Study on the Optimization of Fresh Agricultural Products Logistics Network in Hebei Province

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Abstract. By analyzing the logistics network of fresh agricultural products in Hebei province, this paper optimizes the logistics network of fresh agricultural products in Hebei province from two aspects: the cost of logistics network and the social effect of logistics network nodes. The logistics network optimization model of fresh agricultural products was established based on the research of related basic theories and the network cost and social effect.

Keywords: Fresh agricultural products; Logistics network; The logistics cost; Social effects; Genetic algorithm.

1. Introduction

Fresh agricultural products are the necessities of people's life. Its consumption is universal in time and geography, but at the same time, its development lags behind. This lagging phenomenon is mainly reflected in the low efficiency, high cost and imbalance of supply and demand in the circulation of fresh agricultural products. [1] The production of agricultural products is usually seasonal and regional, leading to great differences and contradictions between supply and demand. Therefore, it is of great significance to build a relatively complete logistics network for balanced and sustainable supply of fresh agricultural products.

Hebei province is an important agricultural province in China. Its economic development is mainly supported by agricultural development. Optimizing the logistics network of fresh agricultural products in Hebei province is conducive to improving the logistics efficiency of agricultural products in the province, reducing the loss rate of goods, thus improving agricultural income and promoting economic growth in the province. This paper will optimize the logistics network of fresh agricultural products in Hebei province from the two aspects of network cost and social effect.

2. Research Status of Fresh Agricultural Logistics

At present, domestic and foreign experts and scholars have studied the logistics of fresh agricultural products in various aspects. Shu Xuli [2] studied the layout of cold chain logistics network, established the mathematical model of fresh agricultural products cold chain logistics network layout, and solved the model by using genetic algorithm. Yu Lin [3] established an evaluation system for site selection of agricultural products logistics center, and established a corresponding BP neural network structure model through this system, so as to solve the problem of site selection of agricultural products logistics distribution center. Omar Ahumada[4] established a relatively comprehensive model for the optimization of fresh agricultural supply chain by studying the optimization and evaluation of agricultural supply chain. On the basis of system dynamics, Yang lei [5] put forward the theoretical framework for the optimization of fresh agricultural products logistics system, and analyzed the spatial layout and logistics distribution mode of fresh agricultural products logistics network in Beijing-Tianjin-Hebei region. Ju-chia Kuo[6] studied the temperature sensitivity of fresh agricultural products, combined the logistics network design of fresh agricultural products with the joint control of multi-temperature zone, and established the optimization model of logistics network.

The nodes of fresh agricultural products logistics network in hebei province mainly have the problems of small quantity, small scale and unsound function. [7] It is difficult to integrate resources and distribute goods, which leads to the increase of logistics cost. [8] Less cold-chain logistics equipment, low circulation and packaging equipment of fresh agricultural products and backward technology in the province have reduced the satisfaction degree of fresh agricultural products logistics service and failed to provide value-added services to the maximum extent. The lack of professionalism has resulted in the goods being unable to meet market requirements, which has hindered agricultural development in hebei province. [9]

3. Optimization Model Construction of Fresh Agricultural Products Logistics Network

Through the comprehensive analysis of fresh agricultural products gathering degree and urban function positioning of each city in Hebei province, six regions including Shijiazhuang, Tangshan, Handan, Zhangjiakou, Chengde and Hengshui are selected as the first-level node alternative cities. According to the analysis of the current situation and existing problems of the fresh agricultural products logistics network in Hebei province in chapter 2, an optimization model is established with the minimum economic cost and social effect as the optimization objectives.

3.1 Model Assumes

The optimization model of fresh agricultural products logistics network established in this paper needs to meet the following assumptions:

(1)Disregarding the differences in the types of different fresh produce;

(2)the logistics node has no transportation capacity limitation;

(3)the demand node allows shortage;

(4)the transportation cost does not take into account the purchase, maintenance and other costs of the transportation vehicle.

