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# Consider the opportunity cost of logistics distribution route research

**[1] Lu-wen Fei, [2]Xiao-bing Xu, [3]Qiu-man Li**

[1]School of Management, University of Shanghai for Science and Technology, Shanghai, China
[2]School of Management, University of Shanghai for Science and Technology, Shanghai, China
[3]School of Management, University of Shanghai for Science and Technology, Shanghai, China

Email: dedeflw@163.com

**Abstract** –The vehicle scheduling problem with time windows is a derivative of the vehicle scheduling problem. In this paper, the opportunity cost for the customer is introduced to the Logistics Distribution Vehicle Routing Problem with time windows. By blurring the time window, processing and transform the opportunity cost for the customer to a faction associated with the delivery service time, this article building the C-W algorithm considering the opportunity cost. Finally use the instance to prove the Vehicle Routing Problem with time windows is meaningful on the vehicle scheduling problem.

**Keywords** –Logistics and distribution; Time windows; Opportunity cost; C-W saving algorithm

## 1. Introduction

In recent years, with the rapid development of the logistics industry, as "the third profit source", Logistics and distribution has become the main competition field, the logistics cost has also received more and more attention. How to combine the actual conditions of demand, the vehicle scheduling problem is studied, further improvement and optimization of logistics and distribution system, as far as possible, reduce cost, reduce the staff fatigue, improve customer satisfaction, will become the important issues of logistics and distribution optimization study.

In the Logistics and distribution process mainly includes three aspects, one is the recipient of goods (customer), another is the distribution of personnel, three essential transportation tool. For customers, their main purpose of delivery time and quality of service. In this paper, comprehensive opportunity cost, delivery personnel service levels and cost optimization, using C-W algorithm, in order to find the best path in logistics and distribution.

## 2. Problem description and mathematical model

### 2.1 Problem description

Distribution center to its services within the scope of customers cargo constitute an undirected graph $V=(P,L)$ , which for the customer set $P=(0,1,2,\cdots)$ , edge set $L$ . The vehicles in the distribution center full of goods, goods will be sent to each customer, complete the task after the return distribution center. In the actual problem, vehicle and task may exist various constraint conditions. In this paper, requirements of vehicle overload, distribution vehicle does not exceed the company has the total number of vehicles, and try to arrange the least vehicle distribution, as far as possible at the request of the customer time distribution. When the distribution over time will cause the customer the opportunity cost, delivery time and expected time difference is bigger, the customer the opportunity cost is high. The problem is how to optimize the transport path so that the customer the opportunity cost and delivery cost minimum.

### 2.2 Variable definition

The definition of the parameters and variables:
P: Customers point, set (P=0, 1, 2 • •), this paper consider only one distribution center, and distribution center for the 0;
q: Vehicle maximum capacity;

c: Vehicle running cost per kilometer;
K: Set of vehicles;
$P_i$: Customer demand for the i;
$d_{ij}$: The distance between the customer i to j;
$T_{ij}$: Time From i to j;
$s_i$: The service starting time for Customer i;
$e_i$: The service end time for Customer i;
[ $ETi$ , $LTi$ ] : Expectation of the business hours range for customer i, $ETi$:Customer expectation service began in the earliest time, $LTi$:Customer expectation service start time the latest;

Many scholars with time window of vehicle scheduling problem is studied, but the practical application of customer requirements for distribution business hours and not hard time window that is not elastic, soft time window that will produce additional cost, so the fuzzy time windows vehicle scheduling more conform to the actual.

Set customer opportunity cost and delivery time of the conversion between:

$$F(s_i)=\begin{cases}\dfrac{ETi-s_i}{ETi-EETi}, & (s_i\in[EETi,ETi))\\ 0, & (s_i\in[ETi,LTi])\\ \dfrac{s_i-LTi}{ELTi-LTi}, & (s_i\in(LTi,ELTi])\\ 1, & (\text{otherwise})\end{cases};$$

When the customer service time in [ $ETi$ , $LTi$ ] , is the lowest opportunity cost; otherwise, opportunity cost with business hours and expect the time gap between the increase and reduce. $EETi$ and $ELTi$ are the customer can tolerate the earliest and latest start time point.

