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Research on Vehicle Routing problem with Soft Time Windows Considering Different Customers Value

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Abstract

With the development of retail industry, enterprises should continuously improve their competitiveness. while maintaining the value of old customers, enterprises also need to develop the value of new customers. So, in the study of vehicle routing problems, the value of new and old customers and the soft time windows provided by customers will have an impact on the vehicle scheduling scheme. This paper refers to the large customer value theory and the traditional VRP problem, so as to build he problem model of soft time window vehicle path optimization with the lowest transportation cost and the greatest value of new and old customers, the transportation cost consists of the cost of vehicle driving, the cost of commissioning and time penalty cost. After solving with LINGO software, comparing with the soft time window vehicle path optimization problem model which only considers the value of the old customer, it is found that although the transport cost of the former is greater than that of the latter, the customer value generated by the former is much greater than that of the latter, which reduces the increase of transport cost to a certain extent, thus making the total cost of the former much less than that of the latter. The above comparison results highlight the validity of this model and provide some reference value for the decision optimization of distribution path of logistics enterprises.

Keywords

Different customers value; different customers value; VRP.

1. Introduction

Now, product differentiation is more and more small, the enterprise to provide the service more and more similar, under the condition of the market environment increasingly fierce, the enterprise has not only depend on the existing value brought by the old customer, must ensure the old customers without loss, digging the value of the new customers at the same time, it's best to do with huge potential new customers for old customers. Therefore, in the process of vehicle dispatching, the more customers can get the service in the optimal time window, the more customers will feel completely satisfied and the more customer value enterprises can obtain. In this way, the competitiveness of enterprises can be naturally enhanced and enterprises can get long-term development.

This paper applies customer value classification to vehicle path optimization to deepen the research of VRP. At the same time, the influence condition of vehicle routing problem, namely customer value, is classified, which enriches the limitation condition of vehicle routing problem and expands the research direction. This paper seeks a balance between transportation cost and the maximum total customer value, and finds out a vehicle dispatching route with the minimum total cost. On the one hand, enterprises can reduce the cost and obtain the value of new and old customers; on the other hand, consumers can also obtain more satisfactory service.

2. Literature Review

Dantzig and Ramser first proposed The Vehicle Routing Problem, namely, The Vehicle Routing Problem, in The Truck Dispatching Problem[1]. Aiming at minimizing vehicle transportation costs and operating costs, Ge Xianlong and Zou Dengbo established a research model of vehicle routing problem in multiple distribution centers, and designed an improved genetic algorithm for solving the problem[2]. Feng Haojie used AtuoCAD to improve the ant algorithm according to the actual distribution and transportation situation, and verified the effectiveness of his algorithm through an example[3]. After studying the general vehicle path problem, some scholars gradually add the time window into the constraint of VRP. Kang et al. solved the VRP problem with time window and penalty value by tabu search algorithm[4]. Salani et al. took the flow-based discrete segmentation model with time window as the main research basis, and solved it in the way of dabtzig-Wolfe decomposition method combined with branch and bound method[5]. In order to reduce the total cost of the distribution system of supermarket chains and combine the timeliness of distribution in each supermarket, Xia Yankun and Fu Zhuo studied a vehicle routing problem with working time and soft time window, and designed an adaptive tabu search algorithm to solve it[6]. Xie Jiuyong et al. analyzed the background and characteristics of the practical application of VRP with multiple soft time Windows, and designed an adaptive tabu search algorithm to solve the problem[7]. In recent years, researchers pay more and more attention to the factor of consumer value. In 2003, Verheof and Donkers proposed for the first time that the current value and potential value of customers constituted the value of customers, and proposed corresponding measurement methods[8]. Fornell et al. proposed a relationship model between market share and customer satisfaction[9]. Claes et al. believe that the method of econometrics is used to obtain the estimation index of customer satisfaction, and it is found that customer satisfaction is in direct proportion to the quantity of goods[10]. Fan takes customer satisfaction as the core, customer waiting time as an important factor, and builds a corresponding index system, using tabu search algorithm as the basic algorithm[11]. Hu Zoan et al. constructed the time satisfaction function based on fuzzy time window and the goods integrity satisfaction function based on the damage rate, and then established the optimization model with the goal of maximizing customer satisfaction and minimizing transportation cost[12].

