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Research on E-commerce Distribution Path Planning Considering Customer Value

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Abstract

The distribution link of E-commerce platform is directly facing consumers and can best reflect the customer experience. At the same time, there are unreasonable distribution routes that affect the interests of different customers in the past. The orders in the community E-commerce platform studied in this paper have the characteristics of more demand points, closer distribution distance and higher punctuality requirements. Therefore, while meeting the basic delivery needs of consumers, we should also consider providing additional services for important customers. Therefore, in the process of distribution, we should reasonably plan the order of distribution services for customers with different degrees of importance, so as to reduce the time penalty cost, and introduce the calculation of customer value into the optimization goal according to the relevant theory of customer relationship management, so as to improve customer satisfaction. Finally, the model is solved through the actual data. The analysis of the results shows that considering the importance of different customers, most important customers of enterprises will get satisfactory service, improve customer value, and prove the effectiveness of the model.

Keywords

Route Planning; E-commerce Distribution; Customer Value; Genetic Algorithm.

1. Introduction

In recent years, due to the rapid development and popularization of information network technologies such as the Internet of things, big data and mobile terminals, E-commerce, as a new business model, has widely penetrated into all fields of the national economy. E-commerce platform has gradually developed into a huge and rapidly growing market because it can provide consumers with more kinds and more convenient shopping services. In the past, people's shopping habits in physical stores have been changed, and people tend to shop online more quickly and conveniently. Nowadays, emerging concepts such as community E-commerce, rural E-commerce and fresh E-commerce emerge one after another. These E-commerce platforms of all walks of life have promoted the upgrading of traditional industries and the development of social economy. Among them, community E-commerce takes the community as the center and provides online sales. However, with the expansion of its own scale, there are also a series of problems in the distribution service of E-commerce platform, such as untimely delivery, product damage and low customer satisfaction. In order to improve these problems, this paper studies the "last mile" distribution problem of E-commerce platform.

In the process of online retail, these E-commerce platforms that provide fresh or perishable products can provide customers with different delivery time window options and require customers to pay corresponding fees. The time window is the time interval for the delivery of order products provided to customers on the community E-commerce platform. In recent years, with the continuous emergence of E-commerce and takeout ordering platforms mainly engaged in fresh products, the competition of community E-commerce is becoming more and more

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fierce. Distribution according to time window has become the mainstream direction of community E-commerce distribution service.

In the process of distribution, E-commerce platform orders have the characteristics of wide range, small scale and low profit. There are some problems, such as high distribution cost, untimely delivery, unreasonable transportation route and so on. When customers are paying higher distribution costs, they do not enjoy the due high-quality distribution service. Therefore, it is necessary to study how to reasonably plan the route of distribution vehicles in order to reduce the corresponding cost of E-commerce platform.

This paper considers a community-based E-commerce platform to provide surrounding customers with various types of fresh products and daily necessities. Every day, different customers will select products on the mobile app of the E-commerce platform, and then select the delivery time of the order according to their own needs and preferences. After the order is completed, the platform provides distribution services. The community E-commerce platform has a distribution center (front warehouse) and multiple distribution vehicles in this area. This problem mainly studies the optimal distribution route decision to provide high-quality distribution services. This issue also considers the factor of customer value, that is, different customers have different loyalty to the platform. In order to maintain these high-quality customers and develop potential customers, the platform will provide differentiated services for customers with different importance, such as giving priority to the distribution of orders from loyal customers.

2. Related Works

Related work mainly includes vehicle routing problem, E-commerce distribution and customer value theory.

Vehicle routing problem (VRP) was first proposed by Dantzig and Ramser [1] in 1959. It has always been one of the most basic problems in network optimization. Solving VRP usually includes precise algorithm and heuristic algorithm. Because the problem has NP hard property, scholars mainly focus on the research of heuristic algorithms. Heuristic algorithms mainly include insertion algorithm, genetic algorithm, simulated annealing algorithm and so on.