## 2.3 Objective function and constraints

Since the distribution cost and the transportation distance, according to the above analysis, this paper studies the optimization problem, which can be expressed as:

Constraint condition

$$\text{Min}\{\sum_{i\in P}\sum_{j\in P}\sum_{k\in M} d_{ij}\cdot x_{ijk},\ \sum_{i\in P}F(\text{s}_\text{i})\}$$

$$x_{ijk}=\begin{cases}1, & (\text{Vechicle K from i to j})\\ 0, & (\text{Otherwise})\end{cases} \quad (2.1)$$

$$y_{ik}=\begin{cases}1, & (i\ complete\ by\ vehicle\ K)\\ 0, & (\text{Otherwise})\end{cases} \quad (2.2)$$

$$\sum_i P_i\cdot y_{ik}\le q\ (\ \forall k\in M\ ) \quad (2.3)$$

$$\sum_{k\in M} y_{ik}=1 \quad (\ \forall i\in P\ ) \quad (2.4)$$

$$\sum_{i\in P}x_{0ik}=\sum_{j\in P}x_{jEk}=1\ (\ \forall k\in M\ ) \quad (2.5)$$

$$\sum_{i\in P1}x_{ihk}-\sum_{j\in P1}x_{hjk}=0 \quad (\ \forall k\in M, h\in P\ ) \quad (2.6)$$

(2.3) said that the delivery vehicle using a uniform load models, in the process of transporting vehicle shall not be overloaded;

(2.4) that each customer can only be a car service time;

(2.5), (2.6) that only one vehicle distribution center, start from the center and finally back to the center.

# 3. Steps of algorithm

## 3.1 The basic idea of save method

Let O be a distribution center, respectively A and B two customers, set O to the customer A and customer B distance were a and B. Customer A and B as the distance between C, the existing two kinds of delivery options, as shown in Figure 1.

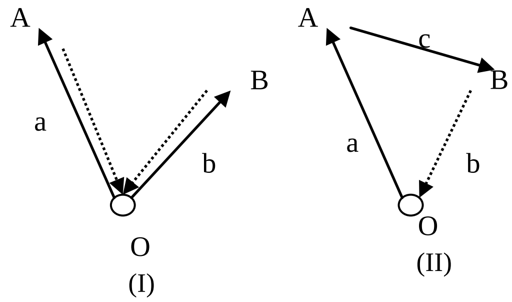


**Figure 1.** Distribution Scheme

In Figure 1 (a) distribution distance $2(a+b)$, figure 1 (b) distribution distance $a+b+c$ , obviously two distribution distance does not equal, figure 1 (I) plan distribution distance is less than $a$. Fig. 1 (II) plan relative scheme saving distribution range:

$$2(a+b)-(a+b+c)=a+b-c>0$$

Based on the basic idea, a distribution center to a plurality of customer delivery goods, in the truck range, each car distribution line service customer number more, then save mileage number increasing, the more reasonable distribution line.

## 3.2 Consider the customer the opportunity cost saving algorithm

Because of the distribution of tasks completed within a certain period of time, according to the cost saving value $S(i, j)$ connection point $i$ and $j$, may make the $j$ following tasks can not meet the time requirements. When the connecting point $i$ and the point $j$ the line, if the vehicle reaches the point of $j$ time later than the original line on the task $j$ start time, might influence

$j$ and vehicles behind the point $j$ task time, lead to customer's opportunity cost increases; similarly, if the connection point of $j$ arrival time than the original line $j$ on the task start time delayed, will also affect the opportunity cost of the point $j$ and vehicles the points after. The specific steps of solving the following:

Step 1: Calculation $S(i, j)$, set $\{ M = \{S(i, j) | S(i, j) > 0 \}$

Step 2: Set $M$ sorting according to $S(i, j)$ from big to small order

Step 3: If $M = \Phi$, end. Otherwise the inspection sorting after the first $S(i, j)$, if it satisfies the following one of three conditions, in turn, fourth step, conversely, in turn, seventh step.

① points $i$ and $j$ are not in the form line;

② $i$ or $j$ in the form lines, but not line point (that is not directly connected with the yard);

③ The points $i$ and $j$ in the form of different line, but not the point, and one is starting point, is a point.

Step 4: Investigation of point $i$ and point $j$ connection line total cargo volume of $Q$, if $Q \le q$, in turn, fifth step, or the seventh step.

Step 5: Calculation $\sum_{i \in P} F(s_i)$

① if $\sum_{i \in P} F(s_i) = 0$, turn step 6；

② if $\sum_{i \in P} F(s_i) = 1$, turn step 7；

Step 6: Connecting the dots $i$ and $j$, turn step 7

Step 7: Set $M = M - S(i, j)$, turn step 3

## 4. Example

For example, a distribution center in the 0 to 8 different customers, each customer relative to the distribution center distance and each customer from the distance between a given table one; table two shows each customer's demand $P_i$, each customer need and customer for business hours business hours requirements. In order to calculate the simple, a distribution center from the point of the beginning of 8, the average speed of 2km/h, the running cost is every kilometer 1, distribution center, vehicle's maximum load is 16.

