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Research on Cold-chain Logistics Distribution System from the Perspective of Low-carbon Logistics

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Abstract

China's social demand for fresh products is getting bigger and bigger, the market demand for fresh products is also increasing. Urban road congestion and environmental problems have attracted more and more attention, and the demand for Low-carbon cold storage transportation is also increasing. To guide refrigerated transport enterprises to purchase new refrigeration vehicles to replace traditional fuel coolers. First, develop new refrigeration vehicles, adopt new new vehicles, adopt new refrigeration vehicles to replace conventional vehicles. On this basis, using the idea of double-layer planning, we construct the optimal decision-making mode of Low-carbon cold chain logistics distribution system based on carbon market.High management is the purpose of the country, and the government is to determine the optimal carbon dioxide emissions and optimal subsidy ratio, so as to reduce the overall transportation costs; low temperature storage is the main direction of China's cold chain transportation industry. The decision of government departments will have a certain effect on the choice of enterprises. The company will choose carbon dioxide emissions and reduce carbon dioxide emissions, and purchase new refrigeration vehicles to reduce the overall cost of the company, so as to make scientific decisions for the government and the company, and provide reference for the energy conservation and emission reduction of the whole country.

Keywords

New Energy Refrigerated Vehicles; Carbon Emission Quota; Double-deck Planning; Government Subsidies.

1. Research Background

China's social demand for fresh products is getting bigger and bigger, the market demand for fresh products is also growing. Traffic congestion and environmental pollution are increasingly attracting attention from the government and residents.For global carbon statistics, transportation accounts for 14% of the total transportation industry, with 70% of the carbon emissions being from road transportation, and refrigerated distribution is a transportation sector with high energy consumption and high carbon emissions. Therefore, in the process of realizing the supply chain, the dual goals of realizing energy saving and emission reduction, reducing carbon dioxide emissions, realizing sustainable development and economic benefits have become the focus of today's society.In order to effectively solve this problem, in February 2021, The State Council issued the Guidelines on Accelerating the Establishment and Improvement of the Development System of Green and Low-carbon and Circular Economy, including the establishment of green logistics and the improvement of the circulation system of green, Low-carbon and circular development. The Chinese government has implemented supervision from two aspects: first, to vigorously promote the application of new energy vehicles to alleviate greenhouse gas emissions in the process of transportation and distribution;

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second, to establish a carbon trading mechanism to guide enterprises to invest and transform in energy conservation and emission reduction through economic means.

So our team took this as an idea, and we first innovated the design of new energy cooling vehicles to improve the diversity of use.Combining with the carbon trading mechanism, an optimal decision model based on hierarchical planning.

2. Design of New Energy Refrigerated Vehicles

2.1. Insufficient Existing Refrigerated Vehicles

Currently, refrigerated vehicles on the market can only open the doors when loading and unloading cargo. While the loading and unloading of goods is inconvenient, it will also cause temperature loss and waste of resources.

2.2. Design of Compartment Partition

Divide the carriage part into four parts. The height ratio of the upper and lower two parts is 2:3. The upper two parts are smaller than the lower two parts. The carriage is 4.2m long, 2.1m wide and 2.1m high. The upper carriage door opens up and the lower part opens left and right.Divide the interior structure, save the interior space, and classify the cold chain goods of the four parts and devices, and place different goods in different areas. The upper and lower parts on the left of the car are refrigerated, and the upper and lower parts on the right are frozen.And when only need to place and take part of the goods, only need to open the corresponding car door, to reduce the unnecessary loss of resources.

