GREEN LOGISTICS INNOVATIONS TO REDUCE THE CARBON FOOTPRINT

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Abstract

The development of logistical operations has raised concerns about carbon emissions and environmental sustainability. Despite being essential for international commerce and economic growth, logistics' primary functions including transportation, warehousing, and distribution, significantly increase greenhouse gas emissions, air pollution, and resource depletion. Carbon footprints increase when transportation relies on fossil fuels, and ineffective routing and warehousing techniques intensify environmental damage. By combining sustainable practices like waste reduction programs, energy-efficient storage, and environmentally friendly transportation, green logistics has become a viable way to address these problems. In addition to reducing carbon emissions, implementing green logistics increases operational effectiveness and guarantees regulatory compliance. This article highlights the significance of green logistics solutions in advancing sustainable development and explores the environmental issues related to logistics. Logistics firms may maintain economic competitiveness while integrating their operations with global environmental goals by adopting innovative technologies and sustainable business strategies.

***Keywords*:** green logistics, logistics, innovations, GL, carbon footprint and carbon

Introduction

Relevance of the research: Green logistics (GL) has been considered an evolution of the logistics industry that not only enhances the business but also gives advantages to governments and society. (Khayyat et al., 2024). The necessity for sustainable practices in many kinds of businesses has increased due to global sustainability issues such as shortages of resources, climate change, and pollution. Since excessive greenhouse gas emissions are a major contributor to global warming, one of the main concerns among these issues is the growing carbon footprint (Qin et al., 2024). Because of its high fuel consumption and operational inefficiencies, the logistics industry, which encompasses distribution, warehousing, and transportation, contributes heavily to carbon emissions. Tetteh et al. (2024) highlighted in their article that green logistics is the main strategy to address the net-zero emission target. This research involves finding practical innovations that improve sustainability in contemporary supply chain management and reduce the carbon footprint.

The novelty of the topic: The ability of green logistics solutions to reduce carbon emissions while maintaining supply chain effectiveness has been considered by many researchers and industry experts (Tetteh, Mensah, et al., 2024). Conventional logistics practices cause significant issues to the environment because they largely depend on fossil fuels and inefficient processes. Green logistics, in contrast to traditional sustainability initiatives, incorporates advanced automation and digitisation, promoting a more flexible and ecologically friendly supply chain (Fareed et al., 2024). As a result, this topic is especially relevant since it explores various perspectives on low-carbon logistics solutions.

Research aim: to suggest effective innovations in green logistics practices to reduce carbon footprints in logistics companies.

The following **objectives** have been set to achieve the aim:

1. To find out the impact of logistics activities on environmental sustainability and carbon emissions.
2. To analyse the importance of green logistics practices to enhance environmental sustainability.
3. To provide green logistics practices to reduce carbon footprints and enhance environmental sustainability.

Research object and methods

Research object: green logistics

A comprehensive literature review has been employed in the study to analyze the green logistics innovations to reduce carbon footprints. Secondary resources including e-books, journals, and websites have been used to find materials related to green logistics. Research papers, journal articles, reports, and case studies were fetched from the sources, using keywords including ‘green logistics’, ‘carbon footprints in logistics’, ‘sustainable logistics’, and ‘green logistics practices’. Google Scholar is a significant database that has been used to collect suitable sources. Thematic analysis has been employed to analyze collected secondary data.

Research results and discussion

Impact of logistics activities on environmental sustainability and carbon emission