Due to the particularity of door-to-door delivery, E-commerce platforms must provide services to customers in a specific time window. Therefore, scholars extended VRP and proposed vehicle routing problem with time window (VRPTW). Kolen [2] proposed this kind of problem for the first time. On the basis of restricting the vehicle load, he adopted the branch and bound algorithm to solve the model to minimize the total distribution path. Lei [3] et al. Proposed the vehicle routing optimization problem with time window and random distribution of customer demand. When a customer's demand exceeds the maximum carrying capacity of a vehicle, it is necessary to split the customer's order and model and solve it with the goal of meeting the customer's time window requirements to the greatest extent. Potvin and Azi [4] studied a dynamic vehicle routing problem and solved it using domain search algorithm. That is, when the vehicle is in the delivery process, it needs to respond in real time to the dynamically arriving customer request. On the basis of traditional VRP, Geunes, Shen [5] and others considered the impact of delivery price on delivery tasks and built an approximate model to study the relationship between price and customer demand. Arslan and Kroon [6] studied the dynamic pick-up and delivery problem under crowdsourcing mode. The results show that this distribution mode will reduce the cost, reduce the distribution cost and improve the efficiency compared with other modes.

At present, the research on E-commerce distribution mostly focuses on the logistics mode of E-commerce platform, the location of distribution center, the optimization of distribution route, the improvement of customer satisfaction and so on. Due to the early development of foreign

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logistics industry, scholars have conducted extensive research on it. Kaptein M [7] and others introduced the existing logistics distribution mode of E-commerce platform, analyzed the advantages and disadvantages of enterprise self-built logistics, third-party logistics company contracting and common logistics from the perspective of technology, and pointed out that it is necessary to establish a logistics mode suitable for the development of enterprises. Scholars Dholakia YF and Zhao M [8] pointed out that in order to improve customer satisfaction, we should pay attention to the timely delivery of products. Reddy GP [9] and others evaluate the logistics services of E-commerce enterprises by establishing a structural model of online shopping customer satisfaction. The factors considered include flexibility, timeliness and accuracy of delivery.

The concept of customer relationship management was first put forward by Gartner Group. It believes that "customer relationship management is a business strategy to help enterprises increase revenue and improve customer satisfaction". It involves all the operation processes of the enterprise, rather than an independent department. Nowadays, due to the progress of science and technology and the emergence and development of big data, customer relationship management has begun a new round of strategic wave in sales and service. The management of customer relationship needs big data technology to obtain useful information, so as to provide customers with high-quality and personalized services. Anshari M [10] and other scholars believe that with the support of big data, enterprises pay more attention to their own marketing strategies, such as "advertising messages" often received on people's mobile phones. In the research field of vehicle routing problem, Sawsan [11] and others took customer priority as a consideration into the constraints of VRP Problem for the first time, which opened a new research idea of VRP Problem. One of the objectives of customer relationship management is to help enterprises achieve effective customer classification, in which the important basis of customer classification is customer value. M khajvand [12] analyzed bank customers as the research object and used RFM model to calculate the value of customers.

3. Problem and Model

This chapter takes the distribution network structure of community E-commerce platform providing distribution services as the research object. In real life, many such E-commerce platforms have emerged in recent years. Its operation mode is to select the corresponding products and delivery time window when customers log in to their website or app. Because the product price is more attractive than offline supermarkets and can provide door-to-door service, many customers tend to choose this consumption mode.

The problem can be described as: in a certain research area, there is a distribution center, several customer nodes and several vehicles, and each vehicle has the maximum capacity limit. In the initial state and after completing the task, the location of the vehicle shall be located in the distribution center. During transportation, different customers can only be served by vehicles once. Since this model considers the distribution business of community E-commerce platform under static conditions, the order demand, distribution address and expected delivery time of each customer are known before the task starts. At the same time, because the historical consumption information of customers is recorded in the system of the platform, the importance of each customer can be known according to their consumption frequency, consumption amount and other data. Therefore, in this model, the importance factor of customers is also known. The workflow of E-commerce platform is shown in the figure below:

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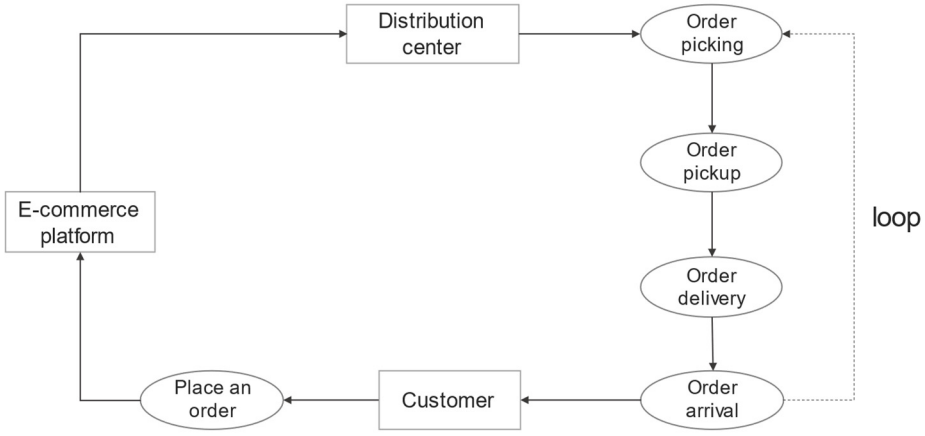

Figure 1. Platform flow chart

On the basis of meeting the requirements of customers' orders and delivery time, considering the different importance of customers, the corresponding time penalty cost is also different. The traditional VRPTW model integrates the platform's differentiated treatment of customers with different values, such as priority delivery for important customers. The goal is to minimize transportation costs and maximize customer value by seeking the best vehicle distribution route and customer service sequence.

3.1. Parameter Description

In practice, the vehicle distribution business of the offline warehouse center of the community E-commerce platform is relatively complex. In order to reduce the difficulty of subsequent modeling and solution, the following assumptions are made first.

(1) The whole model describes the scenario that a distribution center meets multiple customer orders; The distribution center and the geographical location of customers with demand are all known.

(2) The E-commerce platform provides customers with various types of daily necessities. The inventory of the distribution center can meet all customer order requirements, and there is no single customer order exceeding the maximum vehicle load.

(3) The distribution vehicles are of the same type, and the road conditions are good during transportation, that is, the vehicle speed will not be disturbed by factors such as traffic flow, and the vehicles will drive at a uniform speed, and return to the distribution center after completing the task.

(4) The customer has the expected delivery time window. If the vehicle arrives within the specified time, the customer satisfaction is 1, otherwise it is 0.

(5) Only when customers are satisfied will there be a certain probability to publicize the platform. At the same time, the possibility of publicity is also related to the importance of customers, regardless of the negative publicity of customers to the platform.

(6) When calculating the potential value of customers, we only consider the profits brought by customers' future purchase behavior. Other data are difficult to obtain and evaluate, so we don't discuss too much

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Table 1. Parameter

M_0	distribution Centre
$M_c=\{1,2,3,...,m\}$	order set
$M: M_0 \cup M_c=M$	point set
$K=\{1,2,3,...,k\}$	vehicle set
v	average driving speed of vehicle
c	unit distance cost
Q	maximum payload
D	maximum mileage
q_i	order demand
t_{ij}	travel time between i and j
d_{ij}	distance between i and j
t_{si}	service time
t_{ai}	time of arrival at customer
E_i	earliest delivery time
L_i	latest delivery time
c_1	penalty cost of early arrival
c_2	penalty cost of being late
f	fixed cost
θ_i	degree of importance
s_i	relative coefficient of average purchase
p_i	relative coefficient of purchase frequency
b	profit per unit quantity order
σ_i	customer contribution value
QV_i	direct customer value
CV_i	potential value
BV_i	total customer value

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3.2. Optimization Objectives

3.2.1. Distribution Cost

Vehicle driving cost includes fixed cost, distance cost and penalty cost.

