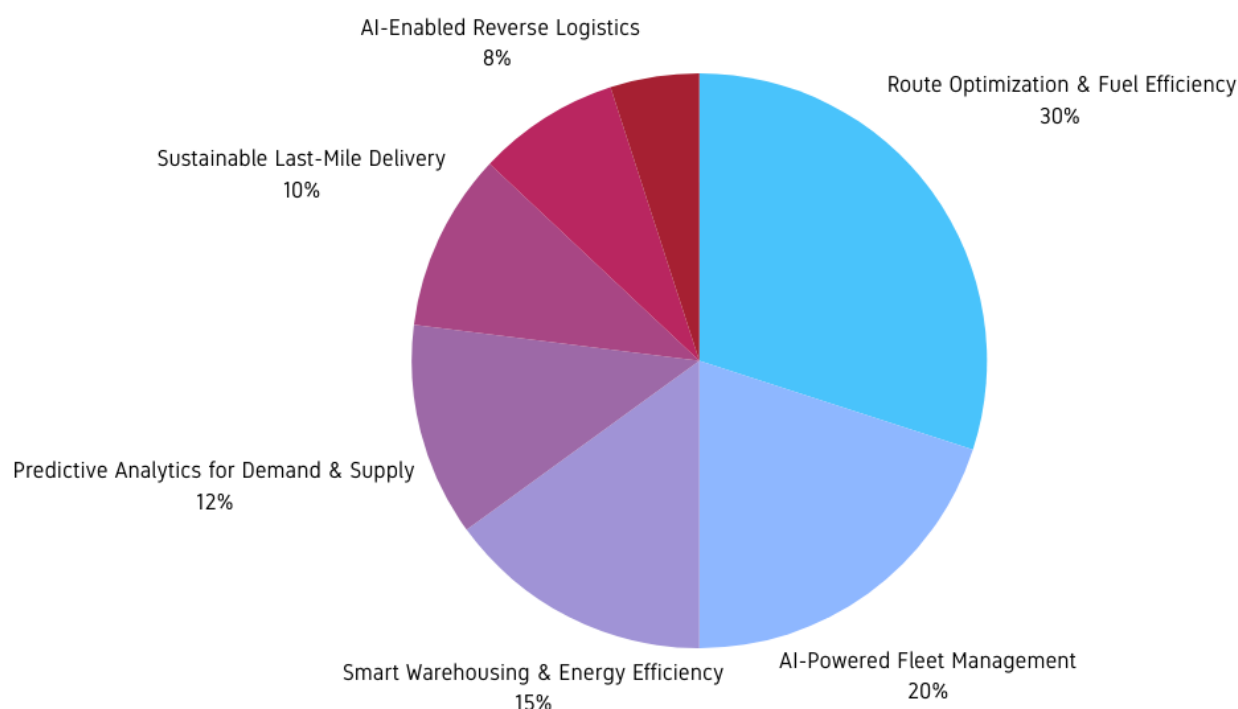


Figure: 2 showing AI-driven strategies for carbon footprint reduction

AI notices road traffic before deciding which route saves the most gas: Weather information lets AI systems plan shipments during favorable periods to prevent fuel waste from bad weather. The technology matches vehicle loads perfectly to space limits to achieve better capacity and fewer deliveries. The system detects unsafe driving practices such as rapid brakes and idling plus rough gas pedals because they all lead to more emissions. Efficient data systems with AI sensors guide drivers into better ways to save fuel in their vehicles [32].

Predictive Analytics for Demand and Supply Management: Through predictive analytics technology logistics firms can predict market needs better which helps them avoid creating too much stock and running unnecessary transports. This helps in: The system plans delivery routes to eliminate empty trips by trucks and delivery vehicles. AI assists businesses in maintaining proper inventory amounts which lowers their warehouse and energy usage. AI analytics detects product demand trends before they occur which keeps unusable supplies from entering the market [33].



AI-Powered Warehouse Automation and Energy Efficiency: AI systems cut warehouse power costs through mechanical optimization coupled with automated operations. Smart robots that use AI assist with picking and sorting tasks which saves on both human and electrical power usage. AI technology controls warehouse lighting and temperature by studying occupancy and weather changes to decrease energy consumption. AI technology plans warehouse areas to use available space better which lowers the need to build new storage areas [34].

