Research on Distribution Line Based on Satisfaction and Optimal Algorithm

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Abstract. Logistics enterprises attach great importance to customer satisfaction. This paper focuses on customer satisfaction, and innovatively designs the measurement formula of customer satisfaction, which provides a theoretical basis for the construction of the model. In addition, a multi-objective planning distribution route optimization model with fuzzy time window is constructed to further seek the minimum transportation cost and maximum satisfaction. The improved particle swarm optimization algorithm is used to obtain the optimal solution on MATLAB 2018A software. By comparing the original path with the optimal path, the applicability and effectiveness of the model under the condition of customer satisfaction are verified, which provides some reference value for the improvement of other enterprises.

1. Introduction

With the vigorous development of economy, logistics has been called "the last frontier of cost reduction", and the importance of "the third source of profit" has become increasingly prominent. In the current fierce market competition, logistics enterprises attach great importance to customer satisfaction. The maintenance of customer relationship and the development of new customers all depend on the improvement of customer satisfaction. With the gradual improvement of logistics enterprises' hardware facilities, customer satisfaction is mainly affected by the level of distribution service. Therefore, it is necessary to focus on customer satisfaction in the study of distribution routes to maintain loyal customers.

At present, the vehicle routing problem has been widely concerned by scholars at home and abroad and has achieved abundant results. Francois (2016) studied the multi-travel vehicle routing problem and proposed two neighborhood search heuristic algorithms for comparison [1]. Hernandez (2015) et al. studied the exact solution of the vehicle routing problem with time Windows. When solving the pricing problem, they proposed the time discretization problem and designed the branch pricing algorithm to seek the optimal path [2]. For the multi-trip problem with time window, short planning cycle and variable delivery time, Karoonsoontawong et al. (2019) improved the insertion heuristic algorithm to solve the inventory path problem [3]. Guo Haixiang et al. (2017) used the mixed algorithm to conduct mathematical analysis on the obtained data of single-vehicle yard and multi-model vehicle routing problems, which reduced the vehicle transportation cost and carbon emissions [4]. Meng Xianqiu, Qiu Chunyan et al. (2018) applied the improved particle swarm optimization algorithm and set the inertia factor as 0 to optimize the logistics distribution lines, shorten the optimization time, and show that the improved particle swarm optimization algorithm has strong convergence [5]. Wang Xueping (2016)
studied the optimization of urban distribution path, established a mileage saving model with the highest efficiency as the optimization goal, mapped out the logistics distribution path network from the regional distribution center to each customer point, and finally put forward the optimal logistics distribution path scheme [6]. Fu Zhuo (2017) used tabu search algorithm to solve the hybrid vehicle routing problem, which improved the solution quality and operation efficiency [7]. Jin Chun (2018) designed and improved the genetic algorithm and particle swarm optimization algorithm to solve the vehicle routing problem with time window, interpreted the literature in the vehicle routing field, and used the algorithm to carry out path planning according to the partition situation [8]. Zhang Xueting (2017) considered factors such as vehicle type, cargo type and delivery time based on the actual situation, and established a vehicle path optimization model, which was optimized by designing the combination of k-means++ and genetic algorithm. By clustering suppliers, the genetic algorithm was used to arrange the vehicle path in each cluster [9]. Tan Jianwei (2019) takes FMCG under the new retail format as the research object. From the perspectives of both enterprises and consumers, he builds a multi-objective urban terminal distribution network path optimization model with lower cost, shorter distribution distance and higher customer satisfaction, and chooses genetic algorithm to solve the model [10]. Luo Zixuan et al. (2020) in consideration of the number of vehicles, customer satisfaction and cost optimization, introduced the non-dominated sorting genetic algorithm (NSGA-II) to solve the model and used Python to write the program [11].