The fixed cost of vehicle use includes the fixed cost of each call of vehicles and the labor cost of dispatchers. This cost is only proportional to the number of vehicles used.

$$W_1 = f\sum_{k\in K}\sum_{i\in M_c} y_{0i}^k \tag{1}$$

Distance cost is the cost of vehicles performing distribution tasks between customer nodes, which is directly proportional to the driving distance.

$$W_2 = c\sum_{k\in K} y_{ij}^k d_{ij} \tag{2}$$

When the vehicle arrival time is within the interval $[E_i, L_i]$, the customer's satisfaction with the platform service will not be affected, so there will be no time penalty cost. When the vehicle arrives at the customer's location before E_i, the penalty cost will be incurred due to early arrival, and the cost is linear with the difference between arrival time and E_i; When the vehicle arrives at the customer's location after time L_i, penalty fees will be incurred due to being late; The cost is linear with the difference between arrival time and L_i.

$$w_i(t_{ai}) = \begin{cases} \theta_i c_1(E_i - t_{ai}) & t_{ai} < E_i \\ 0 & \\ \theta_i c_1(t_{ai} - E_i) & t_{ai} > E_i \end{cases} \tag{3}$$

The total penalty cost is:

$$W_3 = \sum_{i\in M_c} w_i(t_{ai}) \tag{4}$$

3.2.2. Customer Value

In the follow-up questions, it is considered that the current value of customer i is the product profit directly paid by the customer to the community E-commerce platform in this consumption activity QV_i

$$QV_i = q_i b \tag{5}$$

In order to evaluate customer value more comprehensively and accurately, enterprises need to analyze customer contribution from the long-term time dimension. We should not only see the immediate income, but also pay attention to the value that future customers choose to bring to the enterprise. In order to facilitate quantification and reduce the difficulty of modeling, this part only considers the cash income brought by customers' possible purchase behavior in the future.

$$CV_i = \lambda_i p(i) QV_i \tag{6}$$

λ_i is the customer's satisfaction. Only when this distribution service is recognized by the customer can the subsequent customers continue to place orders on the platform. In practice,

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customer service experience is often related to factors such as product quality and the attitude of distribution personnel, which are difficult to quantify. Therefore, this model only considers the influencing factor of delivery time.

To sum up, after completing the distribution service of customer I, the calculation formula of the total value obtained by the community E-commerce platform from the customer is:

$$BV_i = QV_i + CV_i \tag{7}$$

Based on the analysis of the optimization objectives in the previous section, the two objective functions of this model include minimizing the platform distribution cost and maximizing the customer value.

$$\min F_1 = f\sum_{k\in K}\sum_{i\in M_c} y_{0i}^k + c\sum_{k\in K} y_{ij}^k d_{ij} + \sum_{i\in M_c} w_i(t_{ai}) \tag{8}$$

$$\max F_2 = q_i b + \lambda_i p(i) QV_i \tag{9}$$

In order to make the two objective functions have the same optimization direction as a whole, the minimum distribution cost in formula (8) is now transformed into the maximum negative distribution cost, that is, it becomes the maximum value problem of a single objective.

$$\max F = \sum_{i\in M_c}(q_i b + \lambda_i p(i) QV_i) - f\sum_{k\in K}\sum_{i\in M_c} y_{0i}^k + c\sum_{k\in K} y_{ij}^k d_{ij} + \sum_{i\in M_c} w_i(t_{ai}) \tag{10}$$

The constraints of this model are mainly composed of the constraints of vehicle routing problem with time window.