Sustainable Last-Mile Delivery Solutions: Delivery operations within the final mile of transportation produce substantial emission pollution. AI technology creates practical tools which let us decrease our effect on the environment through these methods: The technology manages an electric vehicle and autonomous fleet to lower fuel dependence. Smart Parcel Lockers let AI find strategic delivery centers which cut the number of direct home deliveries and direct supply chain operations. AI technology arranges package drop-offs best so delivery vehicles make less trips and produce less pollution [35].

Data-based artificial intelligence helps establish emission-reducing solutions for logistics operations. AI technologies enhance supply chains by creating efficient routes and detecting future patterns as well as mongering warehouse tasks and last-mile delivery methods. Further AI advancements will drive us toward carbon-neutral logistics systems that support worldwide environmental sustainability [36].

CASE STUDIES AND REAL-WORLD APPLICATIONS

Artificial Intelligence systems help us make our logistics systems greener and run them better with lower expenses. Several organizations from multiple types of businesses use AI smart systems to make their supply chains perform better and generate less carbon pollution. Through practical examples this section shows how artificial intelligence changes logistics into a more sustainable and productive operation [37].

United Parcel Service uses its AI-based: On-Road Integrated Optimization and Navigation technology to enhance delivery routes. Using ORION data about traffic flow plus fuel costs and delivery times helps identify saving routes for transportation [39].





Impact

- Reduced fuel consumption by 10 million gallons annually
- Cut 100,000 metric tons of CO₂ emissions per year

Amazon's AI-Powered Fulfillment Centers: Amazon employs machine learning algorithms and robotics to handle operations better in its warehousing facilities. Robotic systems transport inventory faster with less work and less energy use of personnel [40].

Impact

- 50% reduction in energy usage per order
- The company uses better warehouse space planning to decrease the need for new warehouse areas.
- The system processes orders more quickly which cuts down waiting times and lowers shipment frequency.

AI in Sustainable Fleet Management: By using AI to manage their fleet DHL improves vehicle efficiency and decreases vehicle breakdown rates [41].

Impact

- AI helps the company save up to 30% on fuel through smarter travel routes.
- The intelligent system manages more electric vehicles at intelligent charging stations.
- The system balances delivery needs and combines multiple shipments to reduce harmful pollution.

AI-Powered Supply Chain Visibility: Together IBM and Maersk created TradeLens which uses AI to track shipping containers across all supply chain logistics points. The system both improves how containers are tracked and decreases paperwork making a major difference to our environment [42].



Impact

- By processing containers faster the company cut down on fuel use and reduced waste output by 40%.
- The improved supply chain management helps us avoid sending goods that are not needed.
- Improved decision-making for sustainable shipping routes

AI-Optimized Last-Mile Delivery: FedEx uses artificial intelligence to understand customer delivery choices and determine better delivery areas in the last delivery mile [43].

Impact

- 20% reduction in last-mile emissions
- Our company adds electric vans and drones to deliver goods while preserving the environment.
- Improved customer satisfaction with faster and more accurate deliveries.
- Lessons Learned from Industry Leaders.

Lessons Learned from Industry Leaders: These case studies show companies how to implement AI for green logistics by creating these major lessons [44].

- The use of AI to plan better routes and manage vehicle fleets helps firms reduce fuel expenses plus environmental impact.
- Using artificial intelligence robots in warehouse operations decreases energy needs plus enhances performance.
- Using predictive data and controlling supply chain operations improves how companies meet sustainability targets.
- Companies can lower emission levels and provide better service by using AI technologies for their final delivery operations.



Businesses are discovering that AI uses help decrease environmental impact and make operational work better. Companies that adopt AI technology for their operations will help push supply chains toward environmentally-friendly methods of the future [45].

CHALLENGES AND LIMITATIONS OF AI IN GREEN LOGISTICS

Artificial Intelligence (AI) has revolutionized logistics by improving efficiency and lowering environmental impact, but its implementation also presents challenges, and limitations. To achieve a truly sustainable logistics system, businesses need to tackle these barriers to enable maximum realization of the potential of AI. This can be backed up using Genetic Algorithms and is confirmed using LSP Algorithm [46].

Data Privacy and Security Concerns: To create AI in logistics, it utilizes the collection of real-time data and cloud systems, which both can bring the cybersecurity risks and data privacy risks [47].

