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Research on the Optimization of Logistics Distribution Path of Tianyang Fruit and Vegetable Distribution Center in Guangxi Province

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***Abstract*—In order to study the logistics distribution path of Tianyang fruit and vegetable distribution center in Guangxi Province, we establish an optimization model of distribution path subject to the demand and distribution locations of logistics distribution customers in Tianyang fruit and vegetable distribution center. This paper used the method of saving mileage with soft time window to solve the problem, and analyzed the new distribution line, the related cost of distribution and the original distribution scheme, and finally, found that the new scheme significantly reduces the related distribution cost.**

Keywords*—Logistics distribution; distribution routing; saving mileage model

I. INTRODUCTION

According to the statistics of the national development and Reform Commission, in recent years, China's logistics industry has developed rapidly, and the total logistics volume of the whole society has been growing, showing a trend of growth. Although the logistics distribution service system, service function, service level and supporting facilities have been greatly improved, but the overall level of logistics distribution is not high, the distribution cost remains high, and the efficiency of logistics distribution is low, which is difficult to meet the rapid development of service industry and the demand of consumer upgrading. The total cost of logistics in China accounts for 18% of GDP, while that in developed countries such as Japan and Germany only accounts for about 10%, which is about 8% less than that in China. Therefore, it is urgent to study how to reduce the cost of logistics distribution, and the optimization of distribution path is the main link to reduce the cost of distribution.

In recent years, although many scholars have been studying how to optimize the cost of logistics distribution, they have all mentioned such problems as the reasonable planning of distribution vehicles and the optimization of distribution routes. For example,

Rus-sell G.Thompson (2012) proposed a joint distribution mode composed of the routes of picking up and distributing goods between suppliers and retailers by distribution vehicles[1]. Dantzig and ramser (1959) are the first to mention VRP[2]. One of the main solutions to reduce the distribution cost of Su Zhengrong (2019) in China is to plan the vehicle scheduling problem. The vehicle should achieve the best optimization goal in the shortest distribution path under certain constraints[3]. Chen he, Zhao Di, Mi Tengfei and Bai songrui (2017) emphasized that choosing a reasonable distribution path to reduce distribution costs and achieve high distribution service quality is an important competitive strategy for logistics distribution enterprises[4]. Wang Yin (2013) applied the multi-objective function planning model to plan the distribution path of the urban distribution center, alleviating the problem of urban traffic congestion[5]. Zhao Lu, Zhao Lei, and Zhu Daoli (2013) constructed the mathematical model of vehicle path optimization with the lowest distribution cost as the objective function in the problem of vehicle path planning for fruit and vegetable distribution[6]. However, there is little research on how to plan the distribution path under the constraint of soft time window, so as to complete the distribution service for customers with the lowest distribution cost. G.M. giaglis, (2004) mentioned that the best time period required by customers is called time window[7]. Time window can be hard window or soft window. Under the constraint of hard window, it is the best time period that can not violate customer requirements for service. On the contrary, violations are accepted but punished, so there is a penalty cost. Although many foreign scholars have used the multilevel objective function of mathematical modeling to plan and analyze the distribution path, and also used the improved genetic algorithm and simulated annealing method to study the distribution network, few scholars have studied the logistics distribution path with the method of saving mileage with soft time window. This paper analyzes the distribution path of Tianyang fruit and vegetable distribution center, and finds out the problems of unreasonable distribution path layout, high distribution cost, high damage rate and high damage cost. This paper constructs the model of distribution path optimization of Tianyang fruit and vegetable distribution center, and constructs the model of mileage saving distribution path optimization with soft time window, according to the distribution of Tianyang fruit and vegetable make a reasonable distribution path optimization plan based on your own situation. In the aspect of logistics distribution path

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optimization, it provides new ideas and methods for Tianyang fruit and vegetable distribution center to better promote the development of logistics in Tianyang fruit and vegetable distribution center and improve the income of enterprises.

II. ANALYSIS ON THE CURRENT DISTRIBUTION PATH OF TIANYANG FRUIT AND VEGETABLE DISTRIBUTION CENTER

At present, Tianyang fruit and vegetable distribution center has 11 cities in Guangxi, including Nanning, Yulin, Chongzuo, Guilin, Liuzhou, Wuzhou, Beihai, Guigang, Fangchenggang, Hezhou and Hechi. Most of the fruits and vegetables are delivered separately in different cities. For example, Tianyang fruit and vegetable distribution center - Nanning City - Tianyang fruit and vegetable distribution center, the distribution path is scattered, and there is no integrated planning for the distribution path. Therefore, the transportation cost of Tianyang fruit and vegetable distribution center is still high, and the loss rate of fruit and vegetable is also high. The circulation loss rate of fruits and vegetables is 30% - 37%, while the loss rate of fruits and vegetables in China is 20% - 30%. The loss rate of fruits and vegetables in developed countries is controlled below 5%. The loss rate of Tianyang fruit and vegetable distribution center is about 7% higher than the average loss rate in China, which is huge.