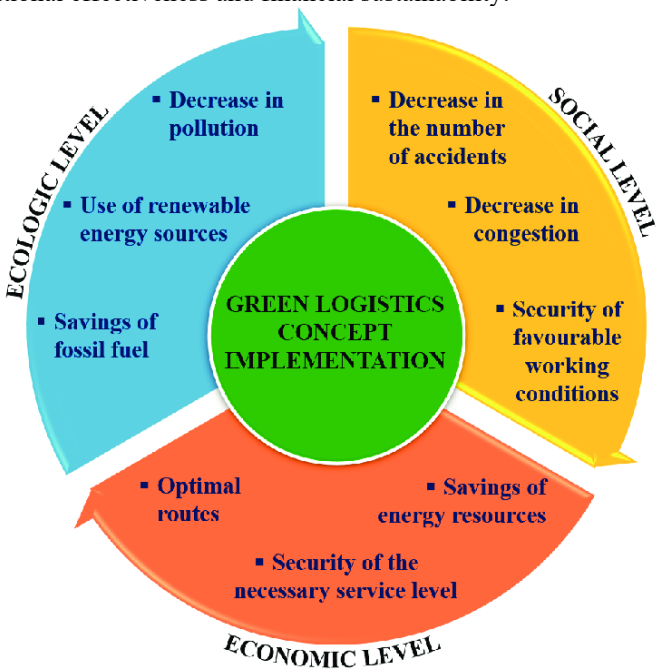
The importance of logistics is increasing and the number of logistics companies in most of the nations has developed. Both developed and developing countries significantly depend on logistics to ensure the efficient flow of

goods and economic development (Perotti et al., 2022). On the other hand, the issues, mainly the problems for environmental sustainability are also increasing along with the logistics development. Transportation, warehousing, and distribution procedures in logistics significantly increase air pollution, carbon emissions, and resource consumption. Because logistics operations mainly depend on fossil fuels for transportation, which is a major source of greenhouse gas (GHG) emissions, carbon emissions continue to be a significant concern (Xu and Xu, 2022). The development of international trade and e-commerce affected the environmental issues even worse. Businesses frequently put speed ahead of sustainability in their search for quick and economical deliveries. It increases the carbon footprint across supply chains. One of the biggest causes of logistics-related environmental effects is transportation, which also contributes significantly to global carbon dioxide (CO_2) emissions (Perotti et al., 2022). Air freight generates significantly higher emissions per ton-kilometer, despite its effectiveness in making quick deliveries. On the other hand, road freight especially diesel-powered trucks, is a significant thing which emits CO2. Because of the size of global trade, maritime shipping contributes significantly to emissions even if it uses less energy per unit (Li and Wang, 2022). The overall environmental impact of logistics operations is further increased by delays and ineffective routing. These things also raise issues like fuel consumption and emissions.

Facilities for warehousing and storage also provide sustainability issues because of their high energy usage and trash production. Numerous warehouses rely on non-renewable energy sources for automated systems, heating, cooling, and lighting, which leads to high electricity consumption and related emissions (Li and Wang, 2022). Furthermore, waste can be raised by ineffective inventory management and storage techniques, especially when perishable commodities decay as a result of incorrect handling or overstocking. Because of the overuse of plastic and non-biodegradable materials, packaging waste makes environmental issues worse by contributing to pollution on land and in the ocean. Logistics activities have an impact on biodiversity and land usage in addition to emissions and energy use. Deforestation, habitat loss, and urbanisation are frequently the results of the growth of logistical infrastructure, such as warehouses, distribution hubs, and transportation networks (Xu and Xu, 2022). These developments disturb ecosystems and reduce the capacity of natural settings to absorb CO2. Consequently, the effects of climate change are increased. Additionally, pollution from logistical operations, like noise and air pollution, has a negative impact on ecosystems and nearby communities, affecting the general quality of life and creating health issues.

The concept of Green Logistics

Green logistics, which integrates social, economic, and environmental goals, is an essential part of contemporary company strategy and supports sustainable development. Historically, financial profitability and economic efficiency have been given top priority in logistics operations (Wu, 2022). However, the desire for more ethical business practices has been fuelled by growing worries about the lack of resources, changing climatic issues, and the degradation of the environment (Agyabeng-Mensah and Tang, 2021). Green logistics has become a key answer, tackling environmental issues while preserving operational effectiveness and financial sustainability.