3.2 Symbol Description

The symbols for the collections, variables, decision variables and parameters related to the model are as follows:

I Production and processing base, $i = 1, 2, \ ..., \ I$;

J Distribution center collection , $j = 1, 2, \ ..., \ J$;

P Demand node set, $p = 1, 2, \ ..., \ P$;

O^j Modes that can be selected by any distribution center $j \in J$;

B^i , F_o^j Indicates the annual fixed cost of the production base i and the distribution center j of size o ;

$\zeta^i \in [0,1]$ Indicates the social impact coefficient of the production base i . The larger the value, the greater the social impact;

$\zeta_o^j \in [0,1]$ When scale $\mathrm{o} \in O^\lambda$ is selected, the social influence coefficient of distribution center $j \in J$;

γ Penalty coefficient for transport costs;

μ The value of the unit of agricultural products;

S_j The annual inventory cost per unit of agricultural products of distribution center j ;

C_s Annual inventory costs for all distribution centers;

C_f The annual fixed cost of all facilities in the logistics network;

δ_p The annual demand of agricultural products at any demand node, $p \in P$;

Z_i The maximum quantity of agricultural products that can be supplied by any production base $i \in I$ within one year, and when production base i starts to provide agricultural products, it will have a social impact ζ^i;

Φ Represents the connection relationship between facilities;

T^{φ} Represents a collection of modes of transport that can be selected on different transport segments, $\varphi \in \Phi$;

$$x_i = \begin{cases} 1 & \text{Represents the decision to build a production and processing base at candidate address } i \\ 0 & \text{otherwise} \end{cases};$$

$$x_j = \begin{cases} 1 & \text{Represents the decision to build a distribution center of size } o \in O^2 \text{ at candidate address} \\ 0 & \text{otherwise} \end{cases}$$

3.3 Objective Function Analysis

The optimization model of fresh agricultural products logistics network is mainly analyzed from two aspects of network cost and social effect.

The network cost mainly includes transportation cost, fixed node cost, inventory cost, and loss of fresh agricultural products. The specific analysis is as follows:

(1) transportation cost

The annual transportation cost of fresh agricultural products shipped from the production base is:

$$C_T^i = \sum_I \sum_J y_t^{ij} \bullet \mathrm{C}_\mathrm{t}^{ij} \bullet \mathrm{L}_\mathrm{t}^{ij} + \sum_I \sum_P y_t^{ip} \bullet \mathrm{C}_\mathrm{t}^{ip} \bullet \mathrm{L}_\mathrm{t}^{ip} \bullet \gamma \tag{1}$$

The annual transportation cost of fresh agricultural products transported from the distribution center to the demand node is:

$$C_T^j = \sum_J \sum_P y_t^{jp} \bullet \mathrm{C}_\mathrm{t}^{jp} \bullet \mathrm{L}_\mathrm{t}^{jp} \tag{2}$$

Thus, it can be concluded that the total transportation cost in the logistics network is:

$$C_t^{\text{transport}} = C_T^i + C_T^j = \sum_I \sum_J y_t^{ij} \bullet \mathrm{C}_\mathrm{t}^{ij} \bullet \mathrm{L}_\mathrm{t}^{ij} + \sum_I \sum_P y_t^{ip} \bullet \mathrm{C}_\mathrm{t}^{ip} \bullet \mathrm{L}_\mathrm{t}^{ip} \bullet \gamma + \sum_J \sum_P y_t^{jp} \bullet \mathrm{C}_\mathrm{t}^{jp} \bullet \mathrm{L}_\mathrm{t}^{jp} \tag{3}$$

(2)product loss

Long-term transportation will lead to a decline in the quality of the goods, and the loss of fresh agricultural products can be expressed in the form of an index.

$$Q = Q_0 \cdot K \cdot e^{-\beta h^{\varphi}} \tag{4}$$

Q_0 represents the initial quality of the product; K refers to the temperature constant of agricultural products changing with time. β represents the time-sensitive coefficient; h^{φ} represents the transport time on any path $\varphi \in \Phi$.

The amount of agricultural products lost in this process can be expressed as:

$$\mathrm{Q}_{\mathrm{tL}}^{\varphi} = \mathrm{Q}_\mathrm{t}^{\varphi} - y_t^{\varphi} = y_t^{\varphi}(1\text{-}Ke^{-\beta h^{\varphi}}) \tag{5}$$

The annual loss of agricultural products shipped from the production base is:

$$\mathrm{Q}_\mathrm{t}^i = \sum_I \sum_J y_t^{ij}(1\text{-}Ke^{-\beta h^{ij}}) + \sum_I \sum_P y_t^{ip}(1\text{-}Ke^{-\beta h^{ip}}) \tag{6}$$

The amount of agricultural products lost each year from the distribution center to the demand node is:

$$\mathrm{Q}_\mathrm{t}^j = \sum_J \sum_P y_t^{jp}(1\text{-}Ke^{-\beta h^{jp}}) \tag{7}$$

