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Design of Agricultural Supply Chain Network Considering New Energy Transportation Mode

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Abstract

In view of the agricultural products transportation problem, a four - level and three - stage supply chain network contains farms, processing center, distribution center and consumption area is established. Considering the two transportation modes of traditional fuel vehicles and new energy vehicles, a mixed integer nonlinear programming model is constructed to minimize the total cost. To determine the number, location, mode of transportation and flow distribution of facilities at all levels. Finally, the feasibility and effectiveness of the model and LINGO program are verified by an experimental example.

Keywords

Agricultural Products Logistics; Supply Chain Network Planning; New Energy Vehicles.

1. Introduction

With the innovation and development of agriculture, building the center of modern logistics market system is closely related to e-commerce, chain operation and logistics distribution activities. However, the traditional logistics mode still has many problems under the production and market mode of agricultural products in China, such as information asymmetry, high uncertainty, cumbersome transaction links and high logistics costs. The circulation link of agricultural products is the key value link of all kinds of supply chain. Facing the loophole of insufficient ability of decentralized operation and dynamic integration of logistics process in the logistics system, we must pay more attention to the circulation of agricultural products, promote the construction of agricultural products logistics service system, and transform the operation network of supply and marketing cooperatives. In this context, the network optimization design of agricultural products supply chain is not only conducive to reduce the cost of agricultural products logistics, improve transportation efficiency, but also has an important significance to optimize the agricultural products logistics service system structure. It is a top priority to build a clean, low-carbon, safe and efficient energy system. Taking new energy vehicles as a new mainstream logistics mode is of great significance to alleviate pollution, realize energy saving and emission reduction, and then build a green supply chain network system of agricultural products.

Existing researches on agricultural supply chain network can be divided into two categories: One is to discuss the basic content of agricultural supply chain and the objective and importance of its optimization from a qualitative perspective, and put forward the significance steps and measures of agricultural supply chain optimization. The other is to study supply chain network optimization from a quantitative perspective by constructing a mathematical model. Some researches consider that the decay of agricultural products is a major factor of cost loss. Taking it into consideration and aiming at the minimum logistics cost, a logistics planning model is established to optimize the node layout of fresh agricultural products logistics network. Rakesh (2020) et al. combined with the existing problems of Agricultural logistics in India, constructed

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a multi-product, multi-period mixed integer nonlinear programming model to reduce the transportation cost of agricultural products.

Existing studies have achieved good results, but few new energy vehicles as a mode of transportation into the research category. In this paper, new energy vehicles are added into the agricultural supply chain network planning for quantitative research. Considering that the transportation cost of new energy vehicle transportation is lower than that of traditional fuel vehicle transportation, but the transportation capacity is limited, a mathematical model is constructed to provide decision support for the optimization design of agricultural supply chain network.

2. Model Construction

2.1. Problem Description

The agricultural products supply chain network is constructed from four levels, including farm, processing center, distribution center and consumption area. The products grown on the farm are transported to the processing center for selection and processing, and the finished products are transported to the distribution center for storage and distribution. The distribution center is responsible for distributing the processed agricultural products to each consumption area to meet the needs of customers. Considering that new energy vehicles are mainly driven by electric energy and have the characteristics of clean, environmental protection and low noise, they are the main equipment in the field of logistics to achieve the goal of carbon peak carbon neutrality and have a great application prospect. In this paper, it is regarded as a mode of transportation, and forms a set of transportation modes together with traditional fuel vehicles. At the same time, considering the limited carrying capacity of new energy vehicles, its transport capacity is set to be less than that of fuel vehicles. Based on this, a corresponding planning model was constructed, and an example was brought into the model to solve the problem. Lingo11.0 was used to solve the result of the lowest total cost under different modes of transportation to determine the location and quantity of each facility node, as well as the mode of transportation and flow distribution between each logistics node.

2.2. Parameter Settings

I: Indicates the collection of consumer regions, $\forall I \in I$;

J: Indicates the collection of optional distribution centers, $\forall J \in J$;

K: Indicates the collection of optional machining centers, $\forall K \in K$;

S: Indicates the collection of optional farms, $\forall S \in S$;

M: Indicates the set of optional modes of transportation, $M \in M$, ($M = 2$ represents new energy modes of transportation);

d_i: Indicates the demand of consumption area I;

w_j: Indicates the maximum capacity of distribution center J;

d_k: Indicates the maximum capacity of processing center K;

e_s: Indicates the maximum capacity of farm S;

W_{max}: Indicates the maximum number of distribution centers allowed;

L_{max}: Indicates the maximum number of machining centers allowed to be built;

U: Indicates the ratio of unit finished product to unit raw material;

v_j: Fixed cost of annual operation of distribution center J;

g_k: Fixed cost of annual operation of machining center K;

cap_{ji}: Maximum transport capacity from distribution center J to consumption region I when adopting new energy transport mode;

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cap_{kj}: maximum transport capacity from processing center K to distribution center J when adopting new energy transport mode;

cap_{sk}: Maximum transportation capacity from farm S to processing center K when adopting new energy transportation mode;

c_{jim}: is the unit product transportation cost of transportation mode M from distribution center J to consumption area I;

a_{kjm}: is the unit product transportation cost from the processing center K to the distribution center J using the transportation mode M;

t_{skm}: unit and transportation cost and procurement cost of distribution mode M from farm S to processing center K;

h_j: Handle the logistics cost of unit agricultural products for distribution center J;

n_k: is the processing cost of unit agricultural product processed by processing center K.