Challenges

- Risk of cyber-attacks compromising supply chain operations
- Data-sharing concerns between logistics partners and third-party AI providers

Potential Solutions

- Developed cybersecurity measures which incorporate encryption and block chain for secure data transactions
- Using strict data governance policies to comply with privacy regulations

Lack of Skilled Workforce and Technical Expertise: If we talk about a wider aspect, there is big gap of skills required for the implementation and the maintenance of AI implementation in the logistics industry. Recruitment of professionals with a high dexterity in AI, machine learning, and big data analytics is something many businesses find challenging to do [48].

Challenges

- Shortage of AI and data science professionals in logistics





- Retraining of employees to work hand in hand with AI based systems.

Potential Solutions

- Offering AI training programs for logistics professionals
- Building AI expertise (partnering with universities and tech companies)

Integration with Legacy Systems: There are still many logistics companies that still work over the old systems, who are not compatible with the modern AI technologies [49].

Challenges

- AI hard to integrate in traditional supply chain management software.
- It also has high costs and operational disruptions when system upgrades occur.

Potential Solutions

- Gradual AI adoption with hybrid models: a combination of AI and human capabilities into existing systems
- Having cloud based AI solutions so as to limit the network or architecture switches

Ethical and Environmental Concerns: AI decreases carbon emissions, but its own development and use are not carbon neutral [50].

Challenges

- High energy consumption of AI-powered data centers
- Ethical issues with robots replacing jobs due to AI in the logistics industry.

Potential Solutions

- Investing in access to renewable energy based AI systems which are energy efficient.
- Implementing policies for AI-assisted job transformation rather than replacement





The challenges notwithstanding, AI is an instrumental tool when it comes to sustainable logistics. Clearly addressing the related cost, security, workforce, integration, and ethical concerns will allow AI adoption to keep driving reduction of carbon footprint while maintaining a balance between efficiency and sustainability. As technology progresses, these barriers can be overcome to allow for a smarter, greener future of logistics [51].

FUTURE PROSPECTS OF AI IN GREEN LOGISTICS

As technology is constantly progressing, green logistics is set to expand its role for Artificial Intelligence (AI) in the years to come. Given the rising demands of supply chains, innovation has begun to take root, which will transform them into more efficient, ecofriendly, and cost effective. The future trends and AI breakthroughs available in logistics are considered in this section [52].

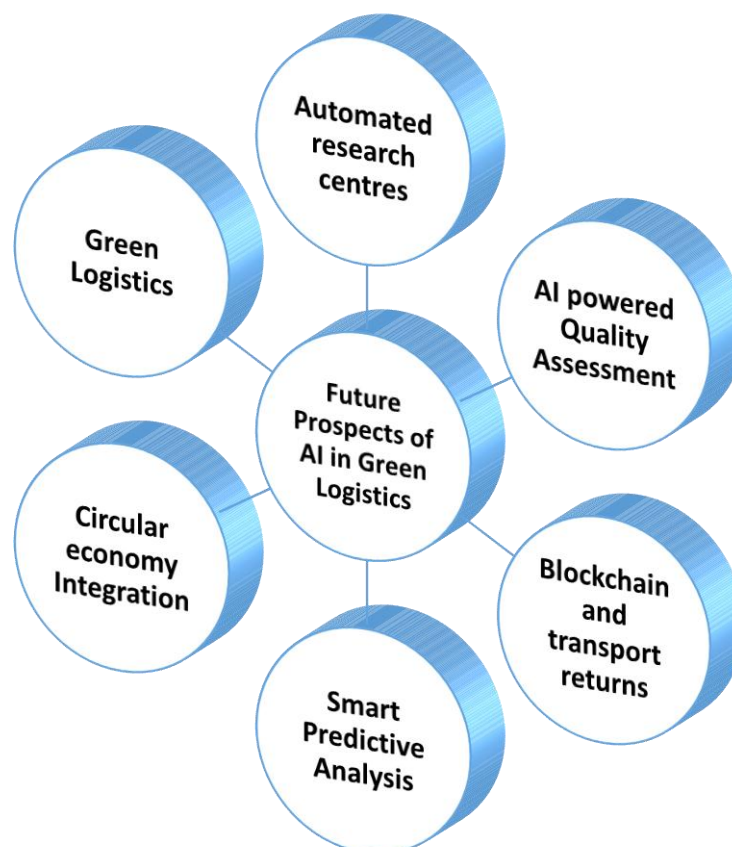


Figure: 3 showing future prospects of AI in green logistics

Widespread Adoption of Autonomous Vehicles and Drones: The AI aided self-driving trucks and delivery drones will also take on a major role in reducing fuel consumption and emissions [53].