Through the review of relevant research literature, abundant research results have been accumulated in the field of distribution route optimization. Combined with contributions and limitations, the following four aspects are summarized. In terms of considering customer satisfaction, there are many researches focusing on customer satisfaction in terms of operational efficiency, service evaluation and strategy optimization, but few researches on path optimization of specialized enterprises based on customer satisfaction. In terms of model construction, most of the constructed VRP models take theory as reference, and theoretical analysis and innovation account for a large proportion. From the perspective of algorithms, scholars have made breakthroughs in the improvement of algorithms and patterns, not only in the traditional single algorithm research, but also in the combination of a variety of intelligent algorithms, in order to complement each other's disadvantages. However, the optimization results also have large deviations. From the perspective of research objects, medicine, military and cold chain logistics are the majority, with less objective constraints, so the difficulty of research needs to be improved.

Problem description: The distribution center has $K$ trucks to distribute goods to customers. There is only one in the distribution center and the vehicles are not fully loaded. Is a single vehicle multi-objective vehicle optimization routing problem. The longitude and latitude coordinates and demand of customer point $i$ are determined. Each truck can serve multiple customers, but each customer can only be served once at most, and the truck finally returns to the distribution center. In consideration of customer satisfaction, a reasonable vehicle scheduling scheme is found to optimize the objective function and the distribution route is optimized.

2. Design of customer satisfaction measure
The measurement standard of customer satisfaction not only shows the difference between customer expectation and logistics service perceived performance, but also reflects the difference between customer evaluation of the two. It is beneficial for enterprises to implement customer satisfaction strategy and improve customer satisfaction through clear measurement criteria. The design of the customer satisfaction measure in this paper is to establish the model goal of minimizing the average customer dissatisfaction, that is, $\min Z_1 = 1 - \frac{1}{N} \sum_{i=1}^{N} \lambda_i f_i(t_i)$. $\lambda_i$: The importance of customer $i$ among all customers; $f_i(t_i)$ is the time satisfaction function, and $N$ is the number of customer points. The importance degree of customers is calculated by the measure formula to obtain dynamic data.
2.1. Determination of customer satisfaction index and weight
Based on the theoretical review, this paper studies the classical theoretical model of satisfaction (SCSB, ACSI, ECSI, CCSI) and the satisfaction index model of logistics industry, and determines the selection of customer satisfaction indexes after combing and analyzing. The selection of carding indicators and the determination of weights are shown in Table 1:

| model | Customer Satisfaction Indicator | Weight or measurement method | Effect evaluation |
|-------|---------------------------------|-----------------------------|------------------|
| SCSB  | Perceived value, expected quality, customer complaints, customer loyalty | Integrating the principle of econometrics, quantitative analysis of customer satisfaction | It is widely used in enterprises to evaluate the whole process of customer's consumption of products or services. |
| ACSI  | Perceived quality is added to the SCSB model. | Six structural variables and nine relationships | The customer satisfaction of different industries and enterprises is compared to realize cross-regional comparison. |
| ECSI  | Perceived value, expected quality, customer expectation, corporate image, customer loyalty | The evaluation of corporate image is aimed at some associations and feelings of the customer's memory. | For the first time, we can measure the quality of both products and services. |
| CCSI  | Perceived value, expected quality, perceived quality, brand image, customer loyalty | Questionnaire questions were set, and the index score was obtained through statistical calculation of the econometric model. | Used in most state-owned enterprises, the response is good. |

Based on the carding analysis and combined with the actual market factors, the measurement index set is determined as the proportion of high demand in distribution conditions, the proportion of customer demand, the conversion rate, the repurchase rate and the customer performance rate. In addition, the weight vector of the measurement index is determined by inviting experienced personnel to score the relative relationship between the indicators. According to the statistical analysis of the scoring situation, the relationship between the indicators is determined. Finally, the customer importance measurement formula is established according to the index and weight. The first is to calculate the proportion according to the actual data, the second is to calculate the index weight, and the third is to solve the formula for calculation.