Based on the above discussion, the problem of the present study is only considering the old customers have long-term and stable relationship of customer value, and only one of the old customer value as the target function to join with soft time Windows vehicle routing optimization model, did not discuss other types of customer value, and this paper will classify customer value - new customer value and the old customer value, and then add to the vehicle routing problem with soft time Windows, to achieve the appropriate distribution route, make the customer delivery requirements are met. So that customer satisfaction, make enterprise and old customers to maintain stable relations of cooperation, and gradually establish a stable relationship with new customers, enhance the competitiveness of enterprises.

3. The VRP model

3.1. Problem Description

The problem studied in this paper belongs to the closed vehicle path problem with single distribution center, single-vehicle, partially-loaded and dual-objective optimization. The specific description is:

A logistics distribution center is known, which has a sufficient number of transport vehicles available for dispatching. Transport vehicles need to deliver goods for multiple customers. The location and demand of each customer are known, and the optimal time window for each

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customer to be served and the time window for acceptable service are also known. Now it is stipulated that each customer must and can only be served by a distribution vehicle once, and the distribution vehicle must return to the distribution center after completing the distribution task. It is required to arrange the distribution route of transportation vehicles reasonably under the premise of satisfying various constraints, so as to minimize the total transportation cost and maximize the total customer value of new and old customers. To sum up, the basic assumptions of this paper are summarized in the following table.

Table 1 Fundamental Assumption

Numble	Scheme 1
1	The geographical location of the distribution center and customer nodes is known
2	Customer needs do not change and are known in advance
3	The driving cost of the vehicle only considers the cost of fuel consumption
4	All vehicles travel at the same speed and at the same speed during transportation
5	the moment when the vehicle starts from the distribution center is 0
6	The transport vehicle will be 100% satisfied if it serves the customer within the optimal time window specified by the customer
7	Customers who feel 100% satisfied will carry out positive word-of-mouth publicity to the enterprises offering products with a certain probability
8	Irresistible factors such as vehicle failure, road congestion and weather influence are not considered in the transportation process

3.2. Proposed Model Description

The modeling process of this problem is shown in the following table.

Table 2 Set

Set	Introduction
N	The customer node
K	vehicles

Table 3 Parameter

Parameter	Introduction	Parameter	Introduction
c_0	Cost of displacement from i to j	c_1	Penalty cost
s_0	The moment the vehicle leaves the distribution center	c_2	Penalty cost
Z	Maximum loading	u	Fixed cost
q_i	Customer demand	P	Depth of information transmission
$[ET_i, LT_i]$	Earliest service time and latest service time	p_0	Intensity of information transmission
PR_i	Purchase record	φ_i	The importance of customers to the enterprise
l	The number of potential customers around the customer who are willing to	H	A sufficiently large positive number

	do business with the enterprise		
a	Profit per unit of goods		

Table 4 Variable

Variable	Introduction
x_{ijk}	If the arc(i,j) is traversed by vehicle k, $x_{ijk}=1$,else, $x_{ijk}=0$
m	Total vehicles used
s_i	The time when the vehicle arrives at the customer node i
$P_i(s_i)$	Penalty cost function
R_i	Old customer value
PV_i	New customer value

The mathematical model is as follows.

$$min\sum_{K=1}^{K}\sum_{i=0}^{n}\sum_{j=0}^{n}c_0 d_{ij}x_{ijk}+c_1\sum_{i=1}^{N}\max\big((E_i-at_i),0\big)+c_2\sum_{i=1}^{N}\max\big((at_i-L_i),0\big)+\sum_{K=1}^{K}\sum_{j=1}^{N}x_{0jk}u$$
$$-y_i\sum_{i=1}^{N}(\varphi_i p_i p_0 \emptyset_i q_i a)-g_i\emptyset_i\varphi_i\sum_{i=1}^{N}R_i \quad (1)$$