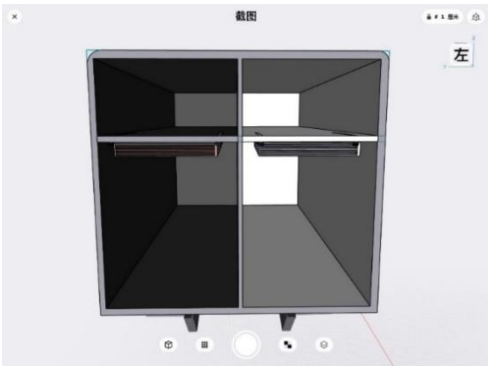

Figure 1. Car partition situation under the shapr3D software

2.3. Install the Automatic Loading and Unloading Device

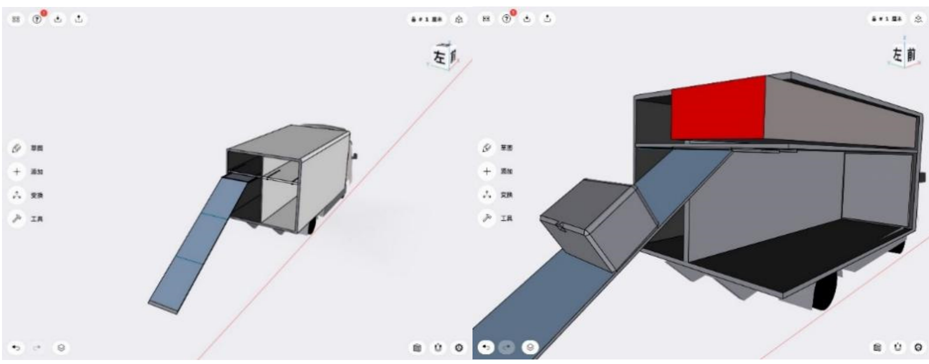

Figure 2. Automatic loading and unloading situation under the shapr3D software

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The upper two parts of the carriage are equipped with a folding ladder. When unloading, the folding ladder folded at the bottom of each part is first opened, and then the remote automatic pushing unloading device pushes the goods from the inside and outside to slide down the opened folding ladder to complete the unloading. The load of the above two parts is 0.9 tons, and the following two parts are 2.1 tons. Through the automatic unloading device, reduce the unloading workload, and improve the unloading efficiency.

3. Build a Mathematical Model based on the Two-layer Planning Method

3.1. Model Assumptions

The basic assumptions of this model are as follows:

1. The planning period is assumed to be one day, and the model is mainly used for strategic planning and policy evaluation.

2. The unit carbon emission quota and subsidy rate of new energy refrigerated vehicles shall be determined by the competent government departments, and the carbon emission and carbon emission reduction decisions of new energy refrigerated vehicles, whether to purchase and purchase quantity shall be determined by the cold chain logistics enterprises.

3. Only the waste gas generated by the transportation of cold chain transportation enterprises is analyzed, and the daily emissions of their operation and infrastructure projects are not calculated.

4. Greenhouse gases mainly include $\mathrm{CO_2}, \mathrm{SF_6}, \mathrm{CH_4}, HFCs$ .This paper mainly considers $\mathrm{CO_2}$

5. Suppose that there is no commercial competition and cooperation between cold chain logistics companies.

6. Suppose that the conventional fuel frozen vehicles are diesel frozen vehicles, while the new frozen vehicles are all-electric frozen vehicles.

7. Transportation costs only, regardless of operating and construction costs.

3.2. Parameter Description

I represents a collection of refrigerated transportation companies; M represents the total number of new energy refrigerated vehicles purchased; U represents carbon emissions from representative unit fuel refrigerated vehicles; β represents carbon emission right limits on behalf of the company; P represents the trading price representing carbon emissions; R unit subsidy on behalf of new energy refrigerated vehicles; H represents the carbon dioxide emissions per unit of refrigerated vehicles; Y represents the unit purchase cost of new energy refrigerated vehicles; W_i representing the company in its decision to purchase new energy refrigerated vehicles; λ represents the company's delivery cost function; α represents the government's environmental protection costs; γ represents the company's carbon emission benefit function; N represents the number of existing conventional refrigerated vehicles of the enterprise; S represent government subsidies for new energy refrigerated vehicles; ϕ represents the company's carbon emission allowance; φ represents each company's CO2 emissions; G representing the company's carbon emissions limits; E represents the capacity of refrigerated vehicles.

