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Optimization of the Front-end Logistics Routes of Agricultural Products Based on Network Platform

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SUMMARY

Aiming to promote the effective connection between the individual farmers and the modern "big market" and improve the logistics efficiency of agricultural products, this paper offers a logistics model for decentralized production to achieve organized information and large-scaled transportation. Based on the in-depth analysis of the traditional agricultural product logistics chain, this paper originates a network logistics model for agricultural products. It constructs a two-stage framework (grouping first and then scheduling), analyzes the "First Mile" logistics routes, and then uses the improved loop routes optimization algorithm to obtain the approximate optimal solution to the model. Through example verification, it is found that the model can help improve the efficiency of logistics distribution and save the logistics costs of small agricultural products from fragmented land. Moreover, the results show that the agricultural product logistics method based on overall transportation and information management is obviously superior to the traditional logistics methods.

KEY WORDS: *agricultural logistics; network platform; routes optimization.*

1. INTRODUCTION

Agricultural products are not only one of the main income sources for rural residents but also the necessities for urban and rural residents in China. Because of the regionality, vulnerability and seasonality, agricultural products are highly dependent on the logistics efficiency. The agricultural land is very fragmented in China, so the logistics of agricultural products is characterized by wide and scattered distribution.

Land fragmentation refers to the disintegration of cultivated land, that is, a form of land structure in which a farmer's land is separated spatially. There is no scale production since the land belonging to a single farmer is not interconnected and each farmer has a small average area [1, 2]. Affected by various factors such as household contract responsibility system, landform, and the traditional separation system in China, the fragmented pattern of agricultural land is prominent in China [3]. Each household has a cultivated area of 0.50 hectares and *5.722* pieces of land on average, so the average size of each piece of cultivated land is only 0.09 hectares in China.

Such fragmentation of land has made the agriculture in China still dominated by the "small-scale production and decentralized management" of small-scale farmers, and agricultural product logistics is still relatively weak aspect of the agricultural development in China [4]. According to the data, the logistics efficiency of agricultural products in China is far lower than that in developed countries. In Europe and the United States, the logistics cost of agricultural products is only about *10%* of the total cost, and the loss rate is strictly kept below *5%*. In China, however, the logistics cost of agricultural products accounts for *60%* of the total cost, and the loss rate in the logistics links is as high as *30%* [5].

Nevertheless, as a basic unit of agricultural economy in China, small-scale peasant production will still remain the main form of agricultural production and trade in this country for a long time. Therefore, this paper proposes the promotion of the effective connection between individual farmers and the modern "big market" to settle the problem of high cost and low efficiency of agricultural product logistics chain in China.

2. LITERATURE REVIEW

The studies on agricultural product logistics started very early in foreign countries and the research results were more mature than those in the domestic market. In 1901, an American scholar John Crowell first proposed the related research on agricultural product logistics in the report of the Industrial Committee on the circulation of agricultural products, and discussed the factors affecting the logistics costs of agricultural products [6]. At present, the integrated supply chain management model has been widely used in some agriculturally developed countries such as Britain, the United States, Canada and the Netherlands [7, 8]. Its main characteristic is that the enterprises establish a dynamic and multidimensional cooperation platform in the management process of the logistics chain, and carry out multi-directional and active exchanges of information on the quality, performance, and price of their own products through the platform, which can improve the flexibility of the entire agricultural product logistics system [9, 10]. Due to the lack of cultivated land and the large population, the agricultural products in South Korea and Taiwan are characterized by diversified production and varieties. Therefore, the two regions have chosen the "common sales system" composed of farmer groups to transport and sell agricultural products uniformly [11, 12]. To solve the contradiction between scattered production and large circulation, Japan has established an agricultural association. *97%* of the farmers have joined this association, and *90%* of the agricultural products are sold by agricultural cooperatives. The association constitutes the main organizer of the agricultural product logistics and also undertakes the main tasks of logistics. It strengthens the circulation of information through the establishment of "roadside stations" [13].

Due to the limitation of terrain conditions and the proportion of population over farmland area, land fragmentation is still difficult to reduce in most areas of China, and this model still has irreplaceable and supportive functions at present, so in the short run, this situation cannot be changed [3]. The endowment of resources determines that China cannot follow the U.S. to solve the problem of agricultural product logistics through large-scale production, and it cannot establish a mature logistics organization mechanism like Japan's within a short term, either. However, through comparison and analysis, it is found that the scale of agricultural production has no decisive influence on the logistics efficiency of agricultural products. In addition to the advanced infrastructures and technologies of storage and transportation in developed countries and regions, the organization and information of its logistics process are the main reasons for its efficient logistics. Therefore, this paper puts forward the "network trading platform" and the "transportation routes optimization" model, which focuses on optimizing the "first mile" logistics routes of agricultural products and features the interactive mode of "production decentralization - information organization - transportation scale".