$$\sum_{k\in K}\sum_{j\in M} y_{ij}^k = 1, \forall i \in M \tag{11}$$

$$\sum_{k\in K} x_{ik} = 1, \forall i \in M \tag{12}$$

$$\sum_{k\in K}\sum_{j\in M} y_{ij}^k - \sum_{k\in K}\sum_{j\in M} y_{ji}^k = 0, \forall i \in M, i \neq j \tag{13}$$

$$\sum_{j\in M} y_{0j}^k \leq 1, \forall k \in K$$
$$\sum_{i\in M} y_{j0}^k \leq 1, \forall k \in K \tag{14}$$

$$\sum_{i,j\in M_c} y_{ij}^k q_i \leq Q, i \neq j, \forall k \in K \tag{15}$$

$$\sum_{i,j\in,M} y_{ij}^k \leq |N_k| - 1, \forall k \in K \tag{16}$$

$$\sum_{j\in M} y_{ij}^k = x_{ik}, \forall i \in M, \forall k \in K \tag{17}$$

$$\sum_{k\in K}\sum_{i\in M} y_{ij}^k (t_{ai} + t_{si} + t_{ij}) = t_{aj}, \forall i \in M, i \neq j \tag{18}$$

$$t_{ij} = d_{ij} / v \tag{19}$$

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$$\sum_{i,j\in,M_c} y_{ij}^k d_{ij} \le D,\forall k \in K \tag{20}$$

(11) and (12) means that each customer will only be served once by one car. (13) means that each vehicle must leave after completing the task at the node. (14) represents the initial time when each vehicle leaves the distribution center; At the end of the task, the vehicle must return to the distribution center. (15) means that the order weight on the vehicle cannot exceed its own load limit. (16) means avoiding sub circuits. (17) represents the traffic balance of network nodes.(18) represents the calculation of the time when vehicle k arrives at customer j from customer i. (19) represents the vehicle travel time from customer i to customer j. (20) means that the transportation distance of each vehicle in this distribution task cannot exceed its maximum mileage limit.

The decision variables of the model include vehicle routing variables, customer satisfaction and vehicle allocation variables, all of which are 0-1 variables.

(1) Vehicle allocation variable:

$$x_{ik} = \begin{cases} 1 \\ 0 \end{cases}$$

1 means the vehicle k provides services to customers; 0 means other.

(2) Vehicle path variable:

$$y_{ij}^k = \begin{cases} 1 \\ 0 \end{cases}$$

1 means vehicle K travels from customer point i to customer point j; 0 means other.

(3) Customer satisfaction variables:

$$\lambda_i = \begin{cases} 1 \\ 0 \end{cases}$$

1 means that the order of customer i is delivered within the expected time window, and the satisfaction is 1; 0 means other.

4. Algorithm

The solution idea of this model is how to allocate all the current orders to the vehicles in the distribution center and the subsequent route arrangement of vehicles. The solution to the path planning problem under static conditions is as follows:

(1) Data processing. By default, all customer information is known before allocation, including order information and consumption information of different customers. The order information includes the quantity of products ordered by the customer on the platform and the expected delivery time; The customer's consumption information refers to the customer's purchase quantity and purchase frequency, so we can get the customer's importance factor.

(2) Generate distribution routes. Considering the location constraints and time constraints of the order, the initial path of vehicle distribution is generated.

(3) Iterative update of route. This model intends to use heuristic algorithm to continuously update the route. By calculating and comparing the objective function value of each path, the better route scheme is selected.

The model established above belongs to NP-Hard problem. According to the analysis, the solution methods for such problems include accurate algorithm and heuristic algorithm. Theoretically, the exact algorithm can obtain the optimal solution of the model, but it takes a long time and is suitable for small-scale problems; The heuristic algorithm has poor accuracy and can obtain the relative optimal solution of the model, but it takes a short time and is suitable

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for large-scale examples. Because many variables will be involved in this problem, considering the solution time, the genetic algorithm in the heuristic algorithm is selected for solution.
The specific flow of solving the model in this paper by using genetic algorithm is as follows:

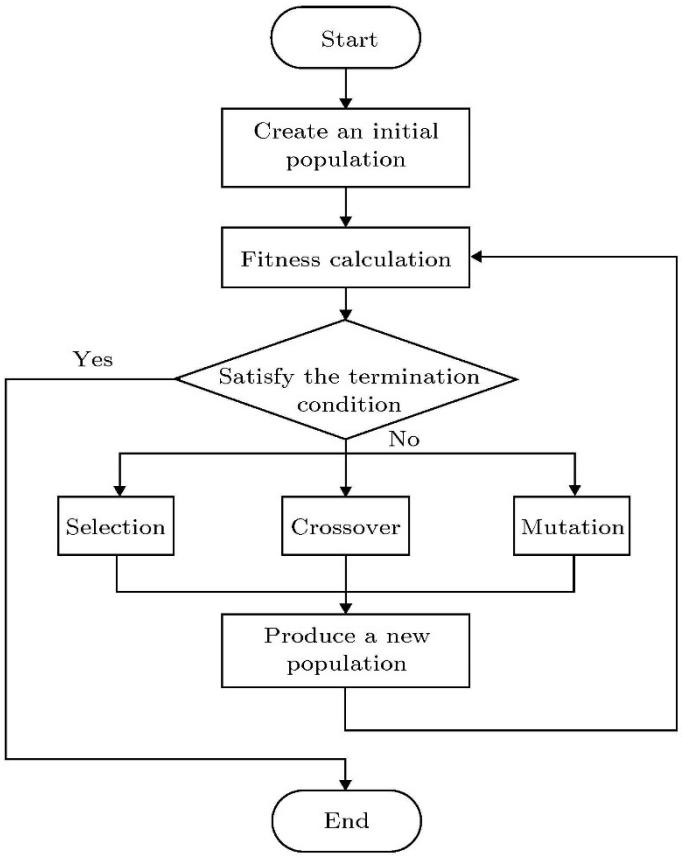

Figure 2. Algorithm flow chart

5. Case Studies

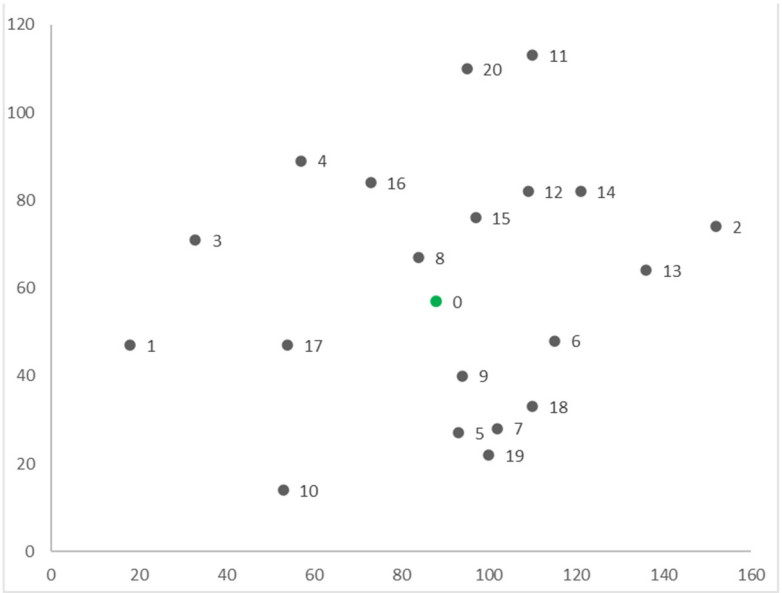

Figure 3. Customer distribution map

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In order to verify the feasibility and effectiveness of the model and algorithm, this chapter solves the model through specific data. Suppose a community E-commerce platform has a front warehouse in place a, which provides customers with the purchase and distribution services of all kinds of fresh and daily necessities within a range of about five kilometers every day. The distribution center has 10 distribution personnel to provide distribution services. All orders are sent from the distribution center. The daily delivery time of the platform is from 8 a.m. to 10 p.m. this chapter mainly studies the distribution path planning in the morning.