Source: according to Pham et al., 2023

Fig. 1. Concept of green logistics

Fundamentally, green logistics includes a range of management techniques meant to reduce the negative effects on the environment. These include cutting CO2 emissions, making the most effective use of available resources, and putting waste reduction plans into action (Agyabeng-Mensah and Tang, 2021). In contrast to traditional logistics, which prioritise speed and cost, GL adopts a long-term strategy by taking into account the wider impacts of logistical operations

on society and the environment (Agyabeng-Mensah and Tang, 2021). Businesses can contribute to resource conservation, pollution reduction, and the development of an environmentally friendly supply chain by implementing sustainable practices. Green logistics covers a wide range of production and distribution activities, such as material handling, waste management, packaging, and transportation, all of which are essential to an effective supply chain (Agyabeng-Mensah and Tang, 2021). Sustainable material handling aims to reduce energy usage in the transportation and storage of products, whereas waste management prioritises recycling and appropriate disposal techniques. Using recyclable or biodegradable materials is the goal of green packaging techniques (Vienažindienė et al., 2021). Green logistics initiatives continue to place a high priority on transport since it contribute significantly to carbon emissions in the logistics industry.

Green logistics offers significant cost-saving potential from an economic perspective. Businesses can reduce operating costs while keeping prices competitive by using intermodal transportation, optimising routing, and intelligently allocating resources (Vienažindienė et al., 2021). Additionally, businesses that put sustainability and quality control first can improve their brand recognition and draw in eco-aware investors and customers (Wu, 2022). Effective logistics practices improve overall company performance and long-term profitability in addition to reducing expenses. The environmental benefits of green logistics are substantial. Emissions are significantly decreased by using cleaner cars, energy-efficient transportation strategies, and renewable energy. Additionally, by reducing their carbon footprint, businesses that use green logistics help to preserve the environment. These programs assist logistics companies in complying with environmental regulations and standards while also advancing global sustainability goals (Agyabeng-Mensah and Tang, 2021).

Green logistics places a high priority on social responsibility in addition to economic and environmental factors (Agyabeng-Mensah and Tang, 2021). Sustainable logistics requires the provision of ergonomic and safe working conditions. The development of a responsible logistics system depends on worker competencies, workplace security, and traffic safety protocols. Additionally, green logistics encourages moral labour standards, guaranteeing equitable treatment and the welfare of employees across the supply chain. The connection of social, environmental, and economic sustainability is emphasised by the triple bottom line approach. All three aspects must be included in logistics operations to guarantee long-term success and promote a sustainable and well-balanced business model (Tetteh, Mensah, et al., 2024). Sustainable transportation, environmentally friendly warehousing, green packaging, strategic planning, and effective waste management are all significant components of green logistics (Agyabeng-Mensah and Tang, 2021). Technological developments reinforce green logistics strategies even more. Businesses can reduce waste and inefficiencies and streamline logistics operations by utilising digital management tools, software, and automation (Wu, 2022). Businesses may increase productivity, encourage sustainability, and adapt to international environmental standards by implementing smart logistics solutions.

Importance of green logistics practices to enhance environmental sustainability

By minimising the ecological impact of logistics operations while maintaining efficiency and profitability, green logistics plays a key role in advancing environmental sustainability. Green logistics techniques are now important for combating climate change, reducing pollution, and saving resources as companies place a greater emphasis on sustainable development (Vienažindienė et al., 2021). GL employs tactics such as energy-efficient warehousing, sustainable packaging, eco-friendly transportation, and sophisticated waste management systems to reduce carbon emissions and safeguard natural resources (Mawandiya et al., 2024). The decrease in greenhouse gas (GHG) emissions is one of the main environmental benefits of green logistics. Because it relies on fossil fuels, the logistics industry, especially in the areas of transportation and warehousing, contributes heavily to carbon emissions. Businesses can successfully lower their carbon footprint by implementing alternative fuels, energy-efficient automobiles, and optimised routing (McKinnon, 2012). Environmental harm can also be reduced by combining electric and hybrid trucks, giving rail and water transportation priority over road transportation, and using renewable energy in warehouses. These programs assist global sustainability goals, such as the Paris Agreement's aim of becoming carbon neutral, in addition to guaranteeing adherence to stringent environmental standards (Wang et al., 2021).