3. ANALYSIS AND OPTIMIZATION OF THE LOGISTICS OPERATION MODE OF FRESH AGRICULTURAL PRODUCE

3.1 ANALYSIS OF THE TRADITIONAL AGRICULTURAL PRODUCT LOGISTICS MODEL

Structural analysis shows the shortcomings of the traditional agricultural product logistics model, Figure 1.

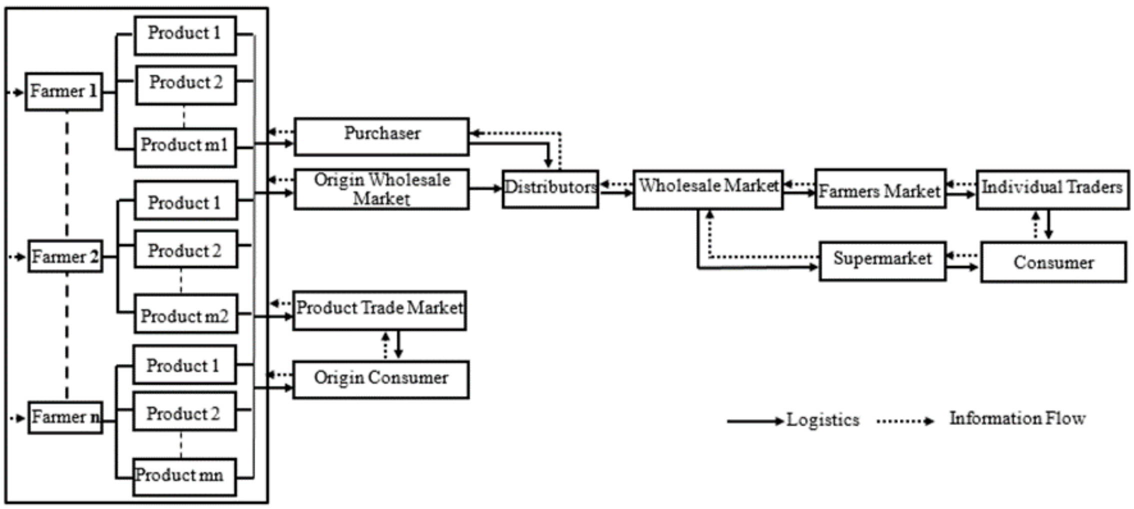


Fig. 1 *Current Agricultural Product Logistics Model in China*

Agricultural product suppliers are individual farmers. They are characterized by small scale planting, geographical dispersion, low level of technology and poor resistance against risks, which make them unable to meet the bulk demand of the "big market". They either choose the "farmer-vendor" method to complete the first link of agricultural product circulation, or directly become the main body of the market linkage.

Agricultural product sellers include agricultural product purchasers, bazaars, and supermarkets. The purchasers of agricultural products are small in scale, shot of storage and transportation equipment, and poor in quality control. Despite the large market, it is difficult for these scattered traders to achieve systematic management and strict quality control. In contrast, supermarkets have large scales, stable sources of customers, high level of informatization, complete storage and transportation facilities as well as strict quality control and management systems.

Distribution centres are the origin wholesale market and the wholesale market for retail outlets. The origin wholesale market gathers a large number of individual agricultural products from different origins. The goods have unclear information and varying quality. The information barriers formed there hinder the circulation of agricultural product information. The same problems also exist in the wholesale market for retail outlets.

Through the analysis of each link of the traditional agricultural product logistics model, the problems are categorized as follows: (1) long logistics chain; (2) asymmetric information; (3) low level of integration; (4) imbalance between the status of individual farmer households and other market trading entities; (5) lack of special equipment by individual farmers.

3.2 CONSTRUCTION OF THE AGRICULTURAL PRODUCT NETWORK TRADING PLATFORM

Through the analysis of the traditional logistics model, considering its shortcomings, this paper proposes the establishment of an e-business B2C network trading platform while maintaining the state of land fragmentation, in order to achieve the following design objectives of the agricultural product logistics system: (1) streamline the logistics chain and enhance the integrity and systematization of the logistics chain; (2) improve the information level of the logistics chain; (3) strengthen the quality and safety management of agricultural products; (4) optimize the logistics routes and reduce the operating costs; (5) increase the revenue of each logistics chain node; (6) integrate scattered farmers and strengthen the market access of farmers. Considering the design objectives for the agricultural product logistics system, the optimized agricultural product logistics model is established, as shown in Figure 2.

