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Research and practice of energy saving and emission reduction technology in green logistics engineering

Yunyan Li, Ziru Cao

Department of Economic Management, North China Electric Power University, Baoding, 071003, China

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Abstract: The development of green logistics engineering has become an important trend in the field of supply chain management. Based on the supply chain model, this paper reduces the distance and frequency of cargo transportation by optimizing the design and layout of logistics network, thus reducing energy consumption and carbon emissions. At the same time, select the appropriate location of warehousing and distribution centers, optimize transportation routes, and establish multimodal transportation systems. Realize real-time monitoring and scheduling of transport vehicles, reasonably arrange the departure time and route of vehicles, improve transport efficiency and reduce energy consumption. It also reduces waste disposal costs and environmental impact by optimizing product recovery, reuse and recycling processes. The analysis found that optimizing transport routes could reduce energy consumption by 20%, while reducing carbon emissions by 100kg. The implementation of green logistics project is not only conducive to environmental protection, but also can bring economic benefits to enterprises.

1. Introduction

With the increasingly serious global climate change and the aggravation of environmental pollution, people have an increasingly urgent need to reduce greenhouse gas emissions and improve environmental quality [1]. With the increasing depletion of global resources and rising energy costs, logistics enterprises are faced with increasingly severe energy and cost pressures [2]. Governments and international organizations have issued a series of policies and regulations aimed at promoting energy conservation and emission reduction, such as greenhouse gas emission reduction targets, energy efficiency standards, etc. These policies have provided policy support and market demand for the development of green logistics projects [3-4]. More and more enterprises are aware of their social responsibilities and begin to pay attention to environmental protection and sustainable development [5]. By promoting the research and practice of green logistics engineering, enterprises can better fulfill their social responsibilities and enhance their own image and brand value.

The innovation of this paper lies in the use of supply chain network optimization methods, linear programming, integer programming and other technologies to optimize transportation routes, storage facility location and inventory management strategies, minimize the impact of logistics activities on the environment, and promote the development of green logistics projects.

2. Related Words

Li R et al. discovered three main states of decoupling in China's transportation carbon emissions: strong negative decoupling, declining negative decoupling, and expanding negative decoupling. This indicates that energy efficiency and urbanization have limited impact on carbon emissions, while income growth, private vehicle ownership, and goods turnover have a more significant effect. They recommend implementing more effective policies to mitigate carbon emissions in the transportation sector, considering the nonlinear effects on emissions[6].Quan C et al. studied carbon emissions in China's logistics industry from 2000 to 2016, using IPCC methodology to calculate total emissions. They used the LMDI decomposition model to analyze factors influencing emissions, such as carbon emission coefficients, energy intensity, energy structure, economic level, and population size. Their suggestions include accelerating the transition to a lower-carbon energy mix, optimizing transportation systems, enhancing logistics efficiency, fostering government-enterprise collaboration, and implementing feasible policies to promote low-carbon development in the logistics industry[7].Zhang W et al. conducted in-depth interviews and identified five factors affecting the effectiveness of green logistics policies: policy and system completeness, government governance capacity, enterprise policy awareness, social supervision level, and logistics industry development stage. They propose a comprehensive model to elucidate how these factors influence the effectiveness of green logistics policies[8].

Liu J et al. focused on the coordinated development of regional emission reduction and low-carbon transportation. They investigated carbon intensity variations across 30 Chinese provinces over time, using the extended STIRPAT and GTWR models to analyze driving factors influencing carbon emission intensity[9].Wu H et al. evaluated energy conservation and emission reduction efficiency in China's provinces from 2006 to 2017 and in 196 cities from 2011 to 2018. They employed various models to study the direct impact of Internet development on energy conservation and emission reduction efficiency, spatial spillover effects, nonlinear relationships, transmission mechanisms, and policy effects. Their findings highlight the significant role of Internet development in promoting energy conservation and emission reduction efficiency[10].Hank C et al. investigated the production costs of PtX energy carriers, ranging from 124 to 156 EUR/MWH, depending on factors such as excess heat availability, product energy density, and liquefaction requirements. They suggest that long-distance transportation and importing PtX products could be viable for integrating renewable electricity into energy systems and industries. Industries like petrochemicals, steel, heavy cargo transport, shipping, and aviation may heavily rely on imported synthetic energy sources in the future[11].