Pollution control is a key element of green logistics. Traditional logistical practices have a detrimental effect on ecosystems and human health by making a substantial contribution to air, noise, and water pollution. Businesses can reduce these negative consequences by implementing eco-friendly technologies like sustainable packaging, intelligent logistics planning, and low-emission cars (Mawandiya et al., 2024). Waste management is further improved and a smaller environmental impact is ensured by using biodegradable materials, cutting back on single-use plastics, and putting in place effective recycling programs (Mawandiya et al., 2024). Furthermore, by encouraging material reuse and repurposing, green logistics contributes to the circular economy by reducing waste production and saving resources (Vienažindienė et al., 2021). Green logistics offers significant social and economic benefits in addition to its environmental benefits. Even though adopting sustainable practices, like eco-friendly materials, training, and cutting-edge technologies, may require a large initial investment, businesses eventually save money over time by using less energy, managing their inventories better, and spending less on transportation (Agyabeng-Mensah and Tang, 2021). Enhanced efficiency from streamlined logistics processes gives businesses a competitive advantage in the marketplace (Vienažindienė et al., 2021). Additionally, companies that prioritise sustainability draw in investors and customers who care about the environment, enhancing their reputation and encouraging repeat business.

By encouraging improved working conditions, moral labour standards, and increased road safety, green logistics methods reinforce corporate responsibility from a social standpoint. Initiatives in sustainable logistics, like community service, staff training, and ergonomic workspaces, improve society and produce a better workplace (Agyabeng-Mensah and Tang, 2021). Furthermore, companies who follow environmental laws and global sustainability trends not only lower

their legal risks but also position themselves as leaders in their field, dedicated to moral and responsible business practices. Green logistics is an essential component of contemporary company plans that concurrently address social, economic, and environmental issues. Businesses may improve efficiency, boost their competitiveness, and help preserve the environment by implementing sustainable practices into their logistical operations. Green logistics adoption will be essential as companies develop to achieve long-term sustainability and create a healthier planet for the coming generations.

Innovative Green logistics practices to reduce carbon footprints

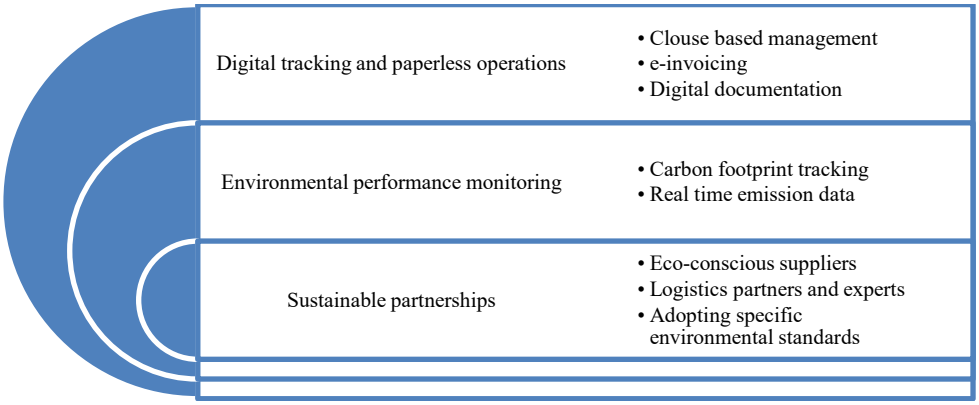
Reducing carbon footprints and advancing sustainability in the logistics sector requires creative green logistics (GL) techniques. Businesses are implementing cutting-edge technologies to reduce emissions and increase resource efficiency as environmental concerns continue to grow. One important strategy is the usage of alternative fuels, where businesses switch from traditional petrol and diesel to greener alternatives like hydrogen, biodiesel, and electric cars (Vienažindienė et al., 2021). Reliance on fossil fuels is decreased and greenhouse gas emissions are decreased due to these sustainable fuel sources. Additionally, as older models are swapped out with low-emission, energy-efficient vehicles like electric and hybrid trucks, fleet upgrades are essential to reducing environmental impact (Wang et al., 2021). This change lowers long-term operating expenses while also improving fuel efficiency.