3.3. Model Establishment

The cold chain logistics distribution system consists of two interrelated players, namely, government departments and cold chain logistics companies.

The goal of the government authorities is to select the best carbon emission quota and subsidy rate for new unit energy refrigerated vehicles to minimize the total cost of the whole cold chain logistics distribution system; according to the decision-making process, enterprises choose whether to control the number of new energy refrigeration vehicles, which can reduce the cost of the whole company.Such options have a greater impact on the authority's decision process, and the relationship between competent government departments and businesses can be represented as a two-tier model.

3.3.1. Upper-layer Decision Model

The purpose of government policy formulation is to reduce the total cost of the whole society. The total cost includes three elements: the total cost of the whole cold chain transportation company, the total cost of new energy refrigerated vehicles subsidized by the government and the total environmental protection cost.approach

$$\min T=\sum_i Z_i+\sum_i F_i\left(R,H_i\right)\cdot D_i\cdot W_i+\sum_i L_i\left(\beta_i\right) \tag{1}$$

$$\sum_i F_i\left(R,H_i\right)\cdot D_i\cdot W_i=\sum_i R\cdot H_i\cdot D_i\cdot W_i \tag{2}$$

$$L_i\left(\beta_i\right)=\sum_i \alpha_i\cdot\beta_i \tag{3}$$

Restriction (2) refers to the government subsidies for new energy refrigerated vehicles, said in the purchase of new energy refrigerated vehicles, choose cold chain logistics company i, namely W_i =1, and purchased a certain number of new energy refrigerated vehicles, D_i > 0, so, for the purchase of new energy refrigerated vehicles enterprise government will give corresponding subsidies, on the contrary, if W_i = 0, D_i = 0, the government to purchase new energy refrigerated vehicle overall subsidies 0. The government subsidy cost function is $F(R, H_i) = R\cdot H_i$, which means that the government new energy refrigerated vehicle subsidy cost is related with R, H; the restriction condition (3) represents the government environmental protection cost, which is proportional to the quota of carbon emission rights. $L_i(0)=0,\quad L_i'\left(\beta_i\right)>0$. Inplace (2), (3) into the target function (1),:

$$\min \mathrm{T}=\sum_i Z_i+\sum_i R\cdot H_i\cdot D_i\cdot W_i+\sum_i \alpha_i\cdot\beta_i \tag{4}$$

s.t. $$0\le\beta_i\le\phi_i\quad\forall i\in I \tag{5}$$

$$0\le\sum_i R\cdot H_i\cdot D_i\cdot W_i\le S\quad\forall D_i\in M\quad\forall i\in I \tag{6}$$

Among them, the restriction condition (5) represents the carbon dioxide emission limit; (6) represents the government subsidy amount for new energy refrigerated vehicles.

3.3.2. Lower-level Decision Model

i Lower is the Cold-chain logistics company decision-making layer, involving multiple decision problem, a cold chain company each need to minimize the cost of cold chain company, so you can minimize the cold chain logistics cost, that is to say, each company's cost including distribution cost, new energy refrigerated vehicle procurement cost and carbon dioxide emissions, its index function is as follows:

$$\min Z_i=A_i\left(U_i\right)+B_i\left(R,H_i,D_i,W_i\right)+C_i\left(U_i,H_i,\beta_i\right) \tag{7}$$

$$A_i\left(U_i\right)=\lambda_i\cdot N_i\cdot U_i \tag{8}$$

$$B_i\left(R,H_i,D_i,W_i\right)=\left(Y_i-\gamma_i\cdot H_i-R\cdot H_i\right)\cdot D_i\cdot W \tag{9}$$

$$C_i\left(U_i,H_i,\beta_i\right)=\left(N_i\cdot U_i-H_i\cdot D_i\cdot W_i-\beta_i\right)\cdot P_i \tag{10}$$