Record the distribution center as 0, there are 20 customer points waiting for the delivery of vehicles to the door, and record the customer number as 1, 2, ..., 20. The relative position distribution of the distribution center and customer demand points is shown in the Figure 3:

5.1. Basic Data

By default, the customer's demand has been known by the platform before the start of distribution. The specific information includes the customer's geographical location information, expected time window, product demand and customer point service time, as shown in the table below:

Table 2. Order information

number	x coordinate	y coordinate	left time window	right time window	service time (min)	order quantity (kg)
0	88	57	8:00	12:00	0	0
1	18	47	8:40	9:10	10	3
2	152	74	9:00	11:00	15	2
3	33	71	8:30	9:00	20	6
4	57	89	8:10	8:40	30	3
5	93	27	10:30	12:00	25	5
6	115	48	10:00	11:30	25	6
7	102	28	8:30	9:00	35	3
8	84	67	8:00	8:15	30	5
9	94	40	8:00	9:00	25	2
10	53	14	9:30	10:30	15	5
11	110	113	8:00	8:25	40	5
12	109	82	9:00	9:40	20	6
13	136	64	9:20	9:50	30	3
14	121	82	8:15	9:15	30	3
15	97	76	10:00	11:00	30	4
16	73	84	9:10	9:40	20	3
17	54	47	8:10	8:40	20	5
18	110	33	8:50	9:50	20	2
19	100	22	8:50	9:50	30	4
20	95	110	9:10	10:00	30	3

σ_i is the product of s_i and p_i. According to the above table, 20 customers are divided into four categories, and their priority factors are 1, 1.1, 1.2 and 1.3 respectively. This parameter will affect the subsequent distribution order. Because the penalty function calculation of different customers is different, while trying to meet the needs of all customers, we should also give priority to the distribution services of more important customers as much as possible. If there

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is a large gap in the importance of customers, a vehicle may only serve few customers in order to ensure on-time delivery. Therefore, in the actual analysis, pay attention to the division of sections.

Table 3. Customer information

number	s_i	p_i	σ_i	θ_i
1	1.2	0.73	0.88	1
2	0.9	1.02	0.92	1
3	0.78	1.38	1.08	1.1
4	1.45	0.87	1.26	1.3
5	0.95	0.82	0.78	1
6	1.33	0.88	1.17	1.2
7	1.21	0.93	1.13	1.2
8	0.94	0.96	0.90	1
9	0.56	0.96	0.54	1
10	1.23	0.59	0.73	1
11	1.02	1.07	1.09	1.1
12	0.88	1.08	0.95	1
13	0.74	1.11	0.82	1
14	1.31	0.51	0.67	1
15	1.24	0.56	0.69	1
16	0.76	1.29	0.98	1
17	0.82	1.44	1.18	1.2
18	1.11	1.14	1.26	1.3
19	1.23	0.59	0.72	1
20	1.47	0.80	1.17	1.2

Table 4. Parameter information

parameter	**numerical value**
speed	18km/h
maximum mileage	30km
load capacity	20kg
unit distribution cost	2 CNY/km
fixed cost	20 CNY/person
early penalty cost	3 CNY /min
delay penalty cost	5 CNY /min
unit product profit	5 CNY /kg

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In the distribution process of such community E-commerce platforms, due to the short distance between customers, small quantity of orders, and considering the traffic conditions of the city, the commonly selected means of transportation is small electric vehicles, and it is assumed that the vehicle models of the distribution center are unified. According to relevant research, the specific parameter settings shown in Table 4.

5.2. Result Analysis

The platform customer order data constructed in the previous section is optimized by genetic algorithm, in which the algorithm parameters are set as follows: the initial population size is 80, the number of iterations is 500, the crossover probability is 0.9, the mutation probability is 0.1, and the elite ratio is 0.1. This model is solved by MATLAB. Because the genetic algorithm has global randomness, the results obtained each time are different, and it needs to be run for many times to obtain better results. Therefore, this problem is solved 10 times to obtain the result of a better operation. It shows that 5 distribution vehicles are required. The iterative curve of genetic algorithm is shown in the figure below:

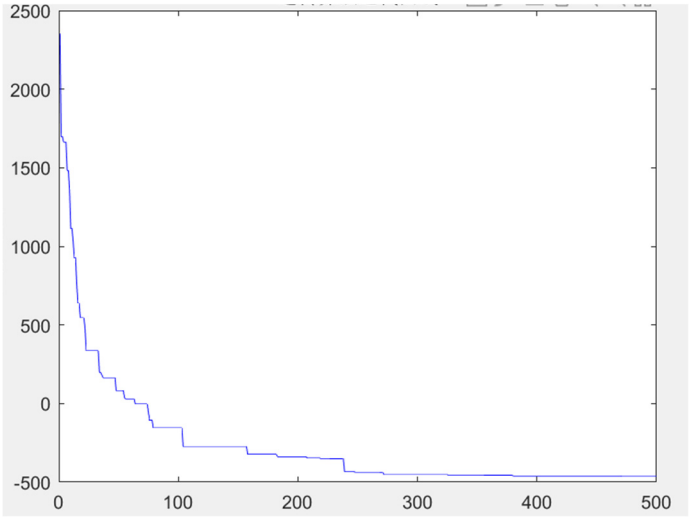

Figure 4. Iterative graph

The driving route map of the vehicle is shown in the figure below:

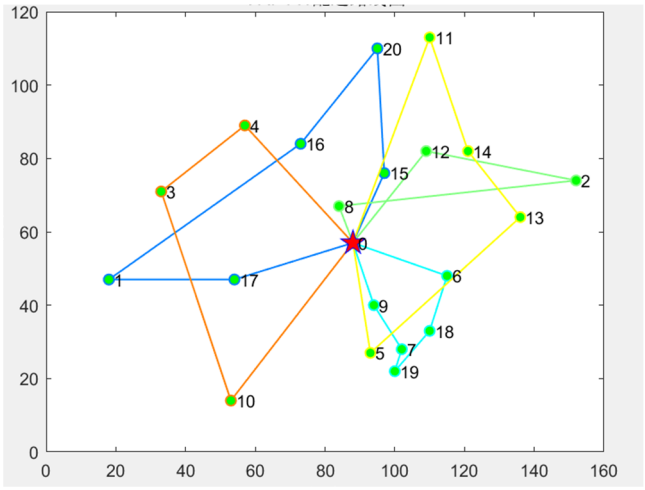

Figure 5. Road map

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The specific distribution route of each vehicle and the time point of arrival at each customer are shown in the table below:

Table 5. Distribution information

vehicle 1	0—>17—>1—>16—>20—>15—>0
arrival time	8:00—8:12—8:44—9:16—9:47—10:29—11:06
vehicle 2	0—>9—>7—>19—>18—>6—>0
arrival time	8:00—8:06—8:36—9:13—9:48—10:13—10:48
vehicle 3	0—>8—>2—>12—>0
arrival time	8:00—8:04—8:56—9:26—9:57
vehicle 4	0—>11—>14—>13—>5—>0
arrival time	8:00—8:20—9:11—9:49—10:38—11:13
vehicle 5	0—>4—>3—>10—>0
arrival time	8:00—8:15—8:55—9:35—10:08
transportation cost	285.73
customer value	794.8
objective function	-464.06

Among the 20 customers, there are 11 general customers and the rest are important customers. According to the results, in this route planning, only the delivery time of customer 2 is not within the expected time window, about 3 minutes in advance, resulting in time penalty cost; Its customer importance factor is 1, that is, ordinary users of the platform. The satisfaction of 9 important customers is 1, and the high satisfaction of important customers helps to improve customers' loyalty to the enterprise and give greater play to customers' value.

6. Conclusion

With the rapid development of E-commerce platform, the service level requirements of customers for E-commerce distribution are also gradually improved. In the face of decentralized and diverse order requirements, how to maximize the satisfaction of customers' personalized needs under the condition of limited resources is a problem that enterprises need to think about at present.

This paper selects the end distribution of community E-commerce platform as the research background, introduces the customer value in customer relationship management, and quantifies its importance through the customer's previous consumption data on the platform. Aiming at the planning of distribution route, a distribution model with minimum total cost and maximum customer value is established.

Through the specific data, the above models are solved respectively. The analysis shows that considering the importance of different customers, not only the distribution cost will be reduced, but also most enterprise customers will get satisfactory service and improve customer value.

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