Decision variables:

b_{skm}: Quantity of raw agricultural products transported by means of M from farm S to processing center K;

f_{kjm}: is the quantity of agricultural products transported by means of M from processing center K to distribution center J;

q_{jim}: is the quantity of agricultural products transported by mode M from distribution center J to consumption area I.

z_j: 0-1 variable, if distribution center j is selected, z_j= 1;Otherwise, z_j= 0;

p_k: 0-1 variable, if machining center K is selected, p_k= 1;Otherwise, p_k= 0;

y_{ji}: 0-1 variable, if distribution center J serves consumption region I, y_{ji}= 1; Otherwise, y_{ji}= 0.

2.3. Model Construction

Objective function:

$$\begin{aligned}\min TC = &\sum_k g_k \cdot p_k + \sum_j v_j \cdot z_j + \sum_j \sum_i \sum_m h_j \cdot q_{jim} \\ &+ \sum_k \sum_j \sum_m n_k \cdot f_{kjm} + \sum_s \sum_k \sum_m t_{skm} \cdot b_{skm} \\ &+ \sum_k \sum_j \sum_m a_{kjm} \cdot f_{kjm} + \sum_j \sum_i \sum_m c_{jim} \cdot q_{jim}\end{aligned} \tag{1}$$

Constraint function:

$$\sum_j y_{ji} = 1, \quad \forall i \tag{2}$$

$$\sum_i d_i y_{ji} \le W_j z_j, \quad \forall j \tag{3}$$

$$\sum_j z_j \le W_{\max} \tag{4}$$

$$\sum_m q_{jim} = d_i y_{ji}, \quad \forall i, j \tag{5}$$

$$\sum_i \sum_m q_{jim} \le \sum_k \sum_m f_{kjm}, \quad \forall j \tag{6}$$

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$$u\sum_{s}\sum_{m}b_{skm}=\sum_{j}\sum_{m}f_{kjm},\quad \forall k \tag{7}$$

$$\sum_{k}\sum_{m}b_{skm}\le E_{s},\quad \forall s \tag{8}$$

$$\sum_{j}\sum_{m}f_{kjm}\le D_{k}p_{k},\quad \forall k \tag{9}$$

$$\sum_{k}p_{k}\le L_{\max} \tag{10}$$

$$b_{skm}\le cap_{sk},\forall s,k,m=2 \tag{11}$$

$$f_{kjm}\le cap_{kj},\forall k,j,m=2 \tag{12}$$

$$q_{jim}\le cap_{ji},\forall j,i,m=2 \tag{13}$$

$$b_{skm},f_{kjm},q_{jim}\ge 0,\quad \forall s,k,j,i,m \tag{14}$$

$$z_{j},p_{k},y_{ji}=0\,or\,1,\quad \forall k,j,i \tag{15}$$

Objective function (1) is composed of seven costs: processing center of the fixed cost, fixed cost of distribution center, processing center processing costs, the distribution center of logistics service cost, farms to processing center of procurement and transportation cost, the transportation cost of processing center and distribution center, distribution center to the transportation cost of consumption area;(2) Restrict the agricultural products in each consumption area to come from only one distribution center; Constraint (3) is the capacity constraint of the distribution center; Constraint (4) limits the maximum number of distribution centers allowed to be established; Constraint (5) is the third stage supply and demand balance constraint; Constraint (6) Flow balance constraint, the quantity of agricultural products before and after the distribution center is consistent; Constraint (7) is the flow balance constraint between the first two stages, which restricts the quantity of agricultural products before and after processing.(8) constraints on farm productivity; Constraints (9) for the processing center capacity constraints; Constraint (10) limits the maximum number of machining centers allowed to be established; Constraints (11) limited the transportation capacity of new energy vehicles from the distribution center to the consumption area; Constraint (12) limits the transportation capacity of new energy vehicles from the processing center to the distribution center; Constraint (13) limits the transportation capacity of new energy vehicles from the farm to the processing center; Constraint (14) Non-negative constraints are applied to these variables; Constraint (15) qualifies these variables as 0-1 variables.

