Research on E-commerce Real-time Distribution Path Optimization Based on Different Customer Satisfaction in the New Retail Background

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Abstract: In the distribution process, the timeliness is one of the important factors affecting customer satisfaction. However, the importance of customers to the business is different, which requires the merchant to pay different attention to the customer in the timeliness of delivery, and this can achieve maximum benefit with limited resources. This paper establishes a corresponding model for the real-time distribution route optimization problem under the new retail background, and divides the customers into VIP and mass customers, respectively setting the satisfaction limit of different standards to achieve the lowest cost and the greatest overall customer satisfaction. And using genetic algorithm to solve the model.

1. Introduction

The introduction and development of new retailing has made major e-commerce companies pay more and more attention to the customer experience. The delivery service is no longer simply to deliver the goods to the customers, but to maximize customer satisfaction while keeping costs as constant as possible. In fact, customers are different to the merchants, which require the merchant to provide targeted delivery services. Therefore, how to achieve the greatest customer satisfaction at the lowest cost is a new concern for new retail companies.

The Vehicle Routing Problem (VRP) was first proposed by Dantzig and Ramser [1], and research on VRP has made some progress in the past 10 years. YF Li and ZY Gao [2] studied a class of urban dynamic network vehicle routing optimization problems under real-time traffic information. Jiang and Pan [3] proposed a two-stage logistics distribution path optimization method based on the combination optimization theory of genetic algorithm and ant colony algorithm. Jin-R LIU and FAN Ti-j [4] established a new agricultural product distribution model based on real-time traffic information to maximize customer satisfaction. Chen Ping and Li Hang [5] proposed an optimization model for take-out delivery based on time satisfaction. Jung and Hahani [6, 7] based on randomly formed data, using genetic algorithm to carry out simulation experiments on TDVRP model, comparing the difference between the performance of genetic algorithm and accurate algorithm.

In summary, most scholars have conducted in-depth research on VRP from the perspectives of goods, traffic conditions, etc.. Although there are studies that consider customer satisfaction, they are treated in a unified manner for customers. In view of the current development trend of the real-time distribution, it is a matter for all e-commerce companies to differentiate customers in order to maximize the benefits with limited resources. Based on this, this paper established a model of real-time distribution path optimization that differentiates customer satisfaction.

2. Problem Model construction and Algorithm Design

2.1 Problem Description and Variable Definition

For the real-time delivery, what directly affect customer satisfaction are delivery time besides the quality of the product. In the real scene, the merchant have a promised delivery time to the customer. When the delivery time deviates from the customer expected time, the satisfaction will be lower and drop to 0 when the merchant's commitment time is exceeded. For merchants, they eager to achieve the highest customer satisfaction while keeping costs constant.

We make the following variable definitions: N=[0, 1, 2,..., n] is a set of nodes, where 0 is the distribution center, 1 to n are n_1 VIP customers and n_2 mass customers. K=[0, 1, 2,..., k] is a collection of delivery vehicles. q_i represents the demand of customer i. Q represents The maximum order quantity that can be carried per delivery vehicle. t_i denotes the time taken from the delivery center to completion the delivery of node i. t_{vi} and t_{oi} denotes the time taken of the delivery of the VIP customer and the mass customer respectively. t_{si} represents the service time for the node i, where t_{s0} indicates the time taken to pick up the goods at the distribution center. t_{ij}^k means the travel time from node i to node j. λ_i indicates the satisfaction of the node i, where in the satisfaction of the VIP customer and the mass customer are respectively recorded as λ_{vi} and λ_{oi}. d_{ij} indicates the distance between node i and node j. V_k represents the speed of the vehicle. C_k is the fixed cost per exit, and C_{ij} is the commission for each order. F represents weighted average satisfaction of n customers. μ_i andω_i indicates minimum satisfaction for the VIP customer and mass customer respectively. x_{ij}^k is a 0-1 variable, x_{ij}^k=1 when vehicle k is going from i to j, otherwise it is 0. y_{ik} is a 0-1 variable, y_{ik}=1 when vehicle k serves customer i, otherwise it is 0.

