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Optimization of Open Distribution Path for Rural Fresh Food under Genetic Algorithm

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Abstract: In recent years, as the market scale of China's cold chain logistics continues to expand, the use of fresh food e-commerce platforms such as Temu, Taocaicai, and Meituan Grocery has become more and more popular in rural areas. In order to reduce the cost of rural fresh logistics, this paper introduces the fresh electricity supplier "community group purchase" distribution mode, starting from improving the distribution efficiency of rural fresh logistics, and comprehensively considering the commodity demand of rural users, the freshness of fresh goods delivered to users, open route planning distribution vehicles and other factors. A capacity-constrained open vehicle routing optimization model with the goal of minimizing the total distribution cost was constructed and solved by genetic algorithm. This paper proves that the open vehicle distribution can improve the efficiency of logistics distribution more effectively, reduce the total cost of logistics distribution, and promote the development of rural fresh food market.

Keywords: rural fresh delivery, route optimization, genetic algorithm, fresh food logistics

1. Introduction

With the rapid development of modern e-commerce and logistics technology, the fresh food delivery industry has also been given better development opportunities. The community group purchase model of the fresh food e-commerce platform solves the problem of rural distribution of fresh food products by allowing consumers to purchase goods online and have them uniformly delivered by the merchant to a fixed point in the community the next day, and picked up by nearby residents, which meets the needs of rural consumers. Fresh food e-commerce to ensure profitability and occupy the rural market share, we need to reduce logistics and distribution costs, improve the efficiency of commodity distribution, improve competitiveness, more benefits to rural consumers, and promote the development of rural fresh food e-commerce.

The key to reduce the cost of rural fresh produce logistics is the problem of how to plan vehicle paths, and the solution of planning vehicle paths is explored by constructing open vehicle path planning. The logistics and distribution of rural fresh products are mostly distributed using ordinary vehicles. Zhao solves the vehicle path problem by constructing a series of logistics and distribution path optimization models, solving them with quantum evolutionary algorithm models, and selecting examples of international standard vehicle path problems for simulation experiments to compare and analyze the relevant performance of the algorithms [1]. Brando solves the multi-warehouse open vehicle path problem by studying iterative local search algorithms [2]. Molina has further improved

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the research on the vehicle path planning problem, which has become one of the popular problems studied by many scholars with the rapid development of economy and e-commerce [3]. Zhang summarizes the basic features of vehicle path planning problems and classifies VRPs according to real traffic problems, giving the future research and development trends of VRPs [4]. Fang constructed a vehicle distribution path optimization model for fresh produce and solved the model using the ant colony algorithm to solve the problems of high cost and carbon emission during the distribution of fresh produce, which improves customer satisfaction and reduces the distribution cost [5]. Qian Zhang considers factors such as distribution cost, freshness, carbon emission and customer demand uncertainty, establishes a multi-objective distribution model and solves it by an improved fruit fly algorithm, which is highly robust and can effectively reduce the interference caused by demand uncertainty [6].

The existing literature provides a large of references for future in-depth study of the distribution of fresh food logistics. These literatures mainly study the problem of urban fresh food logistics distribution, mostly for the closed vehicle path planning problem, and the method of rural fresh food logistics distribution research is relatively single. This paper focuses on the demand of rural consumers' online shopping and the timeliness of group purchasing, and considers the factors of open vehicle path planning, limited vehicle capacity and group purchasing distribution mode, constructs an open vehicle path planning model with the optimization goal of lowest distribution cost, and designs a genetic algorithm to solve the problem.

2. Problem Modeling

2.1. Problem Description

Temu, Taocaicai, and Meituan Grocery are fresh food e-commerce platforms with the main mode of "community group purchase", where customers can place orders directly on the platform, or obtain preferential information through the community leader, and purchase under the leader's organization, and then pick up the food at the designated point or have it delivered to their homes by the leader the next day. Through the online order offline delivery mode to provide customers with convenient and efficient shopping. Assumptions: (i) each delivery vehicle from the site, delivery task is completed, do not need to return to the site. (ii) vehicles will incur certain fixed costs. (iii) Vehicles can arrive at the location of the store in advance, but need to wait for the earliest start of the store service time for delivery, there is a certain vehicle waiting time and unloading time. The open vehicle path planning model is constructed by the above conditions.