2.2. Customer importance measurement formula
Customer importance = \( \beta_1 \times \text{proportion of high demand for distribution conditions} + \beta_2 \times \text{proportion of customer demand} + \beta_3 \times \text{conversion rate} + \beta_4 \times \text{repurchase rate} + \beta_5 \times \text{customer performance rate} \)

\[
(\beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5 = 1)
\]

The calculation time is based on the data obtained from January of the previous year to the present time. Among them, the proportion of high requirements for distribution conditions = the average amount of special approved goods per single customer/the average total amount of special approved goods per total customer; Customer demand ratio = the average demand of a single customer/the average total demand of total customers; The conversion rate is the conversion rate of customer loyalty and user stickiness (whether the purchase channel is single or not, after-sales evaluation) = the average number of after-sales loyalty evaluations of a single customer/the average total number of after-sales loyalty evaluations of total customers; Re-purchase rate (maximum=1) = total number of purchases by a single
customer/total number of purchases by total customers; Customer performance rate = number of individual customer performance/total customer performance value. The determination of \((\partial_1, \partial_2, \partial_3, \partial_4, \partial_5)\) is to ask experts or experienced people to score the relative relationship between the indicators. According to the statistical analysis of the scoring situation, the relationship between the indicators is determined and the value is determined. This formula will change dynamically with the increase of purchase times, customer demand and customer loyalty. This formula combines the actual situation of the company and makes the customer satisfaction measurement more accurate and practical through the combination of qualitative and quantitative methods.

2.3. Time satisfaction function
Since the most important factor affecting customer satisfaction in the vehicle path is on-time delivery, customers prefer to be served in a specific time period within the time window, and earlier or later than this time period will lead to a decline in customer satisfaction. Therefore, the on-time delivery is used to describe customer satisfaction in this vehicle routing problem. In this paper, the satisfaction function method is chosen to measure customer satisfaction. The fuzzy time window includes the time range of customer expectation and the tolerable service time range. Take \([s_i, e_i]\) as the time range within which customer \(i\) expects to be served. If the customer gets the service within this range, customer satisfaction will be 100%. With \([S_i, E_i]\) represents the service time range tolerated by the customer. \([S_i < s_i < e_i < E_i]\) means that the customer can still accept the service if the service is received within \([S_i, s_i]\) or \([e_i, E_i]\), but the satisfaction decreases as the gap between the service time and the expected time increases. After the tolerable time \([S_i, E_i]\), the customer does not accept the service, and the customer satisfaction is 0. Time satisfaction function is expressed as follows:

\[
f_i(t_i) = \begin{cases} 
  u_i = \left[ \frac{t_i - S_i}{s_i - S_i} \right]^\beta, & S_i < t_i < s_i; \\
  1, & s_i \leq t_i \leq e_i; \\
  g_i = \left[ \frac{E_i - t_i}{E_i - e_i} \right]^\beta, & e_i < t_i < E_i; \\
  0, & \text{else} \end{cases}
\]

3. Establishment of mathematical model

3.1. Basic Assumptions and Symbols
Before establishing the model, the following basic assumptions are made:

1. The distribution vehicle is a single model with a certain load capacity;
2. The delivery quantity to all customers on each line shall not exceed the rated load of the delivery vehicle;
3. Each customer's goods can be mixed, the nature of the goods is the same or similar;
4. The longitude and latitude positions of the distribution center and each customer point, the delivery volume and service time requirements of the customer are known;
5. Equipment accidents, road congestion, natural disasters and other factors are not considered in the transportation process.

As the model involves many symbols, the symbols and variables are explained as follows.
\(V\) is the set of all nodes, namely the set of distribution centers and customer points. \(V = \{0,1,2,..., N\}\);
The center 0 table shows the distribution center, \(\{1,2,..., N\}\) represents a set of customer points.
\(R\) ——Collection of distribution vehicles, \(R = \{1,2,..., K\}\)
\( D_i \) —— Customer delivery volume
\( Q \) —— Rated load weight of the vehicle
\( C \) —— Fixed cost per unit vehicle
\( a \) —— Transportation cost per unit distance
\( d_{ij} \) —— the distance between node \( i \) and node \( j \)
\( l_i \) —— Service time of vehicles at customer point \( i \)
\( t_{ij} \) —— Driving time of the vehicle from customer point \( i \) to \( j \)
\( [s_i, e_i] \) —— The time range within which Customer \( i \) expects to be served, where \( s_i \) represents the lower bound and \( e_i \) represents the upper bound
\( [S_i, E_i] \) —— \( S_i \) represents the lower bound and \( E_i \) represents the upper bound for the service time that Customer \( i \) can tolerate
\( f_i(t_i) \) —— Time satisfaction function
\( \lambda_i \) —— The importance of Customer \( i \) among all customers
\( \omega_1, \omega_2 \) —— The weight coefficient of the objective function

\[
x_{ijk} = \begin{cases} 
1, & \text{Vehicle } k \text{ travels from node } i \text{ to node } j; \\
0, & \text{else}.
\end{cases}
\]