2.2 Establishment of Satisfaction Function

This paper divides customers into the VIP customers and the mass customers, assuming that the customer expected delivery time is in [0, ETi] (ETi < LTi), and the satisfaction λvi=λoi=1 under this condition. The customer acceptable delivery time is [0, LTi]. When this time is exceeded, the customer satisfaction λvi=λoi=0. Therefore, the satisfaction function is as follows:

$$\lambda_i(t_i)=\begin{cases} 0 & t_i > L=T_i \\ f_i = 1-\dfrac{t_i - ET_i}{LT_i} & ET_i < t_i \le LT_i \\ 1 & 0 < t_i \le ET_i \end{cases} \tag{1}$$

For the actual situation, the merchant often sets a minimum satisfaction level in order to keep a good reputation. Because the customer importance is different, the minimum satisfaction levels are also different. The satisfaction function of the formula (1) is processed by the minimum satisfaction level μi and ωi, and converted into the maximum time of the VIP and mass customers respectively, VTi and OTi, where VTi= fi-1(μi), OTi= fi-1(ωi), resulting in a new satisfaction function:

$$\lambda_i(t_i) = \begin{cases} \lambda_{vi} = 1-\dfrac{t_{v_i} - ET_i}{LT_i} & ET_i < t_{vi} \le VT_i \\ \lambda_{oi} = 1-\dfrac{t_{o_i} - ET_i}{LT_i} & ET_i < t_{oi} \le OT_i \end{cases} \tag{2}$$

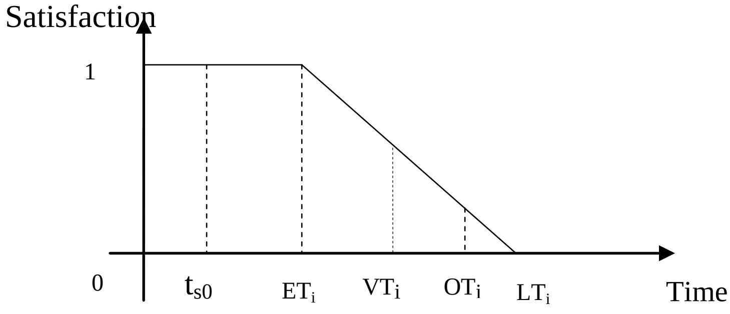

Figure 1. Satisfaction function image

It can be known from equation (2) that the satisfaction is up to λi=1 within the [0, ETi]. The greater the deviation [ti, ETi], the smaller the customer satisfaction. When ti>LTi, the customer satisfaction λi=0. The function image is shown in Figure 1:

2.3 Construction of Real-time Distribution Path Optimization Model on Different Customer Satisfaction

The objective function of this paper is the multi-objective function with the minimum cost and the maximize overall customer satisfaction, which is described as follows:

$$\min C = \sum_{k=1}^{m} c_k + \sum_{k=1}^{m}\sum_{j=1}^{n}\sum_{i=0}^{n} c_{ij}x_{ijk}\text{,}\quad \max F = \frac{w_1\sum_{i=1}^{n_1}\lambda_{vi}(t_i) + w_2\sum_{i=1}^{n_2}\lambda_{oi}(t_i)}{n_1w_1 + n_2w_2}$$

The weights w_1 and w_2 indicate the influence of the satisfaction of the VIP and mass customers on the overall satisfaction, which is related to the number of VIP or mass customers and the limit of their satisfaction. The greater the proportion or the higher the limit, the greater the impact on overall satisfaction, so set $w_1 = \frac{n_1 * \mu_i}{n_1 * \mu_i + n_2 * \omega_i}$, $w_2 = \frac{n_2 * \omega_i}{n_1 * \mu_i + n_2 * \omega_i}$.

This paper transforms the multi-objective function into a single objective function. We set a limit of the customer overall satisfaction according to the actual situation of the enterprise, and transforms the customer satisfaction function into a constraint that not less than the satisfaction limit. Assuming that the limit of the satisfaction is A. The satisfaction objective function F can be converted into the constraint F≥A. Through the above processing, the following mathematical model is obtained:

$$MinC = \sum_{k=1}^{m} c_k + \sum_{k=1}^{m}\sum_{j=1}^{N}\sum_{i=0}^{N} c_{ij}x_{ijk} \tag{3}$$

$$\text{s.t. } F \geq A \tag{4}$$

$$\sum_{j=0}^{n} x_{ij}^{k} = y_{ik}, i = 0,1,2\ldots,n, k = 1,2,\ldots,K \tag{5}$$