According to the survey data of Tianyang fruit and vegetable distribution center and Baidu map, the maximum load capacity of the model is 35t. Under the condition that the traffic flow is not congested, the distance of a tour shall not exceed 1500km, the average speed of driving is 90km / h, the unit freight is 1.5 yuan / km, and the penalty cost for late arrival is 10 yuan / h. In the case of traffic jam, the average driving speed of the two models is 20km / h, the coefficient of traffic jam is 7.9, and the unit time value of vehicle driver is 8 yuan / h. In the process of delivery, the damage ratio of fruits and vegetables is 0.05, the damage ratio of loading and unloading operation is 0.08, and the best shelf life is 3 days. The unit price of fruits and vegetables is 0.25 yuan/Jin, 500 yuan/T. The current distribution path network of the distribution center, the distance between the distribution center and customers, and the distance between customers are shown in the figure below and the table below, where p represents the Tianyang fruit and vegetable distribution center.

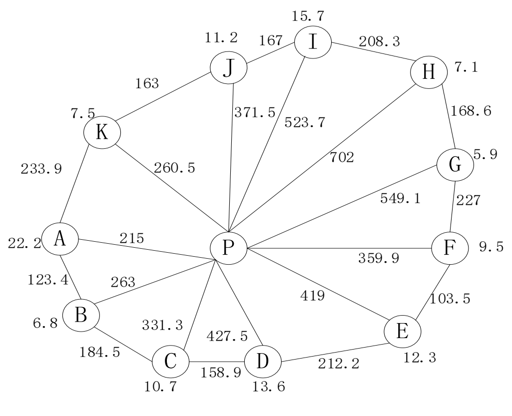

Fig.1. Distance between the distribution center and customers, as well as between customers

TABLE I. DEMAND FOR FRUITS AND VEGETABLES EVERY MONTH

Place	Nanning A	Ch.zuo B	Fang C.G. C	Beihai D	Yulin E	Guigang F
Demand	22.2	6.8	10.7	13.6	12.3	9.5
Place	Wuzhou G	Hezhou H	Guilin I	Liuzhou J	Hechi K	
Demand	5.9	7.1	15.7	11.2	7.5	

III. A MODEL OF SAVING MILEAGE AND OPTIMIZING DISTRIBUTION PATH WITH SOFT TIME WINDOW

(1) Assumption of distribution problems. The model of logistics distribution is a distribution model for Tianyang fruit and vegetable distribution center to distribute related goods to multiple customers. The type of fresh food to be distributed is only fruits and vegetables, and the unit price of fruits and vegetables is the same, and the following conditions should be met:

1) The number of transport vehicles is y, and each vehicle has the limit of approved loading capacity, so that the total capacity of single vehicle is greater than the total demand of all customers on the transport route;

2) Each customer's demand is loaded by a car, and each customer is provided with distribution service. Each customer's demand is known, and only one car is distributed in a distribution path;

3) The distance between the distribution center and customers and between customers is known.

(2) Transportation cost of distribution vehicles. The transportation cost of distribution vehicles includes fixed cost and variable cost. However, for the convenience of calculation, this study only considers the variable cost of mileage driven by the vehicle, and other variable costs (including fuel consumption, damage, etc.) are not included in the scope of consideration, so the model of transportation cost of distribution vehicle is

$$TC_1 = C_1 \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=0}^{m} X_{ijk} Y_{ijk} \tag{1}$$

St
$$\sum_{i=0}^{n} \sum_{j=0}^{n} q_{ij} Y_{ijk} \le Q \quad (k = 1, 2, \cdots, m; Q = 35) \tag{1.1}$$

$$\sum_{i=0}^{n} \sum_{k=0}^{m} Y_{ijk} = 1 \quad \text{(j=1,2,…,n)} \tag{1.2}$$

$$\sum_{j=0}^{n} \sum_{k=0}^{m} Y_{ijk} = 1 \quad \text{(i=1,2,…,n)} \tag{1.3}$$

$$\sum_{j=0}^{n} Y_{ijk} = \sum_{i=0}^{n} Y_{ijk} \le 1, \quad \text{(k=1,2,…,m)} \tag{1.4}$$

$$\sum_{i=0}^{n} \sum_{j=0}^{n} X_{ij} \le S \quad (S = 1500) \tag{1.5}$$

Where i, j is the distribution customer point, when i, j = 0 is the distribution center, and i ≠ j; C_1 is the transportation cost per unit distance of the vehicle, yuan / km; X_{ijk} is the total mileage of the m-th vehicle from customer i to customer j; Y_{ijk} the transportation capacity of the distribution vehicle y from point I to distribution point J when Y_{ijk} = 1, or Y_{ijk} = 0; q is the transportation capacity of one vehicle in one distribution path Q_{ij} is the demand from customer i to customer j; s is the safe driving of the vehicle.