$$\sum_{k=1}^{K}\sum_{j=1}^{j}X_{0jk}\le K \quad (2)$$

$$\sum_{j=1}^{N}x_{j0k}=\sum_{j=1}^{N}x_{0jk}\le 1 \quad k\epsilon\{1,2,\dots k\} \quad (3)$$

$$\sum_{k=1}^{K}\sum_{\substack{i=0\\ i\neq j}}^{N}x_{ijk}=1 j\epsilon\{1,2,\dots N\} \quad (4)$$

$$\sum_{k=1}^{K}\sum_{\substack{j=0\\ i\neq j}}^{N}x_{ijk}=1 i\epsilon\{1,2,\dots N\} \quad (5)$$

$$\sum_{i=0}^{N}\sum_{j=0}^{N}q_i x_{ijk}\le Z k\epsilon\{1,2,\dots K\}, i\neq j \quad (6)$$

$$\sum_{\substack{i=0\\ i\neq r}}^{N}x_{irk}=\sum_{\substack{j=0\\ j\neq r}}^{N}x_{rjk}\ k\epsilon\{1,2,\dots K\}\ , r\epsilon\{1,2,\dots N\} \quad (7)$$

$$at_j=\sum_{\substack{i=0\\ i\neq j}}^{N}\sum_{k=1}^{K}x_{ijk}(at_i+t_{ij}+st_i) \qquad j\epsilon\{1,2,\dots N\} \quad (8)$$

$$at_i+st_i+t_{ij}-H\big(1-x_{ijk}\big)\le at_j\ i,j\epsilon\{1,2,\dots N\}\text{且}i\neq j, k\epsilon\{1,2,\dots K\} \quad (9)$$

$$EE_i\le at_i\le LL_i i\epsilon\{1,2,\dots N\} \quad (10)$$

$$m = \sum_{k=1}^{K} \sum_{j=1}^{N} x_{0jk} \tag{11}$$

$$at_0 = 0 \tag{12}$$

$$x_{ijk} = \begin{cases} 1 \text{ when vehicle k drive from } i \text{ to j} \\ 0 \end{cases} \quad i \neq j \tag{13}$$

$$\emptyset_i = \begin{cases} 1 \; E_i < at_i < L_i \\ 0 \end{cases} \tag{14}$$

$$g_i = \begin{cases} 1 \quad \text{when } PR_i \neq 0 \\ 0 \end{cases} \tag{15}$$

$$y_i = \begin{cases} 1 \text{when } PR_i = 0 \\ 0 \end{cases} \tag{16}$$

Formula 1 represents the objective function, the first part represents the vehicle running cost, the second and third parts represent the penalty cost caused by the vehicle arriving early or late, the fourth part represents the fixed vehicle starting cost, the fifth part represents the potential value of new customers, and the sixth part represents the value of old customers.

Formula 2 represents the limit on the number of vehicles during distribution.

Formula 3 indicates that each transport vehicle must start from the distribution center, and must return to the distribution center after completing all distribution tasks, and the relationship between the former and subsequent nodes.

Formula 4 and Formula 5 represent each customer's intelligence is served once by a transport vehicle.

Formula 6 represents the capacity limit of the vehicle.

Formula 7 indicates that after serving one customer, the vehicle must leave the customer and drive to the next customer node.

Formula 8 said distribution vehicle to reach customers i time calculation.

Formula 9 represents the relationship between the service time of customers before and after.

Formula 10 indicates that the transport vehicle must arrive within a time window acceptable to the customer.

Formula 11 represents the total number of vehicles required in the distribution process.

Formula 12 indicates that the departure time of the transport vehicle is 0.

Formula 14 represents customer satisfaction.

Formula 15 and Formula 16 indicate whether the customer has any purchase record.

4. Numerical Examples Validate

The model in this paper can be described as: there are several vehicles, and these vehicles have to deliver goods to 6 customers. Assuming that each customer has the same service time, the transport vehicle travels at a constant speed of 50 km/h .If you follow the “checklist” your paper will conform to the requirements of the publisher and facilitate a problem-free publication process.