$$\sum_{i=0}^{n} x_{ij}^{k} = y_{jk}, j = 0,1,2,\ldots,n, k = 1,2,\ldots,K \tag{6}$$

$$\sum_{k=1}^{m} y_{ki} = 1, i = 1,2,\ldots,n \tag{7}$$

$$\sum_{k=1}^{m}\sum_{i=1}^{n} y_{ik} = n \tag{8}$$

$$\sum_{i=1}^{n} q_i y_{ik} \leq Q \tag{9}$$

$$t_j = t_i + t_{ij} + t_s, i, j = 0,1,2,\ldots,n \text{ 且 } i \neq j \tag{10}$$

Formula (3) is the objective function of the model. Formula (4) limits the minimum value of overall satisfaction. Formula (5)-(6) ensure the flow of each node must be equal. Formula (7)-(8) indicates all customers can only be served once by one car and all customers must be delivered. Formula (9) means the demand qi that delivered by one car cannot exceed the maximum amount Q. Formula (10) indicates the relationship between the time t_j which the vehicle leaves the node j and the time t_i which the vehicle leaves the previous node i.

2.4 Genetic Algorithm Design

This paper uses the integer encoding method. For example, if a merchant uses m delivery vehicles and there are n customer nodes (n≥m), the integers 1 to n represent n customer nodes, and 0 represents the vehicle yard. The encoding method is completed in three steps: the first step is to randomly sort 1 to n customer nodes to generate a set of permutations. The second step is to randomly select m-1 intervals to insert 0 in n-1 intervals between n numbers. Last, insert 0 at the beginning and the end of the arrangement.

The specific algorithm steps are as follows: Step 1: Generate an initial population and set the population size to100. Step2: Calculate the fitness of each chromosome in the population. The fitness function is designed to the reciprocal of the objective function, f=1/c. Step 3: Perform genetic manipulation on each chromosome in the population. Step 4: Completing the genetic generation of the chromosomes to generate the progeny population, judging whether the algorithm termination condition 600 is satisfied, if yes, executing step 5, otherwise returning to step 2. Step 5: Screen out the chromosome with the largest fitness value from the population and decode it.

3. Case Analysis

This article takes a business scene in a retail store as an example. In order to ensure the best freshness of the product, the company requires delivery within 30 minutes. The distance and demand number between each distribution points are shown in table 1, the relevant parameters of the model are shown in table 2.

Table.1. Distance between points and number of demand

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Demand	Customer Type
0	0	1.0	1.00	1.10	1.40	2.00	0.50	2.40	1.00	1.80	0.70	3.00	2.80	2.20	2.60	1.90	0.70	1.10	2.50	1.60	1.30	—	
1		0	1.45	1.19	2.0	2.6	1.50	4.20	2.00	3.40	2.60	4.10	3.40	3.90	3.20	2.60	1.40	1.80	3.20	2.60	2.60	1	V
2			0	2.1	1.8	1.4	0.70	3.40	1.30	5.40	3.00	2.20	1.50	2.20	2.60	4.60	1.50	1.20	4.30	3.00	3.00	1	M
3				0	0.8	3.0	3.00	4.50	2.30	3.30	0.80	4.50	3.70	3.30	3.70	2.50	1.80	2.20	2.00	0.90	0.90	1	M
4					0	3.7	1.10	6.40	3.10	3.90	1.50	5.40	4.50	3.00	4.90	1.60	1.20	1.60	1.20	0.50	0.50	1	M
5						0	0.95	1.50	0.60	3.30	1.80	1.00	1.30	1.90	1.90	2.60	1.50	1.80	3.00	2.30	2.30	1	V
6							0	1.50	0.60	3.30	1.80	1.00	1.30	1.30	1.90	2.60	1.50	1.80	3.00	2.30	2.30	1	M
7								0	2.45	2.60	1.60	1.60	1.90	1.00	1.60	3.50	2.80	3.20	4.50	3.20	3.20	1	V
8									0	4.70	2.30	2.70	2.00	1.60	1.90	3.90	1.90	2.30	3.60	2.30	2.30	2	M
9										0	3.60	7.70	6.60	4.40	4.50	0.74	4.10	4.50	6.00	3.70	3.70	1	M
10											0	5.36	4.10	3.50	3.90	2.90	2.20	2.60	2.60	1.30	1.20	1	V
11												0	1.20	4.00	4.40	6.90	4.30	3.70	6.60	4.80	4.80	2	M
12													0	2.70	2.70	4.20	3.30	2.60	4.70	3.60	3.80	1	M
13														0	1.70	4.00	2.60	3.00	4.30	3.00	3.00	2	V
14															0	4.70	3.50	3.90	6.10	4.70	4.70	1	M
15																0	3.40	3.70	5.30	2.20	2.40	1	M
16																	0	0.70	1.79	1.80	1.80	2	M
17																		0	1.40	3.36	3.15	1	V
18																			0	3.01	2.90	1	M
19																				0	0.10	2	M
20																					0	1	V