3.2. Model construction
Based on the above, the corresponding mathematical model is as follows.

\[
\begin{align*}
\min \ Z_i & = 1 - \frac{1}{N} \sum_{i=1}^{N} \lambda_i f_i(t_i); \\
\min \ Z_2 & = C \sum_{j=1}^{N} \sum_{k=1}^{K} x_{0jk} + \sum_{i=0}^{N} \sum_{j \neq i}^{N} \sum_{k=1}^{K} a d_{ij} x_{ijk}.
\end{align*}
\]

\[
\text{St} \\
\sum_{i=0}^{N} \sum_{j=0}^{N} D_i x_{ijk} \leq Q, i \neq j, k \in \{1, 2, ..., K\}, \tag{4}
\]

\[
\sum_{j=1}^{N} \sum_{k=1}^{K} x_{0jk} \leq K; \tag{5}
\]

\[
\sum_{k=1}^{K} \sum_{j=0}^{N} x_{ijk} = 1, i \in \{1, 2, ..., N\}, \tag{6}
\]

\[
\sum_{k=1}^{K} \sum_{i=0}^{N} x_{ijk} = 1, j \in \{1, 2, ..., N\}. \tag{7}
\]
\[
\sum_{j=1}^{N} x_{0jk} = \sum_{j=1}^{N} x_{j0k} \leq 1, k \in \{1,2,...K\}; \\
(9)
\]

\[
t_j = \max \left\{ S_j, \sum_{k=1}^{K} \sum_{i=0}^{p} x_{ijk}(t_i + l_i + t_{ij}) \right\}, t_j \leq E_j, \forall j \in \{1,2,...N\}; \\
(10)
\]

\[
t_i + l_i + t_{ij} - H(1 - x_{ijk}) \leq t_j, i,j \in \{1,2,...,N\} \text{ and } i \neq j, k \in \{1,2,...,K\}; \\
(11)
\]

\[
x_{ijk} = 0 \text{ or } 1, i \neq j; \forall i \in \{0,1,2,...,N\}, \forall j \in \{0,1,2,...,N\}, \forall k \in \{1,2,...,K\}. \\
(12)
\]

Where, Equation (1) and (2) are objective functions; Equation (1) represents the minimization of average customer dissatisfaction; Equation (2) represents the minimization of transportation cost, including vehicle running cost (fixed cost per unit vehicle multiplied by number of vehicles) and transportation cost (transportation cost per unit distance multiplied by distance). Equations (6) to (17) are the constraint conditions. Where, Formula (3) is the constraint of vehicle loading capacity; Equation (4) means that the total number of vehicles delivered does not exceed K; Equations (5) and (6) indicate that each customer can only be served by one vehicle; Equation (7) indicates that the vehicle must leave the customer point after reaching the customer point; Formula (8) indicates that only one vehicle in each route starts from and returns to the distribution center. (9) Indicates that the customer is served within the time window; Equation (10) refers to the time when the vehicle arrives at the next customer point later than the current customer point, where H is a large positive number. Equation (11) indicates that the decision variable is 0-1 variable.