Formula (1) indicates the transportation cost of distribution vehicles; formula (1.1) indicates that the total transportation volume of each vehicle completing a distribution path does not exceed the transportation capacity of the vehicle; formula (1.2) and formula (1.3) indicate that each customer's demand is only distributed by the same vehicle, and each distribution point can only be serviced once; formula (1.4) indicates that each distribution vehicle starts from the distribution center and finishes Return to the distribution center after completing the distribution task; formula (1.5) means that the total mileage of each distribution path does not exceed the safe driving mileage of the vehicle.

(3) Vehicle congestion cost. Because the distance between Tianyang fruit and vegetable distribution center and users is relatively long, the grace period for delivery is relatively large, there is no late arrival, and there is no reward for early arrival, so the penalty cost is not calculated. In traffic congestion, the traffic density is relatively large, and vehicles can only drive at a lower speed or park in line, so drivers have to pay extra time cost. The additional time cost paid by drivers is the main component of congestion cost of vehicles. Traffic congestion often occurs in logistics distribution. This study only considers that drivers have to pay extra time cost as congestion cost. Therefore, the traffic congestion cost is equal to the total congestion time in the distribution section multiplied by the unit time value of vehicle users, namely:

$$TC_2 = C_2 \sum_{k=1}^{m} X_m \times (1/v_0 - 1/v) \times \beta \tag{2}$$

Among them, C_2 is the unit time value of vehicle users, unit: yuan / h; XM is the total mileage of the m-th vehicle distribution; V_0 is the average driving speed of vehicles when there is no traffic jam, km / h; V is the average driving speed of vehicles when there is congestion, km / h; β is the congestion coefficient when there is congestion.

(4) Penalty cost. In reality, due to some uncertain factors, such as traffic jams, distribution scheduling errors, etc., the time of logistics delivery may not meet the customer's time requirements. According to the actual situation, customers can accept delivery within a certain time range beyond the specified time, resulting in time penalty cost. Therefore, the penalty cost of soft time window in the process of logistics distribution is as follows:

$$TC_3 = \sum_{k=1}^{m} \sum_{i=1}^{n} y_{ik} z_{ik} \tag{3}$$

$$z_{ik} = \begin{cases} \infty & (\mathrm{N}_i < T_{ik} < M_i) \\ \gamma(E_i - T_{ik}) & (\mathrm{M}_{ik} < T_{ik} < E_i) \\ 0 & (E_i \le T_{ik} \le L_i) \\ \varphi(T_{ik} - L_i) & (L_i \le T_{ik} \le N_i) \end{cases} \tag{4}$$

Among them, TC_3 is the congestion cost in the distribution process; z_{ik} is the penalty cost when the vehicle reaches point i of the community, yuan; x_{ik} is the 0-1 variable, if the k vehicle serves point i of the community, then it is 1, otherwise it is 0; γ is the waiting cost when the vehicle arrives early, yuan/h, according to the actual situation, its value is the same as c_2 ; φ is the penalty cost when the vehicle arrives outside the window at the best time, yuan/h; T_{ik} is the m Time for vehicles to arrive at customer i point; Li, Ei are the upper and lower bounds of the best time window acceptable to customers; Ni, Mi are the upper and lower bounds of the time window acceptable to customers in the community.

After the distribution vehicle serves cell I, the time to arrive at the next cell is expressed as:

$$T_{jk} = T_{ik} + T_i + \frac{X_{ijk}}{v} \tag{5}$$

Where T_i is the service consumption time after arriving at point i of the community, h; $\overline{v}$ is the average running speed of distribution vehicles, $\overline{v}$ = (v0 + v) / 2.

(5) Cost of damage to fruits and vegetables. This study only considers the amount of damage in the distribution process of fruits and vegetables to calculate the damage cost of fruits and vegetables. Due to the perishability of fruits and vegetables, they need to be distributed under certain temperature and humidity conditions during the distribution process. During the distribution process, fruits and vegetables will also be damaged with the change of time. When serving customers, the rear compartment door will open, which will aggravate the speed of fresh food corruption. Therefore, fruits and vegetables will also be damaged with the change of time in the distribution process. The length and frequency of carriage opening after distribution will affect the quality of fruits and vegetables. Therefore, the damage cost model of fruits and vegetables is:

$$TC_4 = p \sum_{j=1}^{n} \sum_{k=1}^{m} y_{jk} (a_1 X_{ij} + a_2 q_j) \tag{6}$$

Among them, a_1, a_2 respectively represent the proportion of damage to fruits and vegetables in the process of fruit and vegetable distribution and loading and unloading operation; P is the unit price of fruits and vegetables; x_{ij} is the mileage to customer j after serving customer i; q_j is the demand of customer j.