Table 1. Innovative solutions in green logistics

Areas	Transportation	Warehousing and other facilities	Packaging and waste control
Innovations	Alternative fuels Route optimization Intermodal transportation Low-emission electric trucks	Instalment of LED lighting Modern climate control systems Automated systems Solar panels and wind turbines Improved inventory management	Use biodegradable, recyclable and reusable materials to enhance sustainable packing Recycling and circular economy initiatives to reduce packaging waste Effective inventory control

Source: Compiled by author

Route optimisation, which uses big data analytics and artificial intelligence (AI) to create effective delivery routes, is another noteworthy invention (Wang et al., 2021). This approach minimises pollution, reduces travel time, and uses less gasoline. In a similar vein, intermodal transport combines several modes of transportation, including road, rail, and sea, to optimise efficiency (Tetteh, Mensah, et al., 2024). For example, rail and water transport are more environmentally friendly options because they emit fewer emissions per ton-mile than driving. Additionally, eco-driving strategies that minimise idling, maintain constant speeds and maximise acceleration help cut down on emissions and fuel consumption. By implementing energy-efficient technologies, warehousing operations are progressively adjusting to the principles of green logistics. Energy usage can be reduced by upgrading warehouse equipment, such as automated transportation systems, LED lighting, and intelligent climate control systems (Wu, 2022). Optimising storage space also improves inventory efficiency by reducing wasteful movement and energy use. The carbon footprint of storage facilities is further reduced by integrating renewable energy sources like wind turbines and solar panels. Another essential element of green logistics is environmentally friendly packaging. By reducing reliance on single-use plastics, the use of recyclable and biodegradable materials lowers trash and its impact on the environment (Wu, 2022). Additionally, putting recycling procedures into place guarantees that packaging materials are recycled, which promotes a circular economy (Fareed et al., 2024). Effective inventory control and appropriate disposal techniques can reduce waste associated with storage, which improves resource efficiency.



Source: Compiled by author

Fig. 2. Digitalized innovations in green logistics to reduce carbon footprints

In the logistics industry, the shift to digitalisation is significantly improving sustainability. Businesses can drastically cut down on paper waste and increase operational efficiency by implementing digital tracking platforms, cloud-based management systems, and electronic invoicing (Khayyat et al., 2024). To promote sustainability programs and encourage ongoing improvements, logistics companies are also including environmental performance monitoring

technologies, such as carbon footprint tracking and real-time emissions data. Another essential component of green logistics is collaborating with groups who share your values. Collaboration with businesses that value environmentally friendly practices is ensured by establishing sustainability standards when choosing suppliers and business partners. Additionally, acquiring certifications such as ISO 14001 facilitates the implementation of standardised environmental management systems by logistics companies, guaranteeing adherence to industry best practices and sustainability standards (Vienažindienė et al., 2021). A key sustainability strategy is improving fleet management, which makes sure that cars are scheduled and maintained for maximum effectiveness (Perotti et al., 2022). This strategy enhances overall logistical operations while lowering pollutants and fuel consumption. To improve transportation efficiency and reduce needless trips, companies are also concentrating on removing empty trips and optimising vehicle load capacity. By reducing travel distances, advanced routing systems also help to ensure that deliveries are made in the most fuel-efficient way possible.

Conclusions

1. Logistics activities, which include distribution, warehousing, and transportation, depend significantly on fossil fuels and inefficient procedures, which contribute significantly to carbon emissions and harm to the environment. Sustainability is becoming a major concern for logistics companies because of the increased carbon footprint caused by global trade and e-commerce.
2. Reducing carbon emissions and promoting sustainable business practices need green logistics. By using sustainable packaging, energy-efficient storage, and eco-friendly transportation, businesses may lessen their impact on the environment without affecting productivity or profitability. Additionally, these measures are in keeping with international environmental goals and legal requirements.
3. Reducing carbon footprints is largely dependent on the usage of green logistics technologies, such as advanced waste management, renewable energy in warehouses, alternative fuel vehicles, and optimised routing. Furthermore, automation and digitisation improve sustainability and operational efficiency, guaranteeing long-term financial and environmental benefits for logistics firms.

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