**Table 1.** Customers and distribution center and the distance between customers

| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 10 | 9 | 7 | 8 | 8 | 8 | 3 | 4 |
| 1 | 10 | 0 | 4 | 9 | 14 | 18 | 18 | 13 | 14 |
| 2 | 9 | 4 | 0 | 5 | 10 | 14 | 17 | 12 | 13 |
| 3 | 7 | 9 | 5 | 0 | 5 | 9 | 15 | 10 | 11 |
| 4 | 8 | 14 | 10 | 5 | 0 | 6 | 13 | 11 | 12 |
| 5 | 8 | 18 | 14 | 9 | 6 | 0 | 7 | 10 | 12 |
| 6 | 8 | 18 | 17 | 15 | 13 | 7 | 0 | 6 | 8 |
| 7 | 3 | 13 | 12 | 10 | 11 | 10 | 6 | 0 | 2 |
| 8 | 4 | 14 | 13 | 11 | 12 | 12 | 8 | 2 | 0 |

**Table 2.** Mission specific requirements

| Mission | Freight traffic | Handing time | Time window | Fuzzy time window |
|---|---|---|---|---|
| 1 | 4 | 1 | [17,19] | [16,20] |
| 2 | 3 | 2 | [14,16] | [13,17] |
| 3 | 9 | 1 | [11,12] | [10,13] |
| 4 | 6 | 3 | [14,17] | [13,18] |
| 5 | 3 | 2 | [12.14] | [11,15] |
| 6 | 8 | 2.5 | [12,18] | [11,19] |
| 7 | 5 | 3 | [10,12] | [9,13] |
| 8 | 3 | 0.8 | [11,14] | [10,15] |

According to the above steps to solve, first by various customers saving mileage sort, as shown in table three.

**Table 3.** Save mileage value sort table

| No. | Connection point | Save mileage |
|---|---|---|
| 1 | A-B | 15 |
| 2 | B-C | 11 |
| 3 | C-D | 10 |
| | D-E | |
| 5 | E-F | 9 |
| 6 | A-C | 8 |
| 7 | B-D | 7 |
| 8 | F-G | 5 |
| | G-H | |
| 10 | A-D | 4 |
| | F-H | |
| 12 | B-E | 3 |
| | C-E | |
| | D-F | |

According to the data in table three, using the above procedure for final considering customer opportunity cost, distribution of the optimal path, the total distribution route for a total of three, as shown in table four.

**Table 4.** The results obtained by this method the path

| Vehicle | The tasks performed by point | Cost | Freight traffic | Opportunity cost | Total cost |
|---|---|---|---|---|---|
| 1 | 0-3-2-1-0 | 26 | 16 | All 0 | 48 |
| 2 | 0-5-4-0 | 22 | 9 | All 0 | |
| 3 | 0-8-7-6-0 | 20 | 16 | 0.2, 0, 0.8 | |

Through the above examples of previous section presents the ideas to verify, in a time window and freight vehicles do not overload constraint conditions based on structure of bicycle transportation, distribution of the case model. The customer timing requirements fuzzy processing, and delivery time and customer opportunity costs associated with, which was established to consider the customer the opportunity cost of C-W saving algorithm. Let the customer the opportunity cost is the choice of connecting point is a condition, in order to find customer lower opportunity cost under the condition of the logistics distribution routing.

## 5. Conclusion

VRP is a combinatorial optimization problem of NP, difficult to use the exact algorithms. This paper is based on the C-W saving algorithm with time window of vehicle routing problem. Considering the time window constraints, single distribution center, not to overload and other aspects of constraint, the distribution business hours and customer opportunity costs associated with, combined with the actual needs on C-W saving algorithm, considering the current customer opportunity cost optimization of vehicle routing problem still not standard validation data, calculating results of an example in the practical application is not necessarily is the optimal solution. But through the example is validated customer opportunity cost and delivery time associate, the customer the opportunity cost for C-W saving algorithm to select connection points of a constraint, to find the optimal path method is feasible. In order to simplify the calculation, this paper uses the fuzzy time window is to the customer time window range is adjusted up and down a time unit, in the practical application of the logistics enterprises can be based on past experience and the actual situation to determine fuzzy time window.

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