Therefore, the annual cost of the agricultural product logistics network due to loss is:

$$\mathrm{Q}_{\mathrm{t}}^{L}=\mu\bullet[\sum_{I}\sum_{J}y_{t}^{ij}(1\text{-}Ke^{-\beta h^{ij}})+\sum_{I}\sum_{P}y_{t}^{ip}(1\text{-}Ke^{-\beta h^{ip}})+\sum_{J}\sum_{P}y_{t}^{jp}(1\text{-}Ke^{-\beta h^{jp}})] \tag{8}$$

(3)Warehousing costs, fixed costs

In any distribution center $j \in J$, agricultural products with a total quantity of y_t^{ij} are transported from production base i every year. Assuming that the quantity of fresh agricultural products to be stored is $y_t^{ij}/2$, the annual inventory cost of all distribution centers can be expressed as:

$$C_s=\sum_{J}(\sum_{I}\frac{y_t^{ij}}{2}\bullet S_j) \tag{9}$$

Because the nodes include production and processing bases and distribution centers ,the annual fixed cost of the nodes is:

$$C_f=\sum_{I}B^i+\sum_{J}F_o^j \tag{10}$$

In conclusion, the cost function of logistics network is as follows:

$$\begin{aligned} f_e(x,y)&=\mathrm{Q}_{\mathrm{t}}^{L}+C_t^{\text{transport}}+C_s+C_f=\mu\bullet[\sum_{I}\sum_{J}y_t^{ij}(1\text{-}Ke^{-\beta h^{ij}}) \\ &+\sum_{I}\sum_{P}y_t^{ip}(1\text{-}Ke^{-\beta h^{ip}})+\sum_{J}\sum_{P}y_t^{jp}(1\text{-}Ke^{-\beta h^{jp}})]+\sum_{J}(\sum_{I}\frac{y_t^{ij}\bullet K\bullet e^{-\beta h^{ij}}}{2}\bullet S_j) \\ &+\sum_{I}\sum_{J}y_t^{ij}\bullet\mathrm{C}_{\mathrm{t}}^{ij}\bullet\mathrm{L}_{\mathrm{t}}^{ij}+\sum_{I}\sum_{P}y_t^{ip}\bullet\mathrm{C}_{\mathrm{t}}^{ip}\bullet\mathrm{L}_{\mathrm{t}}^{ip}\bullet\gamma+\sum_{J}\sum_{P}y_t^{jp}\bullet\mathrm{C}_{\mathrm{t}}^{jp}\bullet\mathrm{L}_{\mathrm{t}}^{jp}+\sum_{I}B^i+\sum_{J}F_o^j \end{aligned} \tag{11}$$

Social effect refers to the role of logistics network nodes in driving economic development and providing jobs for the society. In this paper, the social impact coefficient $\zeta^i \in [0,1]$ is used to represent the impact of the corresponding logistics nodes on the social effect, and only the social effect of the production base and distribution center is considered.

For production base $i \in I$, its social effect can be expressed as:

$$f_1=\sum_{I}\zeta^i x^i \tag{12}$$

For distribution center $j \in J$, its social effect can be expressed as:

$$f_2=\sum_{J}\sum_{O}\zeta_o^j x_o^j \tag{13}$$

The social effect of logistics network is the sum of the social effect of production base and distribution center:

$$f_\zeta(x)=\sum_{I}\zeta^i x^i+\sum_{J}\sum_{O}\zeta_o^j x_o^j \tag{14}$$

3.4 Model Establishment

According to the above analysis, the optimization model of fresh agricultural products logistics network can be obtained as follows:

$$\min f(x,y)=\left(f_e(x,y),-f_\zeta(x)\right) \tag{15}$$

Constraint conditions:

$$\sum_{o\in O^J}x_o^j\le 1, j\in J \tag{16}$$

$$\sum_{J}\sum_{t\in T^{ij}}y_t^{ij}+\sum_{P}\sum_{t\in T^{ip}}y_t^{ip}\ge x^i, i\in I \tag{17}$$

$$\sum_{J}\sum_{t\in T^{ij}}y_t^{ij}+\sum_{P}\sum_{t\in T^{ip}}y_t^{ip}\le z_i, i\in I \tag{18}$$