(6) Distribution route optimization model. The distribution path optimization model is to minimize the sum of transportation cost, vehicle congestion cost and fruit and vegetable damage cost of vehicle distribution, namely:

$$\text{Min} \quad TC = C_1 \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=0}^{m} X_{ijk} y_{ijk} + \mathrm{C}_2 \sum_{k=1}^{m} X_m \times \left(\frac{1}{\mathrm{v}_0} - \frac{1}{\mathrm{v}} \right) \times \beta$$

$$+\sum_{k=1}^{m}\sum_{i=1}^{n} y_{ik} Z_{ik} + p\sum_{j=1}^{n}\sum_{k=1}^{m} y_{jk}(a_1 X_{ij} + a_2 q_j) \quad (7)$$

St $$\sum_{i=1}^{n}\sum_{k=1}^{m} q_{ij} Y_{ik} \le Q(k=1,2,\cdots,m; Q=35) \quad (7.1)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{n} X_{ijk} y_{ijk} \le S \quad (7.2)$$

$$L_i \le E_i \le T_i \quad \text{(i=1,2,....,n)} \quad (7.3)$$

Among them, formula (7) is the objective function of the total cost after the optimization of the distribution path; formula (7.1) is that the total amount of goods carried by the vehicle does not exceed the transportation capacity of the vehicle; formula (7.2) is that the total mileage of the distribution path in a single distribution cannot exceed the safe driving mileage of the vehicle; formula (7.3) is that the time for goods to reach the customer cannot exceed the best time period of customer demand service.

IV. Empirical Research

This model does not consider the fixed distribution cost such as the loss of vehicle distribution process and the control of temperature and humidity in the distribution process. According to the calculation principle of saving mileage method with soft time window, the logistics distribution path of Tianyang fruit and vegetable distribution center is optimized and analyzed, and the total distribution cost is calculated. According to the survey data of Tianyang fruit and vegetable distribution center and Baidu map, the distance between the distribution center and customers and the distance between customers are as follows:

TABLE II. Related costs of distribution route of new scheme

Route	Service point	Traffic volume	Mileage	Transportation cost
1	A, K	29.7	709.4	1064.1
2	B, C, D	31.1	1033.9	1550.9
3	E, F, G	27.7	1298.6	1947.9
4	H, I, J	34.0	1448.8	2173.2
Total		122.5	4490.7	6736.1
Route	Congestion cost	Penalty cost	Damage cost	Total cost
1	640.5	0.0	18923.0	20627.6
2	933.5	0.0	27091.5	29575.8
3	1172.5	0.0	33573.0	36693.4
4	1308.1	4.6	37580.0	41065.9
Total	4054.5	4.6	117167.5	127962.6

Compared with the original plan, the cost of the new plan is reduced. There are 5 less delivery routes and 2134.1km/month less total mileage. The cost of vehicle transportation has been reduced by 192 yuan / month. The cost of vehicle congestion is reduced by 1264.7 yuan / month, and the cost of time penalty is reduced by 124.4 yuan / month. The damage cost of fruits and vegetables decreased by 11739.2 yuan / month, and the total distribution cost decreased by 13320.3 yuan / month.

According to the actual situation of Tianyang fruit and vegetable distribution center, the five distribution paths optimized by mileage saving method are as follows:

Distribution route 1: Tianyang fruit and vegetable distribution center Nanning Hechi Tianyang fruit and vegetable distribution center;

Distribution route 2: Tianyang fruit and vegetable distribution center Chongzuo Fangchenggang Beihai Tianyang fruit and vegetable distribution center;

Distribution route 3: Tianyang fruit and vegetable distribution center Yulin Guigang Wuzhou Tianyang fruit and vegetable distribution center;

Distribution Route 4, Tianyang fruit and vegetable distribution center - Hezhou City - Guilin city - Liuzhou City - Tianyang fruit and vegetable distribution center;

The carrying capacity, safe driving distance, service time required by customers and the best shelf life of fruit and vegetable distribution vehicles in these routes are all within the specified range, with the lowest risk factor. Under the condition of meeting these requirements, the relevant cost is the lowest. Therefore, the total distribution cost is also the lowest, so the four distribution paths optimized by the mileage saving model are the best.

V. Conclusion

Based on the analysis of the current distribution cost of Tianyang fruit and vegetable distribution center, we establish a distribution optimization model. According to the constraints of the distribution customer location, the safe driving mileage of the vehicle, the best quality guarantee period of fruits and vegetables and the service period required by customers, we use the mileage saving model with soft time window to optimize the distribution path, and finally achieve the distribution cost Minimization.

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