Table.2. Values of related parameters

C_k	C_{ij}	Q	V_k	ET_i	t_{s0}	t_{si}	ω_i	μ_i
30yuan	2yuan	7 /V	350m/min	15min	9min	1min	0.5	0.73

This example is solving by coding in MATLAB. Set the population size to N=100, setting a mutation rate of 0.09 and a crossover rate of 0.9, and iterating 600 times. The results are as follows.

a. When the weighted average satisfaction is set to 75%, that is F≥75%, the results obtained after 5 operations are as shown in table 3.

Table.3. Results of 5 operations at F≥75%

	Cost	Delivery Route	Number of Vehicles	Satisfaction
1	190	0-10-20-19-3-18-0-1-17-16-6-8-0-2-5-14-0-4-15-9-0-13-7-11-12-0	5	79.33%
2	190	0-6-5-11-12-2-0-10-20-19-3-16-0-1-17-4-18-0-9-15-0-8-13-7-14-0	5	81.93%
3	190	0-6-5-8-12-11-0-16-4-20-19-3-0-10-7-13-14-0-1-15-9-0-2-17-18-0	5	84.00%
4	190	0-6-5-11-12-2-0-10-20-19-4-15-0-16-17-18-3-0-1-8-14-0-13-7-9-0	5	82.51%
5	190	0-6-8-5-11-12-0-10-3-20-15-9-0-16-4-19-2-0-1-17-18-0-13-7-14-0	5	83.07%

From the above table, the optimal delivery plan is operation 3 when F≥75%. The cost is 75 Yuan and the satisfaction is 84.00% with 5 cars to complete the distribution.

b. When the weighted average satisfaction is set to 85%, which is F ≥ 85%, the results obtained after 5 operations are shown in table 4.

Table.4. Results of 5 operations at F≥85%

	Cost	Delivery Route	Number of Vehicles	Satisfaction
1	220	0-6-8-5-11-12-0-10-3-19-20-4-0-16-17-2-14-0-13-7-0-18-0-1-15-9-0	6	86.81%
2	190	0-6-8-5-11-12-0-10-3-19-20-4-18-0-1-15-9-0-13-7-14-0-16-17-2-0	5	85.39%
3	220	0-6-8-5-11-12-0-10-3-4-20-19-0-16-17-2-14-0-13-18-0-7-0-1-15-9-0	6	87.36%
4	190	0-6-8-5-11-12-0-10-3-19-20-4-0-2-17-16-18-0-1-15-9- 0-13-7-14-0	5	85.01%
5	220	0-6-8-5-11-12-0-10-3-4-20-19-0-16-17-2-14-0-13-7-0-18-0-1-15-9-0	6	88.96%

It can be seen that when F≥85%, the optimal delivery scheme is operation 2. The delivery cost is still 75 Yuan with 5 vehicles to complete the delivery. But the satisfaction is 85.39%.

Comparing several satisfaction values, it can be seen that with the increasing satisfaction, the cost is also rising. As shown in table 5.

Table.5. Objective function comparison table

Satisfaction	Number of vehicles	Cost
75%	5	190
80%	5	190
85%	5	190
90%	6	220

From table 5, we can see that when the overall customer satisfaction is increased from 75% to 85%, the number of vehicles used and the cost are the same. Therefore, when dispatched by 5 vehicles, the customer satisfaction can be increased from 75% to 85% through the optimization of the route while keeping the cost does not rise.

4. Conclusion

In this paper, different satisfaction limits are set for the VIP and mass customers of the new retail store. A real-time delivery route optimization model on different customer satisfaction is proposed. Optimized goals are to improve customer satisfaction and reduce business operating costs. The genetic algorithm is designed to solve the problem. The experimental results verify the rationality and effectiveness of the model and algorithm.

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