Future Impact

- Use of electric autonomous trucks for long haul freight transport will increase.
- Fuel powered last-mile delivery vehicles replaced by AI driven drones.
- Enhanced traffic and route optimization through real-time AI decision-making.

AI-Powered Circular Economy and Reverse Logistics: AI driven reverse logistics will lead the ways of sustainable supply chains for recyclability, reusability and reduction of waste [54].

Future Innovations

- AI Waste Tracking and Recycling automation to decrease environmental impact.
- Smart inventory systems which ensure that product returns and refurbishments are done with efficiency.
- AI driven demand forecasting to produce less as possible to avoid unnecessary excess production and waste

Green Energy Integration in Logistics Operations: Logistics and supply chain will gain more in the adoption of renewable energy sources through AI [54].

Expected Advancements

- AI smart grids dealing with the smart use of solar and wind energy in transportation and warehousing.
- Optimization algorithms to improve efficiency of electric logistics fleets.
- AI mediated energy efficient warehouses with climate controlling systems lowers carbon emissions.
- AI enhanced with block chain technology provides transparency for the sustainable supply chain compliance.

Potential Benefits

- Real-time tracking of carbon footprints across global supply chains.





- AI driven automated sustainability audits to enforce the regulatory compliance.
- Green certification of ecofriendly logistics practices using block chain.
- Hyper-Personalization and AI-Optimized Logistics Networks.

Real time, on demand logistics solutions will be made possible using AI that will reduce waste and improve efficiency at the same time [55].

Future Trends

- Dynamic logistics networks powered by Artificial Intelligence that adjust to the constantly evolving demand patterns.
- Excessive trips and emissions reduction with hyper personal delivery scheduling.
- AI driven crowd sourced delivery models for sustainability based on the use of shared transport.

The bright side of AI in green logistics in the future is about autonomous transportation, circular economy solutions, renewable energy integration, block chain transparency and so on. With the continued progress of AI technology, businesses will move towards near-zero emissions logistics, building up a green and efficient global supply chain. But, to build a greener future for the logistics industry various hardcore technologies will have to be embraced [56].

CONCLUSION

Green logistics is utilizing Artificial Intelligence (AI) as a transformative force in tackling the carbon footprint of operations within supply chain activity. Through route optimization, predictive analytics, smart warehousing and autonomous transportation, AI aids businesses in that being much more productive while also more environmentally sustainable. Although AI offers considerable potential benefits, implementing AI in logistics is fraught with challenges, including high implementation costs, dangers of exposing data, difficulties integrating it with legacy systems and ethical issues. Nevertheless, with further technological advances, government financial aid, and partnerships between governmental agencies and industries, many of these problems can be addressed, leading to green and wiser supply chains.





In the future, AI will enable the logistics industry to become net zero emissions driven by the linear innovations of autonomous vehicles, renewable energy powered warehouses, block chain transparency, AI driven circular economies. By implementing AI driven green logistics strategy, businesses will be friendlier to the environment, while at the same time improving operational efficiency, decrease costs involved and comply to global sustainability measures. As the future becomes more ecological, the AI powered logistics will be an integral part of creating a resilient, intelligent and ecofriendly supply chain network that will benefit business and the planet.