Conditions (8) represents the relationship between transportation costs, indicating the transportation cost and the total carbon emissions of conventional refrigerated vehicles $A_i(0)=0, A_i^{'}\left(U_i\right)>0$; (9) represents the purchase cost of new energy refrigerated vehicles, when W_i=1, D_i > 0, the cold chain company chooses to buy new energy new energy refrigerated vehicles, the cost of purchasing new energy refrigerated vehicles is the sum of new energy refrigerated vehicles minus carbon emissions and government subsidies, otherwise, when W_i =0, D_i =0, the enterprise of new energy vehicle purchase cost is 0. Among them, corporate carbon emission reduction benefits $E_i\left(H_i\right)=\gamma_i\cdot H_i$. It shows that the CO2 emissions of cold chain logistics companies decrease after purchasing new energy refrigerated vehicles. Therefore, the company's carbon dioxide emission reduction benefits are directly proportional to its emission levels. $E_i(0)=0, E_i^{'}\left(H_i\right)>0$ represents the carbon emission cost function, $N_i\cdot U_i-H_i\cdot D_i\cdot Di\cdot W_i-\beta_i$ represents the difference between the demand for carbon emission rights and the amount of carbon emission rights. If $N_i\cdot U_i-H_i\cdot D_i\cdot W_i-\beta_i>0$, it means that the company's carbon emission quota is not enough and must be purchased in the market, on the contrary, it means that the company has surplus carbon emission allowances, and the excess carbon emission allowances can be sold for the carbon emission trading price. With the fluctuation of market supply and demand, the carbon emission trading price $P=c-dx, c, d>0$, where

$$x=\sum_{j=1}^{n}\left(H_j\cdot D_j\cdot W_j+\beta_j-N_j\cdot U_j\right)。$$

Replacing the constraints (8), (9), (10) into the target function (7):

$$\min Z_i=\lambda_i\cdot N_i\cdot U_i+\left(Y_i-\gamma_i\cdot H_i-R\cdot H_i\right)\cdot D_i\cdot W_i+\left(N_i\cdot U_i-H_i\cdot D_i\cdot W_i-\beta_i\right) *\left(c-d\sum_{j=1}^{n}\left(H_j\cdot D_j\cdot W_j+\beta_j-N_j\cdot U_j\right)\right) \tag{11}$$

$$\text{s.t.}\qquad 0\le D_i\le N_i\cdot W_i\quad \forall D_i\in M\quad \forall i\in I \tag{12}$$

$$0\le H_i\le G_i\quad \forall i\in I \tag{13}$$

$$\frac{\varphi_i}{N_i}\le U_i\le\phi_i\quad \forall i\in I \tag{14}$$

$$\begin{aligned}&Y_i-\gamma_i\cdot H_i-R\cdot H_i<0, \text{then} W_i=1,\quad D_i>0,\\&\text{otherwise} W_i=0,\quad D_i=0\quad \forall D_i\in M\quad \forall i\in I\end{aligned} \tag{15}$$

The constraint (12) limits the number of new energy refrigerated vehicles; (13) represents the total carbon emission of the cold chain logistics company; (14) represents the carbon dioxide emissions of the refrigerated transport company; In (15), $Y_i-\gamma_i\cdot H_i-R\cdot H_i$ represents the difference between the purchase cost of new energy refrigerated vehicles and the profit of energy saving and consumption reduction and the sum of the national subsidies for new energy refrigerated vehicles, if $Y_i-\gamma_i\cdot H_i-R\cdot H_i$ <0, it means that the purchase of new energy

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refrigerated vehicles is profitable, so , the company's decision to purchase new energy refrigerated trucks, namely W_i =1, D_i > 0, otherwise W_i=0, D_i =0.

4. Conclusion

For the high cost of traditional distribution tools of high carbon emissions, our team designed a new model, using new energy logistics refrigerated instead of traditional logistics vehicle, combining the carbon emission trading mechanism using double-layer planning method to build low carbon cold chain logistics distribution system optimization policy decision mode, seeking economic and environmental sustainable development win-win situation, in order to the government departments and company policy has certain reference value.It is very significant to promote energy conservation and emission reduction in the whole society, and to reduce emissions.

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