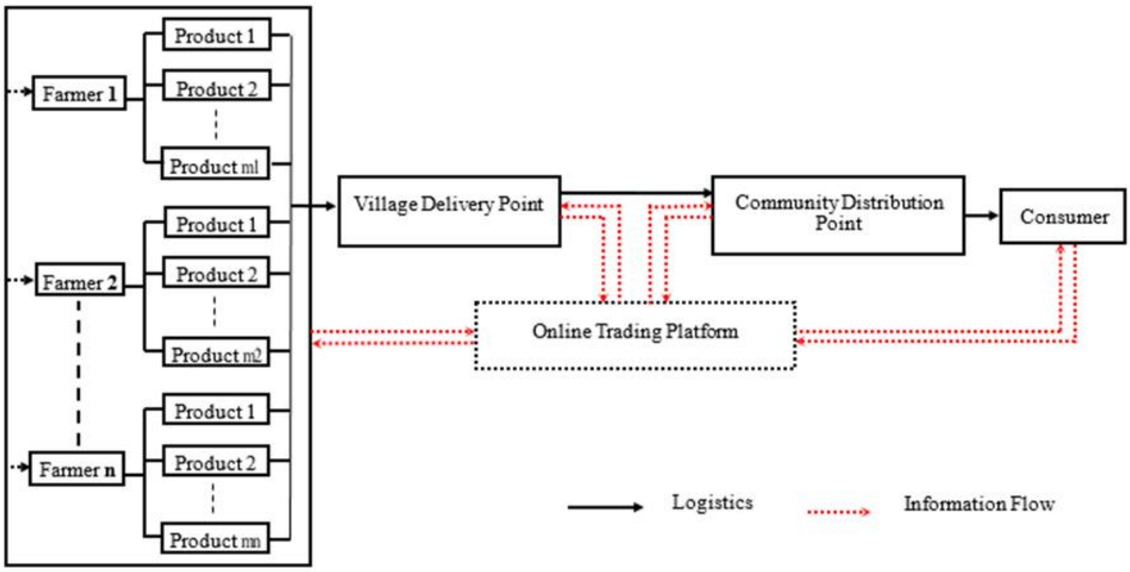


Fig. 2 *Hypothetical agricultural product network logistics model*

In this model, in order to gather scattered agricultural products, a village-level delivery station is set within a certain radius area. Unlike the traditional farmer market, this delivery station is responsible for pre-cooling, classification, processing, packing, transportation, collecting information about demand and distribution from the first mile after the agricultural products are harvested. It is located upstream from the circulation channel of agricultural products, and is joined to the farmers in the places of origin, which strengthens their systematization and makes the relationship between the farmers and the market closer. From the village delivery station to the community pick-up points, scale economy can be realized through the overall transportation. As daily consumer goods, agricultural products have stable demand in a short term. Therefore, this model adopts a centralized distribution network to achieve their distribution in the residential areas. In this distribution mode, all agricultural products are stored in the warehouse of the community distribution centre, and scheduled in a centralized manner through the network platform to the pick-up site in each residential area. This network platform is a complete integrated information system used to achieve communication and distribution connection between the community distribution centre and the pick-up sites, whose service functions include collecting, analyzing, processing, and announcing of agricultural product transactions and related product information, and providing corresponding information feedbacks. Farmers can access virtual electronic malls and directly announce product-related information through the information platform and find out the market demands. Consumers can also learn agricultural product information through the platform and place orders online or by phone. The community distribution centre sends the agricultural products from the storage facility to the pick-up site according to the demands in the orders, and the pick-up site matches each customer's order through the network information system so that consumers can pick up goods from there.

Compared with the traditional agricultural product logistics model, the new model has the following advantages:

(1) The logistics chain is reduced. The distribution centres of agricultural products such as origin and wholesale markets are removed, so there are fewer logistics links, which eliminates the "information barrier" effect.

(2) Standardized distribution centres for agricultural products logistics are introduced, which strengthen the integration capabilities of the logistics chain. Through the establishment of standardized village dispatch sites, individual farmers are integrated into the agricultural organization, which achieves the large-scale distribution of scattered production and effectively stabilizes the supply and demand relationship of agricultural products.

(3) The information flow is centralized, which facilitates the transfer of information and the promotion of technologies. Currently, the level of informatization is generally low in the agricultural product industry. Online platforms can enable farmers to quickly increase their information knowledge and skills, increase the smooth flow of agricultural product logistics information and ease the imbalance between supply and demand.

(4) Storage and transportation costs are reduced. Agricultural products are transported directly from the production site to the distribution centre. Such organized logistics leads to the construction of an efficient storage and transportation system. At the same time, pick-up sites are established on the basis of the existing facilities in each community, which can also reduce storage and transportation costs.