REFERENCES

- [1]. Chen W, Men Y, Fuster N, Osorio C, Juan AA. Artificial intelligence in logistics optimization with sustainable criteria: A review. *Sustainability*. 2024 Oct 22; 16(21):9145.
- [2]. Rane N, Choudhary S, Rane J. Artificial intelligence and machine learning for resilient and sustainable logistics and supply chain management. Available at SSRN 4847087. 2024 May 29.
- [3]. Nicoletti B, Appolloni A. Green Logistics 5.0: a review of sustainability-oriented innovation with foundation models in logistics. *European Journal of Innovation Management*. 2024 Dec 16; 27(9):542-61.
- [4]. Yin Y, Wang H, Deng X. Real-time logistics transport emission monitoring-integrating artificial intelligence and internet of things. *Transportation Research Part D: Transport and Environment*. 2024 Nov 1; 136:104426.
- [5]. Tsolakis N, Zissis D, Papaefthimiou S, Korfiatis N. Towards AI driven environmental sustainability: an application of automated logistics in container port terminals. *International Journal of Production Research*. 2022 Jul 18; 60(14):4508-28.
- [6]. Gupta CP, Kumar VR, Khurana A. Artificial Intelligence integration with the supply chain, making it green and sustainable. In 2023 7th International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech) 2023 Dec 18 (pp. 1-5). IEEE.
- [7]. Mohsen BM. Ai-driven optimization of urban logistics in smart cities: Integrating autonomous vehicles and iot for efficient delivery systems. *Sustainability*. 2024 Dec 22; 16(24):11265.
- [8]. Shi Y, Lin Y, Lim MK, Tseng ML, Tan C, Li Y. An intelligent green scheduling system for sustainable cold chain logistics. *Expert Systems with Applications*. 2022 Dec 15; 209:118378.





- [9]. Shamsuddoha M, Kashem MA, Nasir T. Smart transportation logistics: Achieving supply chain efficiency with green initiatives. In *Data Analytics for Supply Chain Networks 2023* Jun 23 (pp. 243-258). Cham: Springer International Publishing.
- [10]. Kashem MA, Shamsuddoha M, Nasir T. Smart Transportation and Carbon Emission from the Perspective of Artificial Intelligence, Internet of Things, and Blockchain: A Review for Sustainable Future.
- [11]. Huang R, Mao S. Carbon footprint management in global supply chains: A data-driven approach utilizing artificial intelligence algorithms. *IEEE Access*. 2024 Jun 3.
- [12]. Cansu AK. Innovation in Sustainable Logistics Management: A Conceptual Approach. *EUROASIA JOURNAL OF SOCIAL SCIENCES & HUMANITIES*. 2025 Feb 24; 12(1):26-41.
- [13]. Shee Weng L. Green Logistics: Innovations in Sustainable Transportation and Distribution. Available at SSRN 5144977. 2025.
- [14]. Liu C, Ma T. Green logistics management and supply chain system construction based on internet of things technology. *Sustainable Computing: Informatics and Systems*. 2022 Sep 1; 35:100773.
- [15]. Fareed AG, De Felice F, Forcina A, Petrillo A. Role and applications of advanced digital technologies in achieving sustainability in multimodal logistics operations: A systematic literature review. *Sustainable Futures*. 2024 Aug 12:100278.
- [16]. Bolón-Canedo V, Morán-Fernández L, Cancela B, Alonso-Betanzos A. A review of green artificial intelligence: Towards a more sustainable future. *Neurocomputing*. 2024 Jun 22:128096.
- [17]. Su Y, Fan QM. The green vehicle routing problem from a smart logistics perspective. *IEEE access*. 2019 Dec 23; 8:839-46.
- [18]. Le TT, Nguyen HP, Rudzki K, Rowiński L, Bui VD, Truong TH, Le HC, Pham ND. Management strategy for seaports aspiring to green logistical goals of IMO: Technology and policy solutions. *Polish Maritime Research*. 2023; 30:165-87.
- [19]. Mirindi D, Khang A, Mirindi F. Artificial Intelligence (AI) and Automation for Driving Green Transportation Systems: A Comprehensive Review. *Driving Green Transportation System through Artificial Intelligence and Automation: Approaches, Technologies and Applications*. 2025 Jan 12:1-9.