3.3. Processing of the objective function

The commonly used multi-objective optimization methods include weighting method, constraint method, ideal point method, goal achievement method, goal programming method and so on. This paper is multi-objective, considering cost minimization and customer dissatisfaction minimization. The weighted method adopted in this paper is simple in thought, low in time complexity and feasible. In general, the optimal solution obtained by weighting method has the following properties: given a weight vector \( W \), the optimal solution \( X^*(W) \) obtained from the single-objective optimization problem, if \( X^*(W) \) is the only optimal solution of the single-objective optimization problem, or \( W > 0 \), then \( X^*(W) \) is a non-inferior solution of the multi-objective problem. In order to solve the problem easily, it is transformed into a single objective optimization problem by assigning weights to the two objective functions. Meanwhile, in order to unify the two objective functions, the objective function is processed as follows:

\[
\min \ Z = \alpha_1 \left(1 - \frac{1}{N} \sum_{i=1}^{N} \lambda_i f_i(t_i)\right) + \alpha_2 \left( \frac{C \sum_{j=1}^{N} \sum_{k=1}^{K} x_{ijk}}{CN} + \frac{\sum_{i=0}^{N} \sum_{j=0}^{K} \sum_{l=1}^{K} a_{ij} x_{ijk}}{2} \right) \\
(13)
\]
Where, CN represents the fixed cost when the number of vehicles in use is maximum. Theoretically, the number of vehicles in use is maximum when each vehicle serves only one customer point. In this paper, it is assumed that the number of vehicles available in the distribution center is no less than the number of customer points N, so the maximum number of vehicles used is N. \( \sum_{j=1}^{N} a_{0,j} \) represents the variable transportation cost when the transportation distance is the maximum, and the maximum transportation distance is the sum of the transportation distances of all vehicles when each vehicle only serves one customer point.

3.4. Model Solving
The model established in this paper is a nonlinear programming model. For VRP problem, PSO algorithm has been widely concerned by scholars in various fields because of its simple algorithm, easy implementation, fast convergence speed and other characteristics. In this paper, an improved particle swarm optimization algorithm, namely BF-PSO algorithm, is introduced into the microflora algorithm. By introducing the process of replication, extinction and migration, the PSO can avoid the precocity and the problem of falling into the local optimal value. The optimization model constructed in this paper is verified by comparing the optimized route with the original distribution route in terms of customer satisfaction and transportation cost through Matlab calculation.

4. Validation of calculation examples and analysis of results

4.1. Calculation example description
Suppose there is a distribution center with 5 distribution vehicles available to deliver goods to 24 customer points. The distribution center coordinates are (0,0), and the same load weight of the vehicles is 2 tons. The customer's sensitivity to time is \( \beta = 1 \), unit distance transportation cost \( a = 3 \) yuan, unit vehicle fixed cost \( C = 150 \) yuan, \( \omega_1 = 0.72, \omega_2 = 0.28 \). The longitude, latitude, demand and time window of 24 customer points are shown in Table 2:

| number | latitude | longitude | time window | demand | latitude | longitude | time window | demand |
|--------|----------|------------|-------------|--------|----------|------------|-------------|--------|
| 1      | 36.650   | 116.961    | [0.60,300,480] | 82     | 13       | 36.688     | 117.005     | 65     |
| 2      | 36.669   | 117.010    | [0.21,150,490] | 46     | 14       | 36.690     | 117.071     | 83     |
| 3      | 36.633   | 116.881    | [18.160,340,450] | 48     | 15       | 36.614     | 116.918     | 101    |
| 4      | 36.665   | 117.107    | [62.150,285,320] | 180    | 16       | 36.684     | 116.319     | 85     |
| 5      | 36.291   | 116.463    | [7.89,200,250] | 105    | 17       | 36.688     | 117.020     | 77     |
| 6      | 36.669   | 117.030    | [35.115,200,260] | 70     | 18       | 36.668     | 117.020     | 48     |
| 7      | 36.720   | 117.169    | [21.110,190,250] | 50     | 19       | 36.620     | 116.799     | 108    |
| 8      | 36.622   | 116.994    | [62.120,200,250] | 67     | 20       | 36.713     | 117.081     | 179    |
| 9      | 36.717   | 116.976    | [0.80,160,230] | 70     | 21       | 36.689     | 117.137     | 110    |
| 10     | 36.695   | 116.994    | [0.48,100,150] | 114    | 22       | 36.976     | 117.164     | 42     |
| 11     | 36.635   | 116.469    | [8.48,150,180] | 112    | 23       | 36.986     | 116.780     | 57     |
| 12     | 36.835   | 116.788    | [32.100,200,350] | 183    | 24       | 36.615     | 117.003     | 30     |
4.2. Example calculation and results