4. "THE FIRST MILE" TRANSPORT ROUTE OPTIMIZATION MODEL

Agricultural products can only be preserved for a very short time, so fast and convenient transportation is particularly important for reducing their loss and improving their trading efficiency. Considering the small-scale production and numerous nodes of agricultural products, a two-stage solution method is used, which groups the products first and then dispatches them, to optimize the transportation distances between agricultural production sites and village delivery station, and reduce logistics costs. First, the clustering method is used. Under certain constraint conditions, the pick-up sites are zoned and integrated according to the relative positions of the nodes so the routes to these sites can be optimized. To achieve this, the multi-node vehicle routing problem is converted into a number of TSP problems. The improved loop routes optimization algorithm is used to optimize the solution.

4.1. ZONING OF LOGISTICS PICK-UP SITES BASED ON K-MEANS CLUSTERING

For the routing problem with obvious clustering characteristics of nodes distribution, the nodes can be zoned to reduce the size of the problem, shorten the computation time and improve the efficiency of decision-making. Here the clustering algorithm is used to cluster the pick-up sites based on their geographical locations and with the "maximum vehicle load" as the constraint. The concrete steps are as follows:

- Step 1: Determine the initial cluster number $k = Q/q$, where Q is the total amount of goods to be transported during the transportation process, and q is the maximum load of each vehicle.
- Step 2: Determine the initial cluster centre. If the initial cluster number $k = mn$, the nodes on the map are divided into m rows and n columns by the equipartition method, and the initial nodes in each area are the initial cluster centres.
- Step 3: Cluster division. Calculate the distance between each non-centre node and each cluster centre in the Geographic Information System to obtain the shortest distance, and respectively, classify each non-centre node into the class with the nearest cluster centre node.
- Step 4: Determine the balance index. In this paper, the "vehicle maximum load" is the constraint condition, so $\sum_{i=1}^{x} q_i \le q$ is the equilibrium condition, in which q_i is the total amount of goods for each pick-up site, and x is the number of nodes in each cluster.
- Step 5: Adjust the node set. Adjust the clusters formed in Step 3 according to the equilibrium index. If $\sum_{i=1}^{x} q_i \le q$ is true, the clustering ends. If it is not, there must be an overloaded cluster of goods. Clusters that do not meet the constraints should be adjusted. Move the node furthest from the centre point in the cluster and add it to another cluster and recalculate $\sum_{i=1}^{x} q_i$. Repeat step 5 until $\sum_{i=1}^{x} q_i \le q$ in each cluster is true.

4.2. IMPROVED LOOP ROUTES OPTIMIZATION ALGORITHM

In this study, all nodes in the class are combined with P_0 to form a closed loop after clustering. It starts from P_0 to each node and at last returns to P_0, which is a typical TSP combination optimization problem. The travelling salesman (TSP) problem, also known as the street vendor problem, supposes a salesman has to visit a number of cities in a single closed tour, but he must start and end the route in his home city and visit all other cities on the route exactly once [14]. Traditional methods generally cannot obtain the optimal solution to this kind of problem. This paper proposes the use of the improved loop routes optimization algorithm to obtain the approximate optimal solution. The basic idea of this algorithm is to find a Hamilton circle C first, and then make appropriate modifications to C to obtain another Hamilton circle with a smaller weight, and modify it repeatedly to obtain a better solution [15]. The concrete steps are as follows:

- Step 1: Get the initial circle. Randomly select a point v_1 as the starting point and find an edge associated with it and having the smallest weight, which is denoted as v_2; and in a similar fashion, the Hamilton initial circle $C = v_1 v_2 ... v_n v_1$ is obtained by the nearest neighbour method.
- Step 2: Modify the initial Hamilton circle. Check the initial circle C. If there is v_i, v_j, v_{i+1} and v_{j+1}, $(i \neq j)$ in C, make $w(v_i v_j) + w(v_{i+1} v_{j+1}) < w(v_i v_{i+1}) + w(v_j v_{j+1})$, remove edges $v_i v_{i+1}$ and $v_j v_{j+1}$ from circle C, and add edge $v_i v_j$ and edge $v_{i+1} v_{j+1}$ to construct a new improved circle: $C_1 = v_1 v_2 ... v_i v_j v_{j-1} v_{j-2} ... v_{i+1} v_{j+1} v_{j+2} ... v_n v_1$.
- Step 3: Replace C with C_1 and go back to step 2. Repeat until it cannot be improved, and finally obtain the approximate optimal circle C_n.

5. DEFINITION OF THE TRANSPORTATION COST MODEL

5.1. MODEL HYPOTHESES

(1) Vehicles are dispatched in a unified manner from the village delivery station, providing transportation services for each production sites, and the location of every site is known.

(2) During the transportation, the carrying capacity of the vehicle, the unit transportation cost, and the driving speed of the vehicle are certain.

(3) The total cargo weight picked at all sites does not exceed the maximum load of the vehicle.