- [20]. Moghaddam GK, Karimzadeh M. AI-Driven Digital Transformation and Sustainable Logistics: Innovations in Global Supply Chain Management.
- [21]. Gaur L, Afaq A, Arora GK, Khan N. Artificial intelligence for carbon emissions using system of systems theory. *Ecological Informatics*. 2023 Sep 1; 76:102165.
- [22]. Ruan M. The application of multimodal AI large model in the green supply chain of energy industry. *Energy Informatics*. 2024 Oct 5; 7(1):98.
- [23]. Kolasińska-Morawska K, Sułkowski Ł, Buła P, Brzozowska M, Morawski P. Smart logistics—Sustainable technological innovations in customer service at the last-mile stage: The polish perspective. *Energies*. 2022 Sep 1; 15(17):6395.
- [24]. Bradu P, Biswas A, Nair C, Sreevalsakumar S, Patil M, Kannampuzha S, Mukherjee AG, Wanjari UR, Renu K, Vellingiri B, Gopalakrishnan AV. RETRACTED ARTICLE: Recent advances in green technology and Industrial Revolution 4.0 for a sustainable future. *Environmental Science and Pollution Research*. 2023 Dec; 30(60):124488-519.
- [25]. Sun X, Yu H, Solvang WD, Wang Y, Wang K. The application of Industry 4.0 technologies in sustainable logistics: a systematic literature review (2012–2020) to explore future research opportunities. *Environmental Science and Pollution Research*. 2022 Feb 1:1-32.
- [26]. Ayoubi H, Tabaa Y. Artificial intelligence in green management and the rise of digital lean for sustainable efficiency. *InE3S Web of Conferences 2023 (Vol. 412, p. 01053)*. EDP Sciences.
- [27]. Ameh B. Digital tools and AI: Using technology to monitor carbon emissions and waste at each stage of the supply chain, enabling real-time adjustments for sustainability improvements. *Int J Sci Res Arch*. 2024 Oct; 13(1):2741-54.
- [28]. Issa Zadeh SB, Garay-Rondero CL. Enhancing urban sustainability: unravelling carbon footprint reduction in smart cities through modern supply-chain measures. *Smart Cities*. 2023 Nov 23; 6(6):3225-50.
- [29]. Bhambri P, Khang A. Edge Computing for Enhancing Efficiency and Sustainability in Green Transportation Systems. *InDriving Green Transportation System through Artificial Intelligence and Automation: Approaches, Technologies and Applications 2025 Jan 12 (pp. 43-65)*. Cham: Springer Nature Switzerland.



- [30]. Durlik I, Miller T, Kostecka E, Łobodzińska A, Kostecki T. Harnessing AI for sustainable shipping and green ports: Challenges and opportunities. *Applied Sciences*. 2024 Jul 9; 14(14):5994.
- [31]. Irenita N. Mapping Technological Innovation for the Implementation of Green Logistics in the Indonesian Courier Express Parcel (CEP) Industry. *Dinasti International Journal of Economics, Finance & Accounting (DIJEFA)*. 2025 Jan 1; 5(6).
- [32]. Fraga-Lamas P, Lopes SI, Fernández-Caramés TM. Green IoT and edge AI as key technological enablers for a sustainable digital transition towards a smart circular economy: An industry 5.0 use case. *Sensors*. 2021 Aug 26; 21(17):5745.
- [33]. Mandala V, Surabhi SN, Kommisetty PD, Kuppala BM, Ingole R. towards Carbon-Free Automotive Futures: Leveraging AI and ML for Sustainable Transformation. *Educational Administration: Theory and Practice*. 2024; 30(5):3485-97.
- [34]. Hasan MR, Islam MZ, Sumon MF, Osiujjaman M, Debnath P, Pant L. Integrating artificial intelligence and predictive analytics in supply chain management to minimize carbon footprint and enhance business growth in the USA. *Journal of Business and Management Studies*. 2024 Aug 15; 6(4):195-212.
- [35]. Hasan MR, Islam MZ, Sumon MF, Osiujjaman M, Debnath P, Pant L. Integrating artificial intelligence and predictive analytics in supply chain management to minimize carbon footprint and enhance business growth in the USA. *Journal of Business and Management Studies*. 2024 Aug 15; 6(4):195-212.
- [36]. Golinska-Dawson P, Mrugalska B, Lai KK, Weber GW. Smart and sustainable supply chain and logistics-trends, challenges, methods and best practices. *Annals of Operations Research*. 2023 May; 324(1):1-1.
- [37]. Chen L, Chen Z, Zhang Y, Liu Y, Osman AI, Farghali M, Hua J, Al-Fatesh A, Ihara I, Rooney DW, Yap PS. Artificial intelligence-based solutions for climate change: a review. *Environmental Chemistry Letters*. 2023 Oct; 21(5):2525-57.
- [38]. Dauvergne P. Is artificial intelligence greening global supply chains? Exposing the political economy of environmental costs. *Review of International Political Economy*. 2022 May 4;29(3):696-718.
- [39]. Rane N, Paramesha M, Choudhary S, Rane J. Business intelligence and artificial intelligence for sustainable development: Integrating internet of things, machine learning, and big data