3. Method

The development of green logistics engineering has become an important trend in the field of supply chain management. By adopting energy-saving and emission reduction technologies, energy consumption and environmental pollution can be effectively reduced, and the sustainability and competitiveness of the supply chain can be improved. The supply chain model is shown in Figure 1. By optimizing the design and layout of the logistics network, the distance and frequency of goods transportation can be reduced, and energy consumption and carbon emissions can be reduced. This includes selecting suitable storage and distribution center locations, optimizing transportation routes, and establishing multimodal transportation systems [12]. With the help of the Internet of Things, artificial intelligence and other technologies, real-time monitoring and scheduling of transport vehicles are realized. Through intelligent scheduling algorithm, reasonable arrangement of vehicle departure time and route, avoid no-load and detour, improve transportation efficiency, reduce energy consumption. Based on the concept of sharing economy, the mode of sharing transportation resources is implemented to centrally distribute the goods of multiple enterprises [13]. This can reduce transportation costs and the number of empty vehicles, reducing carbon emissions and traffic congestion. Work with green suppliers to select raw materials and products that meet environmental standards and build a sustainable supply chain [14]. Through the evaluation and monitoring of suppliers to ensure that they are using energy saving and emission reduction technologies and processes in the production process. Consider the environmental friendliness and energy consumption of products in the procurement process, and select suppliers and products that meet the requirements of energy conservation and emission reduction. Through the development of procurement policies and standards, suppliers are encouraged to improve production methods and reduce resource consumption and emissions. Optimize product recovery, reuse and recycling processes to reduce waste disposal costs and environmental impact. Establish a sound recycling network and treatment system to realize the utilization of waste resources and reduce the exploitation of natural resources.

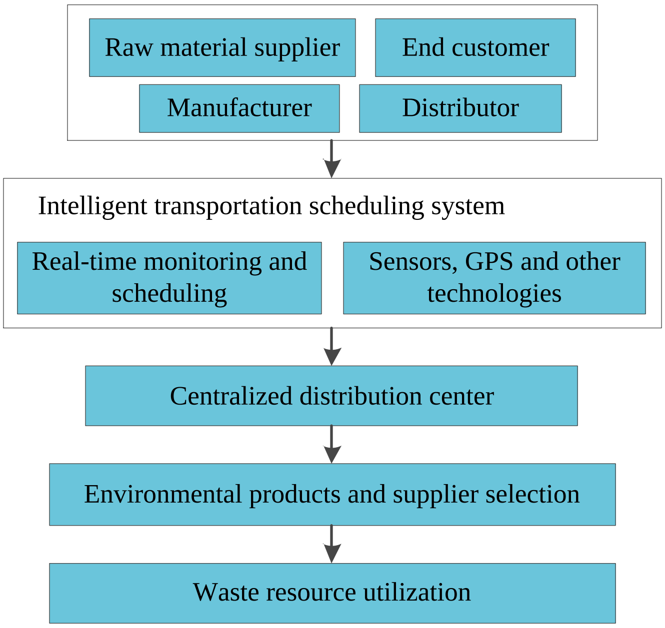

Figure 1: Supply chain model

3.1 Supply chain network optimization

The method of supply chain network optimization is used to design and optimize the logistics network of supply chain in order to reduce energy consumption and carbon emissions. Methods such as linear programming and integer programming can be adopted to optimize transportation routes, location of storage facilities and inventory management strategies to minimize the impact of logistics activities on the environment [15]. In green logistics engineering, transport routes are optimized as follows:

$$Minimize \sum_i = 1n \sum_j = 1m c_{ij} \cdot x_{ij} \tag{1}$$

c_{ij} represents the transportation cost from node i to node j; x_{ij} indicates whether to select the transportation path from node i to node j. The value can be 0 or 1. The goal is to minimize total transportation costs while ensuring that each node has one and only one incoming and one outgoing edge. Storage facility location optimization as follows:

$$Minimize \sum_i = 1n \sum_j = 1m d_{ij} \cdot y_{ij} \tag{2}$$

d_{ij} represents the distance or cost between location i and node j; y_{ij} indicates whether to establish storage facilities at location i to meet the needs of node j. The value can be 0 or 1. The goal is to minimize total construction costs while ensuring that each node has one and only one storage facility. Inventory management strategy optimization is expressed as:

$$Minimize \sum t = 1Th_t \cdot I_t \tag{3}$$

I_t represents the inventory level at time t; h_t represents the unit inventory carrying cost at time t. The goal is to minimize total inventory carrying costs while ensuring B inventory levels are within a reasonable range.

4. Results and Discussion

4.1 Comparison of energy consumption

The data of energy consumption before and after the experiment were collected, including fuel consumption during transportation and electric energy consumption of equipment. Table 1 shows the comparison results of energy transportation consumption. By optimizing transportation routes, energy consumption is reduced from 500 tons of coal to 400 tons of coal, and the energy saving ratio is 20%. Optimizing transportation routes can reduce transportation distances and improve transportation efficiency, thereby reducing energy consumption and reducing carbon emissions. The use of energy-efficient equipment in logistics facilities, such as energy-saving lamps and intelligent control systems, reduced energy consumption from 3,000 KWH to 2,500 KWH, with an energy saving ratio of 16.7 percent. This indicates that optimizing the energy utilization efficiency of logistics facilities is also an important strategy for energy conservation and emission reduction. Through waste recycling, such as the recycling of renewable resources, energy consumption is reduced from 1,000 tons of waste to 800 tons of waste, and the energy saving ratio is also 20%. This shows that in green logistics engineering, the demand for new resources can be reduced through resource reuse, thus saving energy and reducing waste emissions.