4.2.1. Determine the weight coefficient of satisfaction function. According to the actual situation, $V_1, V_2, V_3, V_4, V_5$ represents the proportion of high demand in distribution conditions, the proportion of customer demand, the conversion rate, the repurchase rate and the customer performance rate respectively. In this paper, the data of 24 customers based on an enterprise are obtained as shown in Table 3:

### Table 3. Proportion of each index

|   | U  | V1(%) | V2(%) | V3(%) | V4(%) | V5(%) | U  | V1(%) | V2(%) | V3(%) | V4(%) | V5(%) |
|---|----|-------|-------|-------|-------|-------|----|-------|-------|-------|-------|-------|
| 1 | 0.0104 | 0.0097 | 0.0171 | 0.0159 | 0.0118 | 13 | 0.009 | 0.0081 | 0.0078 | 0.0111 | 0.0119 |
| 2 | 0.0106 | 0.0057 | 0.0126 | 0.0111 | 0.0114 | 14 | 0.0092 | 0.0099 | 0.0057 | 0.0158 | 0.0107 |
| 3 | 0.0085 | 0.005 | 0.0192 | 0.0163 | 0.0106 | 15 | 0.0106 | 0.0125 | 0.0114 | 0.0067 | 0.0101 |
| 4 | 0.0108 | 0.0224 | 0.0096 | 0.0095 | 0.0123 | 16 | 0.0107 | 0.0106 | 0.0165 | 0.0121 | 0.0117 |
| 5 | 0.0103 | 0.013 | 0.0099 | 0.0082 | 0.0097 | 17 | 0.0121 | 0.0096 | 0.0108 | 0.0156 | 0.0115 |
| 6 | 0.0089 | 0.0084 | 0.0135 | 0.0116 | 0.0107 | 18 | 0.0082 | 0.0061 | 0.0126 | 0.0115 |       |
| 7 | 0.015 | 0.0062 | 0.0198 | 0.014 | 0.0119 | 19 | 0.0093 | 0.0134 | 0.0234 | 0.0203 | 0.0118 |
| 8 | 0.0139 | 0.0083 | 0.0087 | 0.0125 | 0.0117 | 20 | 0.0114 | 0.0222 | 0.0096 | 0.0154 | 0.0112 |
| 9 | 0.0106 | 0.0087 | 0.0141 | 0.0126 | 0.0123 | 21 | 0.0105 | 0.0137 | 0.0126 | 0.0126 | 0.0108 |
| 10 | 0.0092 | 0.0129 | 0.0222 | 0.0081 | 0.0118 | 22 | 0.0121 | 0.0047 | 0.0048 | 0.0072 | 0.0103 |
| 11 | 0.0116 | 0.0139 | 0.0129 | 0.0086 | 0.0117 | 23 | 0.0143 | 0.0071 | 0.0042 | 0.0084 | 0.0117 |
| 12 | 0.0082 | 0.0217 | 0.0045 | 0.0083 | 0.0115 | 24 | 0.0132 | 0.0035 | 0.0129 | 0.0157 | 0.0115 |

As can be seen from Table 4, the index weight vector $V'=(0.083219, 0.112026, 0.411523, 0.132602, 0.260631)$, the conversion rate, customer loyalty and user stickiness weight is the highest, followed by customer performance rate, and the weight proportion of high requirements of distribution conditions is the least. This indicates that enterprise managers believe that customer loyalty has the greatest impact on customer value, and loyal customers will bring more profits to the enterprise.