(4) The total length of route for each transportation vehicle does not exceed its maximum mileage.

(5) The agricultural products at each site are only loaded onto one vehicle, and each transport vehicle can load agricultural products at multiple sites.

5.2. RELATED PARAMETERS AND VARIABLE DEFINITIONS

C_1	-	Fixed costs, fixed service fees for vehicles, including driver's salary
f^k	-	The fixed cost of the vehicle *k*
C_2	-	Variable costs, costs of vehicle maintenance and petrol
c	-	Unit distance transportation cost
d_{ij}	-	Distance between the pick-up point *i* and *j*
$x_{ij}^k = \{^1_0$	-	Vehicle k travels from pick-up point *i* to *j* Vehicle k did not travel from pickup point *i* to *j*
$y_{ij}^k = \{^1_0$	-	Vehicle k picks up from pick-up point *i* to *j* Vehicle k is not picked up from pick-up point *i* to *j*
C_3	-	Damage cost
p	-	Unit price of agricultural products
s_j	-	Total amount of goods when vehicle arrived at *j*
l_1	-	Unit time loss rate during transportation
l_2	-	Unit time loss rate during loading and unloading

q_j	-	Loading weight at point *j*
v	-	Handling efficiency
C_4	-	Energy cost
e_1	-	Unit time energy consumption during transportation
e_2	-	Unit time energy consumption during loading
t_j	-	Time when a vehicle arrives at the delivery point *j*
ts_{ij}^k	-	The time when vehicle *k* departs from point *i* to *j*
q_j	-	Total amount of goods at point *j*

5.3. MODEL CONSTRAINTS

(1) Constraint on the number of the transport routes. The number of transport routes dose not exceed the total number of the transport vehicles.

(2) Constraint on the maximum carrying capacity of the vehicle. The total weight of goods at the pick-up sites does not exceed the maximum carrying capacity of the transport vehicle.

(3) Constraint on the vehicle transportation distance. The route distance of each vehicle is shorter than its maximum mileage.

5.4. MODEL CONSTRUCTION

The "shortest route" can be calculated using the "transport route design model". According to the optimization goal, the total logistics cost model for agricultural products under the network platform is established as follows:

Objective function:

$$Min\left\{\sum_{k=1}^{m} f^k + \sum_{k=1}^{m}\sum_{i=0}^{n}\sum_{j=0}^{n} c d_{ij} x_{ij}^k + p\sum_{k=1}^{m}\sum_{j=1}^{n} y_{ij}^k \left[l_1(t_j - ts_{ij}^k) + \frac{l_2 q_j}{v} \right] s_j + \sum_{k=1}^{m}\sum_{j=1}^{n} y_{ij}^k \left[e_1(t_j - ts_{ij}^k) + \frac{e_2 q_j}{v} \right] \right\} \quad \textbf{(1)}$$

Constraint functions:

$$\sum_{j=1}^{n}\sum_{k=1}^{m} y_{ij}^k \le m,\ i=0 \quad \textbf{(2)}$$

$$\sum_{j=1}^{n} q_j y_j^k \le V,\ k=1,2,3,\ldots,m \quad \textbf{(3)}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}^k d_{ij} \le L, k=1,2,3\ldots,m \quad \textbf{(4)}$$

$$\sum_{k=1}^{m} y_j^k = 1, j=1,1,3,\ldots,n \quad \textbf{(5)}$$

Eq. (1) is an objective function of the transportation cost, including fixed cost, variable cost, cargo damage cost, and energy consumption cost. The objective is to minimize them. In Eq. (1), the first term is the fixed cost, which refers to the labour cost of transportation personnel and the fixed usage fee of the vehicles, which is proportional to the number of vehicles used. The formula is:

$$C_1 = \sum_{k=1}^{m} f^k \tag{6}$$

The second term represents the variable costs, including the maintenance cost of the vehicles and the gasoline costs, which is proportional to the transportation distance of the vehicles. The formula is:

$$C_2 = \sum_{k=1}^{m}\sum_{i=0}^{n}\sum_{j=0}^{n} c d_{ij} x_{ij}^k \tag{7}$$

The third term indicates the loss cost of goods. The fresh agricultural products perish easily during the process of transportation, loading and unloading. Therefore, the loss cost is divided into the loss cost during transportation and that during loading and unloading. The calculation formula is as follows:

$$C_3 = p\sum_{k=1}^{m}\sum_{j=1}^{n} y_{ij}^k \left[s_j l_1 (t_j - ts_{ij}^k) + \frac{q_j l_2 q_j}{v} \right] \tag{8}$$

The fourth term represents the cost of energy consumed to preserve fresh agricultural products during transportation and loading on the vehicle cooled. Assuming that the energy costs of transport vehicles are directly proportional to the transportation time and the number of pick-up sites along the route, the formula is as follows:

$$C_4 = \sum_{k=1}^{m}\sum_{j=1}^{n} y_{ij}^k \left[e_1 (t_j - ts_j^k) + \frac{e_2 q_j}{v} \right] \tag{9}$$

Eq. (2) is the constraint function of the logistic route, which indicates that the total number of transport routes dose not exceed the total number of the transport vehicles.