$$\sum_{P}\sum_{t\in T^{jp}}y_t^{jp}\ge\sum_{o\in O^j}x_o^j, j\in J \tag{19}$$

$$\sum_{I}\sum_{t\in T^{ij}} y_t^{ij} \le \beta_o^j x_o^j,\ j\in J, o\in O^j \tag{20}$$

$$\sum_{I}\sum_{t\in T^{ij}} y_t^{ij} \ge \sum_{P}\sum_{t\in T^{jp}} y_t^{jp},\ j\in J \tag{21}$$

$$\sum_{I}\sum_{t\in T^{ip}} y_t^{ip}\cdot K\cdot e^{-\beta h^{ip}} + \sum_{J}\sum_{t\in T^{jp}} y_t^{jp}\cdot K\cdot e^{-\beta h^{jp}} \ge \delta_p,\ p\in P \tag{22}$$

$$x^i \in \{0,1\},\ i\in I \tag{23}$$

$$x_o^j \in \{0,1\},\quad j\in J, o\in O^j \tag{24}$$

$$y_t^{ij}, y_t^{ip},\ \ y_t^{jp} \in R\ge 0,\ t\in T^{\varphi}, \varphi\in\Phi \tag{25}$$

Among them, formula (3-15) minimizes the multi-objective function $f(x,y)$ to achieve the goal of the lowest logistics network cost and the largest social effect. Constraints (3-16) ensure that each selected distribution center can only choose one scale for construction; Constraint (3-17) ensures that candidate point i is selected only when the alternative production base supplies the distribution center or demand node; (3-18) to ensure that the output of the production base cannot exceed its maximum capacity; Constraint (3-19) means that if alternative distribution center j does not distribute to any demand node, the alternative point will not be selected; Constraint (3-20) means that the quantity of products entering the distribution center cannot exceed its maximum capacity limit; Constraint (3-21) means that the quantity of products that the distribution center can supply is not less than the quantity that it needs to supply to the downstream. Constraint (3-22) means that the requirement of the demand node must be satisfied; The constraint (3-23) - (3-25) is the variable constraint.

Since all the objective functions in this paper are non-negative, for the cost-type objective function $f_e(x,y)$, the minimum value $f_e^{\min}(x,y)$ in the feasible domain can be solved, and for the beneficent objective function $f_\zeta(x)$, the maximum value $f_\zeta^{\max}(x)$ in the feasible domain can be solved. Then, the three sub-objective functions in the original formula can be replaced by functions $f_e(x,y)/f_e^{\min}(x,y)$ and $f_\zeta(x)/f_\zeta^{\max}(x)$ respectively, and the single objective function can be obtained:

$$\min f'(x,y)=\frac{w_1 f_e(x,y)}{f_e^{\min}(x,y)}+\frac{w_3 f_\zeta(x)}{f_\zeta^{\max}(x)} \tag{26}$$

On the type, $w_k=\dfrac{random_k}{\sum_{k=1}^{2} random_k}$, $k=1,2$, $random_k$ is a nonnegative random integer, and $\sum_{k=1}^{2} w_k = 1$.

4. The Example Analysis

According to the alternative logistics nodes determined in chapter 3 and the analysis of the logistics network of fresh agricultural products in hebei province, the optimization model of the logistics network in hebei province is analyzed and solved by genetic algorithm, and the network optimization scheme is given.

4.1 Data Given

At present, the logistics transport of fresh agricultural products in hebei province and even the whole country is mainly carried out by road transport for transport and distribution, therefore, this paper only considers road transport. Trucks in road transportation are divided into fuel trucks and natural gas trucks, and the transportation costs and speeds of the two are different. Table 1 below shows the relevant parameters of the two types of trucks.

Table 1. parameters of fuel trucks and natural gas trucks

parameter	The average velocity	The cost of transportation
Fuel truck	85km/h	0.76 yuan/ton/km
Gas truck	75km/h	1.03 yuan/ton/km

The social effect coefficients of alternative city nodes are shown in table 2 .

Table 2. quantitative coefficient of social effect of each city

city	The unemployment rate	score G_1	The proportion of GDP	score G_2
shijiazhuang	3.64	7	20.14	3
Zhangjiakou	3.89	7	5.05	8
Tang shan	4.00	8	22.59	2
Bao ding	4.02	8	12.22	5
Cang zhou	3.49	6	12.29	5
Cheng de	3.09	6	5.03	8
Heng shui	3.68	7	4.52	8
Xing tai	3.60	7	6.53	7
Han dan	3.54	7	11.63	5

It can be obtained from the above table that the social impact coefficient of the construction of production base on the local society can be quantified as $(G_1+G_2)/18$. Assuming that the larger the scale is, the better the social effect will be generated. Therefore, the social impact coefficients of distribution centers of different sizes from large to small are $0.8*(G_1+G_2)/18$, $0.4*(G_1+G_2)/18$ and $0.2*(G_1+G_2)/18$ respectively. Thus, the social impact coefficient can be calculated, and the social effect can be quantitatively used in the model calculation.