Based on the above data, LINGO is used to solve the model established in this paper. The model solution interface is shown in Fig.1.

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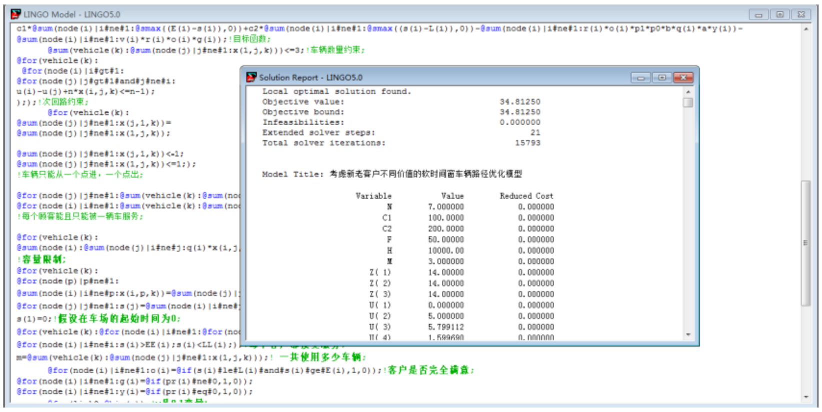

Fig. 1 Consider new and old customer value

According to the above solution results, the distribution in Figure 2 as well as customer satisfaction in Table 5 can be obtained.

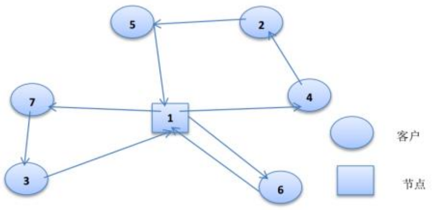

Fig. 2 Route

Table 5 Customer satisfaction

Customer	Important degree	Arrival time	Service window	Optimum time window	Customer satisfaction
1	1	2.8	[2.8,3.3]	[1,2]	no
2	1	4	[4,4.5]	[4,5]	yes
3	1.5	1.5	[1.5,2]	[1,2]	yes
4	1.2	5.3	[5.3,5.8]	[4,6]	yes
5	2.5	4	[4,4.5]	[3,4.5]	yes
6	1.3	2	[2,2.5]	[2,4]	yes

The solution results of the soft time window vehicle routing problem without considering the new customer value are compared with the solution results of the soft time window vehicle routing problem with considering the new and old customer value.

By comparing the results can be analyzed out, although only consider the transportation cost of the old customer value delivery routes (435) less than consider to bring new and old customer value delivery routes of transportation cost (655.75), but at the same time, considering the new old customer value delivery route were completely satisfied with five customers and thus obtained the customer value of 1130.95, and only consider the old customer value delivery routes made four customers fully satisfied, but only three old customers create customer value, and only won the 863 customer value, can be seen clearly, the customer value of the former than the latter. This has allowed the firm to reduce transport costs to a certain extent, showing that the total cost for the former is only 34.8 compared with 312 for the latter.

To sum up, in the study of vehicle path optimization, considering the value of new and old customers at the same time is less than the total cost generated by only considering the value of old customers. Because the more customers who are determined to produce value and feel completely satisfied at the same time, the more customer value they are likely to obtain. If these customers are of great importance, the accumulated value will be far greater than the increase of transportation cost in the end, so as to reach the lowest total cost and obtain the optimal vehicle scheduling. This also shows that the model established in this paper is accurate.

5. Summary

This paper combine the minimum total transportation cost and customer value as the single objective function, at the same time, considering the new and old customer value of the total cost far less than simply consider the old customer value of the total cost, and the more fully satisfied customers, for customer value is the more appropriate, this greatly reduces the transportation process of transportation costs.

In view of the limitation of my knowledge and time, as well as the complexity of the impact of realistic factors on the vehicle path problem, further research is necessary in this paper: 1) In order to facilitate the verification of the accuracy of this model, the realistic factors taken into account in the model established in this paper are not comprehensive.2) The calculation method of customer value still needs to be improved.

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