Eq. (3) is the constraint function of the vehicle load, which indicates that the total cargo weight at all pick-up sites along the transportation route should not be greater than the maximum carrying capacity of the transport vehicle.

Eq. (4) is the constraint function of the vehicle mileage, which indicates that the length of the transport routes should not be greater than the maximum mileage of the vehicle K during transportation.

Eq. (5) indicates that each pick-up site is served by only one vehicle.

6. EXAMPLE ANALYSIS

6.1. EXAMPLE DESCRIPTION

The transportation of fresh agricultural produce in *19* villages scattered in a certain area of Yunnan is taken as an example. The village level dispatch station provides transportation services for each village. The transportation vehicles start from the village level dispatch station to each node to load the goods. Finally, the goods are gathered at the village level dispatch station and distributed with the help of the network platform. Therefore, the agricultural product logistics optimization model in this area contains *20* location nodes, among which the village level dispatch station is P_0, and the other villages are P_1, P_2, P_3... P_{19}. The carrying weight of each vehicle is *5* tons, and the average speed of the vehicle to the pick-up sites is 50 km/h. The fixed transportation cost is *400* Yuan per vehicle, and the cost per unit distance of transportation is *3* Yuan/km. The unit price of agricultural products is *5000* Yuan per ton. The average loss rate of agricultural products in the transportation and loading process is *1%*, the energy consumption rate in the transportation process is *10* Yuan/h, the energy consumption rate during the loading and unloading process is *20* Yuan/h, and the loading and unloading efficiency is *5* tons/h. The location coordinates of each node and the quantity of agricultural products supplied are shown in Table 1.

Table 1 *Locations of the Pick-up sites and Supply of Agricultural Products*

Nodes	Location		Supply quantity (kg)	Nodes	Location		Supply quantity (kg)
	Latitude	longitude			Latitude	longitude	
P_0	24°10'28.81"	102°37'36.69"	0	P_{10}	24° 7'49.61"	102°39'14.81"	700
P_1	24°11'10.69"	102°45'42.07"	500	P_{11}	24° 6'15.36"	102°40'26.63"	1000
P_2	24°10'24.69"	102°43'52.13"	900	P_{12}	24° 6'30.45"	102°41'53.50"	1100
P_3	24°10'36.70"	102°42'40.94"	400	P_{13}	24° 7'48.03"	102°43'12.67"	600
P_4	24°10'40.82"	102°41'38.87"	800	P_{14}	24° 8'37.78"	102°48'15.17"	800
P_5	24° 9'47.40"	102°43'9.82"	400	P_{15}	24° 8'34.29"	102°46'42.91"	1200
P_6	24° 8'51.29"	102°42'24.43"	900	P_{16}	24° 7'28.68"	102°46'15.49"	700
P_7	24° 9'6.27"	102°41'1.70"	500	P_{17}	24° 7'4.03"	102°46'45.06"	500
P_8	24° 9'28.47"	102°39'21.27"	900	P_{18}	24° 7'32.86"	102°47'21.29"	1100
P_9	24° 8'26.27"	102°40'7.38"	1200	P_{19}	24° 7'11.49"	102°48'38.24"	600

6.2. ZONING OF LOGISTICS PICK-UP SITES

The production nodes in the example can be clustered by the *K*-means clustering method, described in Section 3.1. According to the total quantity of goods in all production places in Table 1 and the carrying capacity of the transport vehicle, the initial cluster number $k=3$ can be obtained. Initially, the nodes in the study zone are divided into three zones M_1, M_2, M_3 by the method of equalization, and the nodes P_9, P_5 and P_{18} near the center of each zone are selected as the initial cluster center nodes, as shown in Figure 3.