According to the formula and table data, the importance degree vector matrix of 24 customers is calculated as follows. $\lambda_i = (0.0262897, 0.0247356, 0.0246057, 0.0239093, 0.0237663, 0.0230719, 0.0229915, 0.0224029, 0.0223843, 0.0223448, 0.0221705, 0.0221275, 0.0219807, 0.0218360, 0.0217968, 0.0221692, 0.0221531, 0.02214560)$

### Table 4. Indicator weight calculation table

|   | V1 | V2 | V3 | V4 | V5 | ai  |
|---|----|----|----|----|----|-----|
| V1 | 1  | 1/2| 1  | 1/5| 1/3| 0.083219 |
| V2 | 2  | 1  | 1/2| 1  | 1/3| 0.112026 |
| V3 | 5  | 4  | 3  | 1  | 2  | 0.411523 |
| V4 | 1  | 2  | 1  | 1/3| 1/2| 0.132602 |
| V5 | 3  | 3  | 2  | 1/2| 1  | 0.260631 |

4.2.2. Example results. According to the model built above, data were brought in, and MATLAB programming was used to solve the optimal distribution path. There were 5 optimal distribution paths (as shown in Figure 1), which were represented by different colors in the legend. Route: The first vehicle distribution route: $U_0 - U_11 - U_23 - U_1 - U_19 - U_8 - U_15 - U_0$; The second vehicle: $U_0 - U_7 - U_18 - U_2 - U_24 - U_14 -$
U22-U6-U0; The third vehicle: U0-U10-U17-U13-U3-U0; The fourth vehicle: U0-U21-U16-U9-U0; Fifth vehicle: U0-U20-U12-U5-U4-U0.

![Graph](image)

**Fig 1.** Path optimization result graph

### 4.3. Comparison of schemes

**Table 5.** Comparison of the original and optimized distribution line information data

| Distribution line | Demand for Transport distance (KM) | Customer satisfaction (%) |
|-------------------|------------------------------------|---------------------------|
| **Original distribution line** | | |
| Line 1            | 357                                | 65.77                     |
| Line 2            | 249                                | 69                        |
| Line 3            | 416                                | 73.12                     |
| Line 4            | 277                                | 58.79                     |
| Line 5            | 311                                | 60.44                     |
| Line 6            | 502                                | 55.95                     |
| **total**         | 2112                               | 383.07                    |
| **Transportation cost per time** | 326.8353                           |
| **Vehicle number** | 6                                  |                           |
| **Optimized distribution lines** | | |
| Line 1            | 527                                | 80.66                     |
| Line 2            | 369                                | 75.54                     |
| Line 3            | 304                                | 90.37                     |
| Line 4            | 265                                | 50.89                     |
| Line 5            | 647                                | 88.61                     |
| **total**         | 2112                               | 386.07                    |
| **Transportation cost per time** | 329.3949                           |
| **Vehicle number** | 5                                  |                           |
To sum up, after the optimization of distribution routes, although the transportation cost did not decrease, considering the change from 6 vehicles to 5 vehicles after the optimization, the market purchase price of one transport vehicle, one year’s maintenance cost and one driver’s salary, the total savings in the first year was about 109,000 RMB. By adding the customer satisfaction function into the objective function of the model and measuring the weight coefficient of customer satisfaction through the combination of qualitative and quantitative methods, the overall customer satisfaction of delivery increased from 73.64% to 95.45%, an increase of 29.62%. The improvement of customer satisfaction is of great significance to prevent customer loss, increase loyal customers, achieve long-term development and obtain long-term benefits. The results show that the optimization results are reasonable and operable. The model and algorithm are used to plan the distribution route, so that the driver no longer chooses the distribution route according to his will and experience. In the era of big data and artificial intelligence, its role will become more and more obvious, which will effectively reduce the rate of route overlap, reduce transportation costs and improve economic benefits.

5. Conclusion
Aiming at the vehicle routing problem, this paper takes the lowest cost and the highest customer satisfaction as the optimization goals to establish a multi-objective optimization model. By innovating the customer importance measure formula and using BF-PSO algorithm, the programming language is used to solve the problem on the operating platform of MATLAB 2018a. With the change of demand, complaint rate and other indicators, the measurement of customer satisfaction is dynamic. This paper analyzes the problem through the combination of qualitative and quantitative methods, and the final optimization results are presented in the form of quantification. By comparing the original path with the optimal path, the applicability and effectiveness of the model under the condition of customer satisfaction are verified, which provides some reference value for the improvement of other enterprises.

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