The relevant parameters of alternative city nodes are shown in table 3.

Table 3. correlation coefficient of distribution center

Serial number	location	Inventory holding cost (yuan/ton)	Construction costs F_o^j (Ten thousand yuan) (Big, medium ,small)		
1	Shi Jiazhuang	120	377	275	167
2	Zhang jiakou	105	306	196	134
3	Tang shan	125	375	274	182
4	Bao ding	120	345	263	172
5	Cang zhou	115	336	259	169
6	Cheng de	100	297	198	135
7	Heng shui	100	312	212	140
8	Xing tai	110	327	219	142
9	Han dan	115	346	266	171

4.2 Case Study

This model is based on matlab software. The genetic algorithm can be used to solve the multi-objective solution into a single-objective solution problem. Then the multi-objective problem is solved by weighted integration. The specific solution process is as follows.

(1) Solve the two single-objective problems separately

Substituting relevant data into the model for calculation can obtain the single target optimization scheme of the following table.

Table 4. Single target optimization scheme

Program	Network cost	Social effect	Number of production bases	Number of distribution centers
Optimal cost	57779	3.033	3	4
Optimal social effect	137820	4.258	3	8

1)Optimize the solution by random weighting

After obtaining the single-objective optimization scheme in Table 4, the random weighting method in equation (3-26) is used to solve the problem, and a partial feasible solution can be obtained as shown in Figure 1.

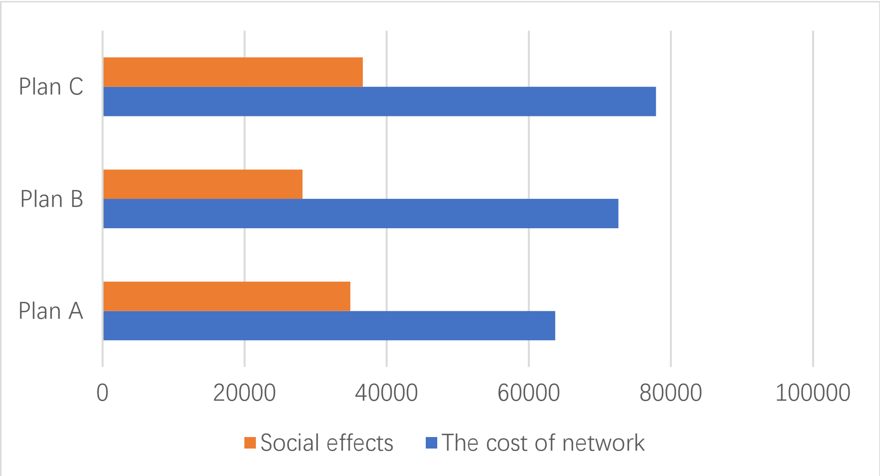

Figure 1. Partial feasibility solution obtained after weighting

After obtaining the feasible solution, different priorities can be considered from the aspects of network cost and social effect. This paper mainly studies from the perspective of network cost, so the network cost is given priority. Plan A shown in Figure 1 has more advantages in reducing network costs. Therefore, plan A is an optimization scheme for agricultural product logistics network in Hebei Province. In the first scenario, the network cost is the primary consideration. The network cost of this scheme is 63.721 million yuan, the social effect is 3.489, and the loss of agricultural products during transportation is 12.599 million yuan. In this layout mode, the distribution centers are located in Chengde, Zhangzhou, Xingtai, Baoding and Handan. The distribution center in Zhangzhou is large-scale, the distribution center in Baoding is medium-sized, and the other distribution centers are small-scale.

5. Conclusion

This paper starts from the current situation and existing problems of logistics network of fresh agricultural products in Hebei Province, and establishes the logistics network optimization model of fresh agricultural products from the aspects of logistics network cost cost and social effect, and uses genetic algorithm and weighting algorithm to model the model. Solve and verify the correctness of the model, and solve the optimization scheme of the logistics network.

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