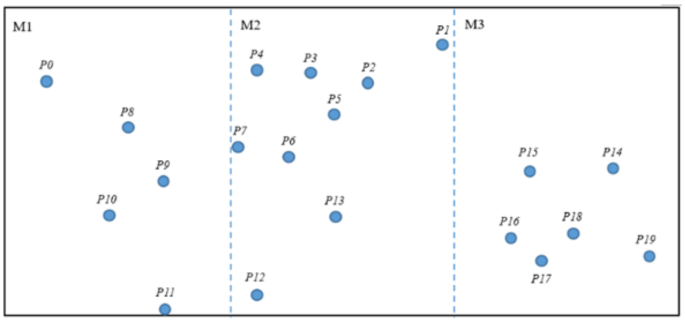


Fig. 3 *Spatial Distribution of Agricultural Production Sites*

The distance between each non-centre node and the above 3 initial cluster centre nodes is calculated in the Geographic Information System, and then the nodes can be clustered. The clustering information is as follows:

P_1, P_2, P_3, P_4, P_5, P_6 and P_{13} are classified into cluster I,

P_7, P_8, P_9, P_{10}, P_{11} and P_{12} are classified into cluster II and

P_{14}, P_{15}, P_{16}, P_{17}, P_{18} and P_{19} are classified into cluster III.

According to the actual situation, the vehicle load capacity of 5 tons, i.e. $\sum_{i=1}^{x} q_i \le 5$ t, is used as the constraint condition to test the clusters, and the results are as follows: t (tons)

In cluster I: $\sum q_i = 4.5\text{ t} < 5\text{ t}$,

In cluster II: $\sum q_i = 5.4\text{ t} > 5\text{ t}$,

In cluster III: $\sum q_i = 4.9\text{ t} < 5\text{ t}$.

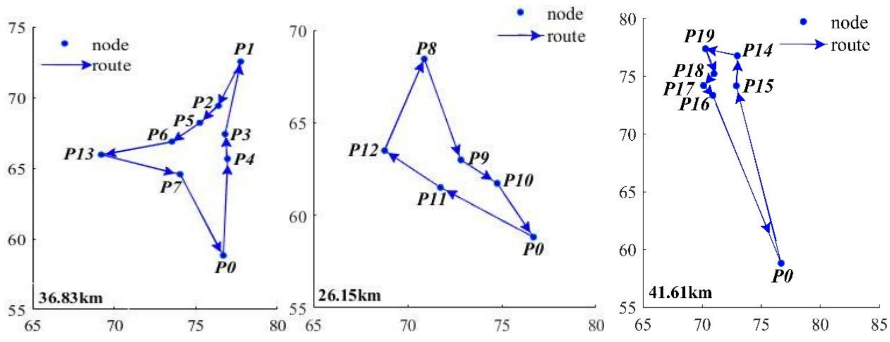
As can be seen, the nodes in cluster II do not conform to the constraint condition, so these nodes should be clustered again. The final results are shown in Table 2.

Table 2 *Cluster Grouping of Agricultural Production Sites*

Clusters	*Nodes*	*Supply quantity*
Cluster I	P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_{13}	*5.0* t
Cluster II	P_8, P_9, P_{10}, P_{11}, P_{12}	*4.9* t
Cluster III	P_{14}, P_{15}, P_{16}, P_{17}, P_{18}, P_{19}	*4.9* t

6.3. ROUTES OPTIMIZATION

Based on the specific coordinates of the village dispatch station P_0 and the agricultural production sites P_1, P_2, P_3, ..., P_{19} given in Table 1 and the cluster groupings in Table 2, the distances between the sites are calculated in the Geographic Information System, and a modified distance matrix is established, as shown in Table 3. For the pick-up sites and village dispatch station in each cluster group, the initial Hamilton circle is constructed separately. Based on the improved circle algorithm, the main program script file is built by Matlab, and then the adjacency matrix is put into the program to obtain the transport route of each cluster group, as shown in Figure 4 and Table 4.