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3. Example Analysis

The maximum capacity and consumption area demand of each farm, processing center and distribution center are shown in Table 1. The fixed cost and variable cost of the processing center and distribution center are shown in Table 2. The variable cost includes the cost of processing unit product of the processing center and the logistics processing cost of transporting unit agricultural product of the distribution center. Farm to processing center adopts two kinds of modes of transportation units purchasing agricultural products and transport costs are shown in table 3, the processing center to the distribution center in two mode of transportation of the units produce transport costs are shown in table 4, distribution center to the consumption areas are two units of agricultural transportation costs are shown in table 5, new energy automobile transport capacity constraints are shown in table 6, the following is a relevant parameter selection:

Table 1. Maximum capacity and consumption area demand of facilities at all levels

	1	2	3	4	5	6	7	8
e_s	300	220	150	200	270	260		
d_k	240	210	150	200				
w_j	200	240	150	180				
d_i	100	80	50	60	80	60	50	50

Table 2. Variable cost and fixed cost of machining center and distribution center

	1	2	3	4
h_j	3	2	4	3
n_k	2	1	2	3
g_k	2000	1200	1300	1000
v_j	500	500	300	200

Table 3. Purchasing and transportation costs per unit of agricultural products from farm to processing center with two modes of transportation

t_{skm}		S					
		1	2	3	4	5	6
K	1	(8,6)	(6,4)	(5,3)	(5,3)	(6,4)	(4,2)
	2	(5,3)	(8,6)	(6,4)	(7,5)	(4,2)	(8,6)
	3	(6,4)	(7,5)	(8,6)	(6,4)	(7,5)	(3,1)
	4	(7,5)	(4,2)	(7,5)	(4,2)	(5,3)	(7,5)

Table 4. Transportation cost of agricultural products per unit from processing center to distribution center using two transportation modes

a_{kjm}		K			
		1	2	3	4
J	1	(4,2)	(2,1)	(2,1)	(4,2)
	2	(2,1)	(3,1.5)	(3,1.5)	(2,1)
	3	(1,0.5)	(2,1)	(4,2)	(3,1.5)
	4	(2,1)	(3,1.5)	(3,1.5)	(2,1)

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Table 5. Transportation cost of agricultural products per unit from distribution center to consumption area with two modes of transportation

c_{jim}		I							
		1	2	3	4	5	6	7	8
J	1	7 ,3.5	4 ,2	7 ,3.5	7 ,3.5	6 ,3	5 ,2.5	6 ,3	7 ,3.5
	2	4 ,2	2 ,1	3 ,1.5	8 ,4	6,3	5 ,2.5	7, 3.5	8 ,4
	3	6 ,3	7,3.5	3 ,1.5	6 ,3	5 ,2.5	3 ,1.5	3 ,1.5	4 ,2
	4	2 ,1	5 ,2.5	3 ,1.5	7,3.5	3 ,1.5	5 ,2.5	4 ,2	5 ,2.5

Table 6. Transportation capacity limitation of new energy transportation mode

cap_{sk}		S							
		1	2	3	4	5	6		
K	1	80	50	40	40	40	30		
	2	50	30	30	30	30	30		
	3	50	30	30	30	50	40		
	4	60	40	40	40	20	50		
cap_{kj}		J							
		1		2		3		4	
K	1	100		150		100		200	
	2	100		40		40		40	
	3	90		80		100		100	
	4	200		150		130		150	
cap_{ji}		I							
		1	2	3	4	5	6	7	8
J	1	200	200	300	200	100	200	300	150
	2	100	60	50	40	70	50	50	90
	3	100	80	40	80	40	30	80	50
	4	60	50	70	80	70	50	80	100

In this calculation example, there are 6 farms S, 4 alternative processing centers K, 4 alternative distribution centers J, and 8 known consumption areas I. The ratio of raw materials and finished products of agricultural products processed by processing centers u is 0.8. Lingo11.0 was used for solving, and after 821 iterations, the global optimal solution was 10927.5.

As the goal is to minimize the total cost of new energy vehicle transportation and traditional transportation, the specific site selection results are as follows: processing centers 2, 3 and 4 are selected, and distribution centers 2, 3 and 4 are selected.

Specific traffic allocation is as follows:

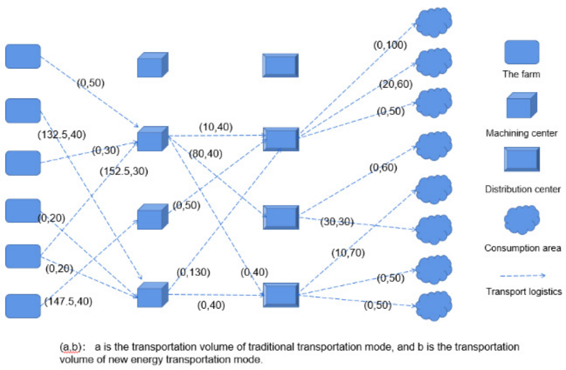

Figure 1. Traffic distribution of each node

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4. Conclusion

In this paper, considering that new energy vehicles as a way to transport agricultural products have the characteristics of low freight, less energy consumption and environmental protection, a new mixed integer nonlinear programming model is constructed. Experimental examples show that the model can truly simulate the network planning of agricultural supply chain. The LINGO program can effectively plan the agricultural supply chain network. In addition, due to the characteristics of agricultural products, the supply chain network of agricultural products also needs to consider the influence of other factors, such as transportation time, product loss during transportation, etc. The next research can be carried out from these directions.

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