2.2. Build Model

N represents the set of customers; q_i represents a customer's demand; R represents a set of customer paths (c_1, c_2,... ,c_n); r represents the path planning of a group of customers (r_1, r_2,... , r_k); S_1 represents the total distribution distance of vehicles with open route planning; d_{ij} indicates the distance between customer node i and customer node j. Q represents the maximum load of the vehicle; W_o represents a fixed salary for drivers of open path planning vehicles; K represents the combination of vehicles; FC_{ij} represents the fuel subsidy of k unit distance per vehicle, where $FC_{ij} \leq F_{k1}$; C_{Best} represents the optimal cost; L_i represents the customer who has not visited at node i; Re_j represents a certain incentive cost increased by delivery vehicles at customer node j; Pu_j represents a certain penalty cost increased by the delivery vehicle at the customer node j; t_{ij} represents the time for the delivery vehicle to arrive at customer node j from customer i; a_j represents the earliest time for delivery vehicles to arrive at customer node j; b_j represents the latest time for delivery vehicles to arrive at customer node j; e_j represents the time when the delivery vehicle actually arrives at customer node j.

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Decision variable: x_{ijk} indicates whether vehicle k travels from node i to node j, if so, the value is 1, otherwise it is 0; v_k indicates whether vehicle k is enabled, if yes, the value is 1, otherwise 0; y_{ik} indicates whether vehicle k completes the task of customer node i, if so, the value is 1, otherwise it is 0.

Represents the optimal objective function of the total distance traveled by vehicles:

$$\sum_{k\in K}\sum_{(i,j)\in N} d_{ij}x_{ijk} \tag{1}$$

Optimal open path planning vehicle distribution cost:

$$C^{Best} = FC_{ij}\sum_{k\in K} v_k \sum_{k\in K}\sum_{(i.j)\in N} d_{ij}x_{ijk} + W_o\sum_{k\in K} v_k + \mathrm{Re}_j\sum_{k\in K} v_k \sum_{(i.j)\in N} x_{ijk} + Pu_j\sum_{k\in K} v_k \sum_{(i.j)\in N} x_{ijk} \tag{2}$$

Constraint condition:

$$\sum_{k\in K}\sum_{j\in\Delta^*(i)} x_{ijk} = 1, \forall i\in N \tag{3}$$

$$\sum_{i\in N}\sum_{k=K} x_{ijk} = 1, \forall i\in N \tag{4}$$

$$\sum_{i\in N} q_i \sum_{j\in\Delta^*(i)} d_{ijk} \le Q, \forall k\in K \tag{5}$$

$$x_{0j}^{k} = v_k, \forall k\in K, \forall j\in N \tag{6}$$

$$\sum_{j\in N} x_{ojk} \le 1, \forall k\in K \tag{7}$$

$$x_{ijk} \in \{0,1\}, \forall k\in K, \forall (i,j)\in N \tag{8}$$

$$y_{ik} \in \{0,1\}, \forall k\in K, \forall i\in N \tag{9}$$

As follows:(3) Limit each customer to be assigned to only one path. (4) Indicates that each customer node can be accessed only once. (5) means that the goods assembled by each vehicle in the distribution center are not greater than the maximum carrying capacity of the vehicle itself. (6) indicates that when the vehicle is activated, it must depart from the distribution center. (7) Indicates that each vehicle can only be activated once. (8) Will be divided into hard time window and soft time window.

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3. Algorithm Verification and Analysis

Genetic algorithm is a series of search algorithms inspired by the theory of natural evolution, which converts the solution of the problem into a process similar to the crossover and variation of chromosome genes in biological evolution. Genetic algorithm can provide high quality solutions for various problems involving search, optimization and learning, and has the advantages of strong search ability and strong scalability.