(a) Cluster I (b)Cluster II (c) Cluster III

Fig. 4 *Optimized Routes of Agricultural Products Logistics*

Table 3 *Modified Distance Matrix*

	P_0	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}
P_0	0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
P_1	13.8	0	3.4	5.2	6.9	5.0	7.1	8.8	∞	∞	∞	∞	∞	7.6	∞	∞	∞	∞	∞	∞
P_2	10.6	3.4	0	2.0	3.8	1.6	3.8	5.4	∞	∞	∞	∞	∞	4.9	∞	∞	∞	∞	∞	∞
P_3	8.6	5.2	2.0	0	1.8	1.7	3.3	3.9	∞	∞	∞	∞	∞	5.3	∞	∞	∞	∞	∞	∞
P_4	6.9	6.9	3.8	1.8	0	3.1	3.6	3.1	∞	∞	∞	∞	∞	5.9	∞	∞	∞	∞	∞	∞
P_5	9.5	5.0	1.7	1.7	3.1	0	2.2	3.8	∞	∞	∞	∞	∞	3.7	∞	∞	∞	∞	∞	∞
P_6	8.7	7.1	3.8	3.3	3.6	2.2	0	2.4	∞	∞	∞	∞	∞	2.4	∞	∞	∞	∞	∞	∞
P_7	6.3	8.8	5.4	3.9	3.1	3.8	2.4	0	∞	∞	∞	∞	∞	4.4	∞	∞	∞	∞	∞	∞
P_8	3.5	∞	∞	∞	∞	∞	∞	∞	0	2.3	3.1	6.2	6.9	∞	∞	∞	∞	∞	∞	∞
P_9	5.7	∞	∞	∞	∞	∞	∞	∞	2.3	0	1.9	4.1	4.7	∞	∞	∞	∞	∞	∞	∞
P_{10}	5.6	∞	∞	∞	∞	∞	∞	∞	3.1	1.9	0	3.5	5.1	∞	∞	∞	∞	∞	∞	∞
P_{11}	9.2	∞	∞	∞	∞	∞	∞	∞	6.2	4.1	3.5	0	2.5	∞	∞	∞	∞	∞	∞	∞
P_{12}	10.3	∞	∞	∞	∞	∞	∞	∞	6.9	4.7	5.1	2.5	0	∞	∞	∞	∞	∞	∞	∞
P_{13}	10.7	7.6	4.9	5.3	5.9	3.7	2.4	4.4	∞	∞	∞	∞	∞	0	∞	∞	∞	∞	∞	∞
P_{14}	18.4	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	0	2.6	4.0	3.9	2.5	2.8
P_{15}	15.8	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	2.6	0	2.2	2.9	2.2	4.1
P_{16}	15.7	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	4.0	2.2	0	1.1	1.9	4.1
P_{17}	16.7	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.9	2.9	1.1	0	1.4	3.2
P_{18}	17.4	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	2.5	2.2	1.9	1.4	0	2.3
P_{19}	19.6	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	2.8	4.1	4.1	3.2	2.3	0

Table 4 *Transport Routes and Costs*

Clusters	*Routes*	*Routes length* (km)	*Cost (*Yuan*)*
I	$P_0 \to P_4 \to P_3 \to P_1 \to P_2 \to P_5 \to P_6 \to P_{13} \to P_7 \to P_0$	*36.83*	*775.84*
II	$P_0 \to P_{11} \to P_{12} \to P_8 \to P_9 \to P_{10} \to P_0$	*26.15*	*707.08*
III	$P_0 \to P_{15} \to P_{14} \to P_{19} \to P_{18} \to P_{17} \to P_{16} \to P_0$	*41.61*	*795.79*

Therefore, the calculation results of the three routes obtained by the routes optimization method are as follows: for cluster I, the route length is *36.83* km and the transportation cost *775.84* Yuan; for cluster II, the route length is *26.15* km and the transportation cost *707.08* Yuan; and for cluster III, the route length is *41.61* km and the transportation cost *705.79* Yuan. The total cost of transportation is *2278.71* Yuan.

In the traditional scattered transportation model, suppose that each village has one transportation vehicle with a load capacity of *2* tons, that the fixed transportation cost is *200* Yuan per vehicle and that other conditions remain unchanged. Through calculation, it is found that the total transportation distance is *213* km and that the total cost is *4464.86* Yuan. It is clear that the cost of the traditional transport model is much higher than that of the route optimization model model.

Through the two-stage method, the multi-node routing problem is transformed into several TSP problems, which reduces the complexity of the whole problem. Considering the perishability of agricultural products, it is necessary to arrange transportation routes reasonably, during storage and preservation, and to divide logistics costs into four parts: fixed cost, variable cost, damage cost, and energy consumption cost. Based on the hypotheses, a transport route optimization model with minimum transport cost as the objective is established, and the improved loop routes optimization algorithm is used to obtain an approximate optimal solution for the model.

7. CONCLUSION

With the trend of economic globalization, the contradictions between the organized "big market" and the decentralized individual farmers have become more prominent under the background of fragmented land in China. Because of the large number of production sites and the small scale of production, the "first mile" transportation has become a bottleneck preventing farmers from increasing their income. After in-depth analysis of the agricultural product logistics models in developed countries, and based on the characteristics of the agricultural products logistics and the current situation of agricultural land utilization in China, this paper optimizes the traditional logistics routes by constructing a network logistics model for agricultural products to strengthen the organization, integration, information and scale of logistics, reduce the logistics links and lower the costs of storage and transportation. In order to achieve fast and efficient "first mile" transportation of agricultural products for individual farmers, this paper provides a two-stage solution method, which carries out first grouping and then dispatching, and transforms the complex multi-node routes problem into TSP problems. After clustering, the pick-up sites are more closely conneected and the scope of pick-up is clearer, which can effectively improve the "first mile" transportation efficiency, and promote the interconnections between individual farmers and the "big market". In the case analysis, the improved loop routes optimization algorithm and the Matlab numerical calculation are used to verify that this model can provide technical reference for the fresh agricultural product logistics under the fragmented pattern of cultivated land in China.

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