- analytics for enhanced sustainability. Machine Learning, and Big Data Analytics for Enhanced Sustainability (May 20, 2024). 2024 May 20.
- [40]. Kalinowski TB, Rażniewska M, Brzeziński J, Szudrowicz I, Adamczak M, Toboła-Walaszczyk A, Cyplik P, Kopeć M, Maletič D, Maletič M, Roblek M. Digital, Intelligent & Sustainable Logistics. Nextlog Project; 2023.
- [41]. Ioanid A, Andrei N. Artificial Intelligence and Geospatial Technologies for Sustainable Maritime Logistics. Case Study: Port Of Constanta, Romania. 15 [Internet]. 2020
- [42]. Gera R, Banerjee S, Saratchandran DV, Arora S, Whig A. Machine Learning for Environmental Sustainability in the Corporate World. In Driving Business Success through Eco-Friendly Strategies 2025 (pp. 283-302). IGI Global Scientific Publishing.
- [43]. Pham ND, Dinh GH, Pham HT, Kozak J, Hoang PN. Role of green logistics in the construction of sustainable supply chains. Polish Maritime Research. 2023; 30:191-211.
- [44]. Suganya R, Joseph LL, Kollem S. Integrating Artificial Intelligence in Electric Vehicles and Optimizing Logistics for Sustainable Transportation. In Cases on AI-Driven Solutions to Environmental Challenges 2025 (pp. 385-418). IGI Global Scientific Publishing.
- [45]. Sah BP, Shirin B, Minhazur Rahman B, Shahjalal M. The Role of AI in Promoting Sustainability within the Manufacturing Supply Chain Achieving Lean and Green Objectives. Academic Journal on Business Administration, Innovation & Sustainability. 2024; 4(3):79-93.
- [46]. Sejana JV, Sandhya H, Varghese B. Artificial Intelligence in Green Transportation: A Conceptual Review. AI, Blockchain, and Metaverse in Hospitality and Tourism Industry 4.0.:289-99.
- [47]. Alkhodair M, Alkhudhayr H. Harnessing Industry 4.0 for SMEs: Advancing Smart Manufacturing and Logistics for Sustainable Supply Chains. Sustainability. 2025 Jan 21; 17(3):813.
- [48]. Muthuswamy M, Ali AM. Sustainable supply chain management in the age of machine intelligence: addressing challenges, capitalizing on opportunities, and shaping the future landscape. Sustainable machine intelligence journal. 2023 Jun 25; 3:3-1.
- [49]. Rashid A, Baloch N, Rasheed R, Ngah AH. Big data analytics-artificial intelligence and sustainable performance through green supply chain practices in manufacturing firms of a



- developing country. *Journal of Science and Technology Policy Management*. 2025 Jan 2; 16(1):42-67.
- [50]. Zhou Y, Xia Q, Zhang Z, Quan M, Li H. RETRACTED ARTICLE: Artificial intelligence and machine learning for the green development of agriculture in the emerging manufacturing industry in the IoT platform. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*. 2022 Dec 31; 72(1):284-99.
- [51]. Liu L, Song W, Liu Y. Leveraging digital capabilities toward a circular economy: Reinforcing sustainable supply chain management with Industry 4.0 technologies. *Computers & Industrial Engineering*. 2023 Apr 1; 178:109113.
- [52]. Popova P, Popov V. Artificial Intelligence and Big Data Analytics for Supply Chain Sustainability. In 2024 7th International Conference on Advanced Communication Technologies and Networking (CommNet) 2024 Dec 4 (pp. 1-8). IEEE.
- [53]. Mishra N, Garg A. Smart manufacturing: Intelligent systems in Industry 5.0. In *Aspects of Quality Management in Value Creating in the Industry 5.0 Way* (pp. 21-45). CRC Press.
- [54]. Hong Z, Xiao K. Digital economy structuring for sustainable development: the role of blockchain and artificial intelligence in improving supply chain and reducing negative environmental impacts. *Scientific Reports*. 2024 Feb 16; 14(1):3912.
- [55]. Wang Y, Yang Y, Qin Z, Yang Y, Li J. A literature review on the application of digital technology in achieving green supply chain management. *Sustainability*. 2023 May 25; 15(11):8564.
- [56]. Zhang Q, Gao B, Luqman A. Linking green supply chain management practices with competitiveness during covid 19: The role of big data analytics. *Technology in Society*. 2022 Aug 1; 70:102021.