For the validity and feasibility of the genetic optimization algorithm adopted in this paper, the relevant data of a rural logistics distribution center and 30 rural logistics distribution outlets under the jurisdiction of Xiangtan County, Hunan Province are used.

Table 1: Data information of distribution outlets.

Distribution network Serial number	Latitude	Longitude	Logistics demand	Start time	End time	Service time
1	112.961	27.682	0	8:30	17:30	0
2	112.922	27.761	175	9:15	10:20	10
3	112.951	27.734	93	9:35	10:30	15
4	112.962	27.691	106	8:30	9:20	18
5	112.874	27.741	121	9:15	10:30	11
6	112.911	27.71	135	9:20	11:00	17
7	113.068	27.73	175	9:15	10:55	15
8	113.097	27.744	98	9:30	11:40	23
9	113.027	27.743	176	10:20	11:30	12
10	112.979	27.755	78	10:15	11:20	8
11	112.986	27.75	92	8:30	9:20	10
12	112.968	27.744	105	9:00	10:40	8
13	112.942	27.756	151	10:00	11:00	15
14	112.928	27.746	72	8:40	10:20	17
15	112.91	27.75	91	8:45	9:25	12
16	112.911	27.751	199	9:20	10:00	16
17	112.915	27.759	108	9:30	11:00	13
18	112.93	27.752	162	9:20	10:20	8
19	112.928	27.746	98	9:30	11:30	12
20	112.934	27.746	186	9:15	10:00	15
21	112.93	27.741	141	10:00	10:40	17
22	112.926	27.738	172	8:50	9:40	19
23	112.914	27.716	201	9:20	10:20	12
24	112.946	27.713	102	9:30	10:40	10
25	112.995	27.722	135	9:10	10:10	6
26	112.979	27.741	108	9:40	10:20	15
27	112.968	27.744	179	9:30	10:30	20
28	112.974	27.724	71	9:00	10:00	15
29	112.952	27.734	131	8:50	10:00	12
30	112.927	27.732	119	8:40	10:20	16
31	112.944	27.757	163	9:00	10:00	11

(The longitude and latitude coordinates, logistics demand, time window and service time information of the distribution outlets are shown in Table 1.) [7]

3.1. Experimental Results and Analysis of Closed Path

In this study, data from 31 grocery stores were selected in the simulation test. There were 5 distribution vehicles with a maximum load of 700kg. The speed of the vehicle is set to 60 km/h. The fixed cost of the vehicle is 50 yuan; The average fuel consumption of vehicles is 15 litre.

In this paper, the maximum iteration times iter_ max = 1000, population size S is 50, crossover probability pc=0.8, mutation probability pm=0.5. Using matlab tool, the genetic algorithm is calculated, and the minimum cost is 437.92 yuan. The results of the algorithm are stable, the running time is short, and the efficiency is high. The vehicle optimal path planning is shown in Figure 1, and the process of searching for the minimum cost change of each generation is shown in Figure 2.

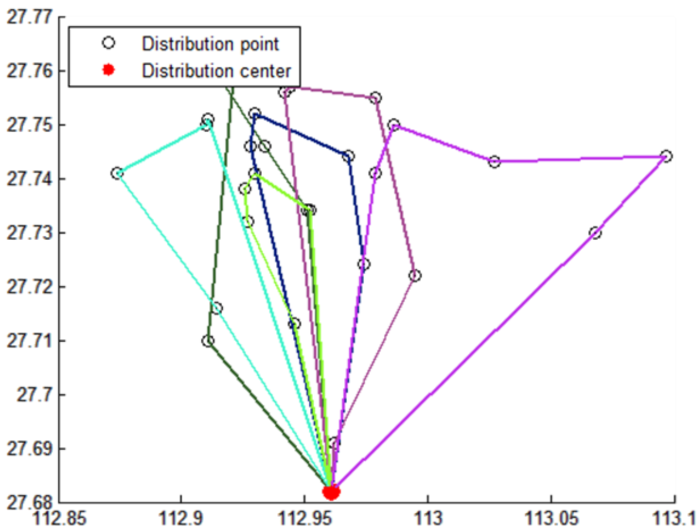

Figure 1: Closed vehicle path diagram.