Table 1: Comparison of energy consumption

Energy saving and emission reduction technology	Before energy consumption	After energy consumption	Energy saving ratio
Use renewable energy	1000 kilowatt-hours	800 kilowatt-hours	20%
Optimize transportation routes	500 tons of coal	400 tons of coal	20%
Vehicle modification technology	2000 liters of gasoline	1200 liters of gasoline	40%
Adopt high efficiency and energy saving equipment	3000 kilowatt-hours	2500 kilowatt-hours	16.7%
Waste recycling	1000 tons of waste	800 tons of waste	20%

4.2 Calculation of carbon emissions

The comparison of carbon emissions before and after the optimization of the supply chain network is shown in Table 2. The adoption of renewable energy can significantly reduce carbon emissions, with carbon emissions of 0.5kg per KWH. Through the use of renewable energy, the total carbon emissions were reduced by 100kg from 500kg before optimization to 400kg after optimization. The use of energy-efficient equipment can reduce carbon emissions per kilowatt-hour by 0.6kg. By using energy-efficient equipment, total carbon emissions were reduced by 300kg from 1,800 kg before optimization to 1,500 kg after optimization. It is indicated that the energy saving and emission reduction technology in green logistics engineering can significantly reduce the carbon emissions of supply chain network, and help to realize environment-friendly logistics transportation and management.

Table 2: Carbon emission measurement results

Energy saving and emission reduction technology	Unit carbon emission	Before total carbon emissions	After total carbon emissions
Use renewable energy	0.5 kg/ KWH	500 kg	400 kg
Optimize transportation routes	2.5kg/ton	1250 kg	1000 kg
Vehicle modification technology	2.3 kg/ L	4600 kg	2760 kg
Adopt high efficiency and energy saving equipment	0.6kg/KWH	1800 kg	1500 kg
Waste recycling	1.2kg/ton	1200 kg	960 kg

4.3 Cost-benefit analysis

Figure 2 shows the results of the cost-benefit analysis, with implementation costs of $20,000 and expected annual savings of $5,000. Despite the high implementation costs, the annual savings are relatively low. This means a longer payback period, but the use of renewable energy remains an economically viable option in the long term. Optimized transportation routes cost $10,000 to implement, but expected savings of up to $15,000 per year. This suggests that optimizing transport routes is an efficient and economically viable technology for energy saving and emission reduction, with potentially short payback periods.

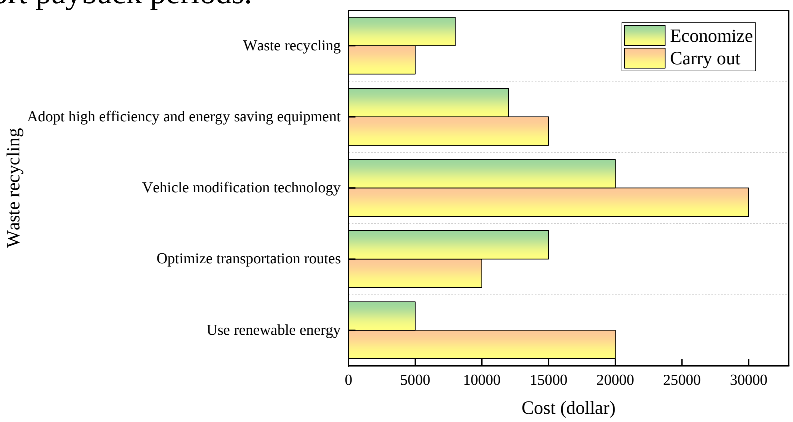

Figure 2: Cost-effectiveness and analysis

5. Conclusion

Based on the optimization of supply chain, this paper studies the research and practice of energy saving and emission reduction technology in green logistics engineering, and draws the following conclusions:

(1) The adoption of energy-efficient equipment in logistics facilities also had a positive impact, with energy consumption reduced by 16.7% and carbon emissions reduced by 300 kg. This indicates that optimizing the energy utilization efficiency of logistics facilities is one of the important strategies to reduce carbon emissions.

(2) Cost savings are relatively low and remain an economically viable option. For example, the use of renewable energy can reduce carbon emissions by 100 kg, and the return on investment is longer, but it is beneficial in the long term.

(3) Waste recycling is another effective strategy for energy conservation and emission reduction. Through the recycling of renewable resources, energy consumption and carbon emissions have been reduced by 20%. This shows that in green logistics engineering, resource reuse can reduce the demand for new resources, thereby saving energy and reducing waste emissions.

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