As shown in Figure 1, the experimental results of the paper are feasible and effective, and the distribution path shown is as follows: Delivery route 1 is 1→6→2→17→20→3→1; delivery route 2 is 1→14→19→18→27→12→28→1; Delivery route 3 is 1→16→15→5→23→1; Delivery route 4 is 1→13→31→10→25→4→1; Distribution route 5 is 1→24→30→22→21→29→1, and distribution route 6 is 1→26→11→9→8→7→1.

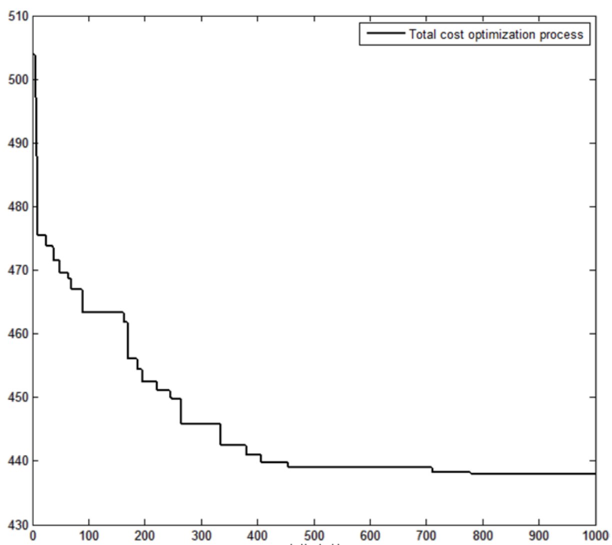

Figure 2: Total cost optimization process.

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3.2. Experimental Results and Analysis of Open Path

In order to prove that open vehicle path planning is more cost saving than closed vehicle path planning, genetic calculation is used to calculate open vehicle path planning of 31 stores. The optimal path planning is shown in Figure 3. Compared with the closed optimal vehicle distribution path, the distribution cost is 106.16 yuan more.

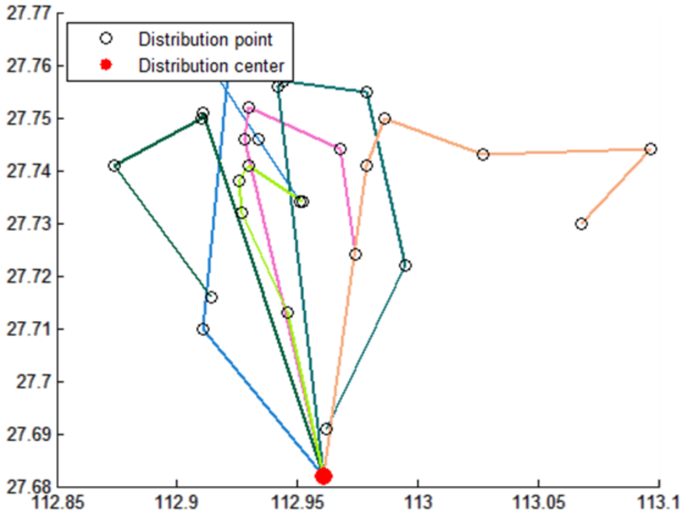

Figure 3: Open vehicle path diagram.

4. Conclusion

In this paper, the traditional TSP problem is added to open, capacity limited and other elements, and the closed vehicle routing is compared, aiming at the minimum total distance of distribution and the optimal cost of distribution, so as to build a genetic algorithm. It provides a new idea for the route planning of rural fresh food distribution in real life. The experimental results show that: (i) open vehicle route planning can save distribution cost, reduce distribution distance and save vehicle distribution time. After the delivery task is completed, the driver can spend his time freely, which improves the flexibility of vehicle use. (ii) The long-standing distribution problems in rural areas have been solved, providing a solid foundation for the revitalization of rural logistics. (iii) Compared with closed vehicle path planning, open vehicle path planning has better optimization effect and is not easy to fall into local optimal.

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