Optimization of Dynamic Vehicle Routing Problem for Fresh Agricultural Products

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Abstract. The perishability of fresh agricultural products and real-time traffic information greatly reduce the customers’ satisfaction with fresh products distribution. In this paper, the vehicle distribution model for fresh agricultural products was established to maximize customers’ satisfaction with delivery time and freshness based on real-time traffic information. Genetic algorithm was adapted to get initial routes and dynamic adjusted routes. The results show that customers’ satisfaction can be improved and effect of dynamic traffic can be weakened by rational initial routing optimization and dynamic adjustment.

Introduction

With the improvement of people's living standard and the change of consumption concept, consumers are paying more and more attention to the freshness of fresh agricultural products, which brings a huge challenge for the distribution process of fresh products retailers. For one thing, the perishable characteristics of fresh agricultural products greatly reduces the quality degree; for another, a series of traffic conditions lead to the uncertainty of delivery time, which all greatly influence the customers’ satisfaction. Therefore, considering the freshness of fresh agricultural products, how to reasonable arrange initial vehicle distribution routes and flexibly adjust the routes under the condition of complex traffic conditions is the key to improve customers’ satisfaction level.

At present, the study on dynamic vehicle routing problem (DVRP) for fresh agricultural products is basically for one aspect of them. In the DVRP, it can be tracked to 1980s, Bertsimas and Ryzin [1] conducted an earlier study in this area. Later, Pillac et al. [2] made a review about DVRP. DVRP mainly includes two aspects: variable customer needs and delivery time, the latter is still rarely studied [3]. Kok et al. [4], Guner et al. [5] all researched dynamic vehicle routing problem when sudden traffic congestion happened. As for fresh agricultural products, after entering the 21st century, perishable characteristics of fresh agricultural products started to be considered into the VRP and achieved good results. Amorim et al. [6], Marlies et al. [7] studied static distribution of fresh agricultural products considering quality decay. Flamini et al. [8] compared the cost of initial distribution path and adjusted path under the condition of real-time traffic information.

In this paper, considering freshness decay of fresh agricultural products and real-time traffic information, customers’ satisfaction model about delivery time and product freshness is established to get initial distribution routes and adjusted routes to maximize the customers’ satisfaction level.

Model

(1) Each vehicle starts from the retailer and returns to the retailer after delivery. Each vehicle can serve multiple customers, but each customer's goods can only be served by one vehicle;

(2) Customers have correct acknowledge of the freshness of the received products;

(3) Do not change the customer mix for each car service after the vehicle starts;

(4) When the road traffic congestion take place, due to the duration cannot be estimated, so the vehicle will change the distribution path.

Other variables and parameters are as follows:
Model is as follows:

\[
\max U = \sum_{i=1}^{N} \left( \alpha_{1i} U_{1i} + \alpha_{2i} \right) / N
\]

Subject to

\[(1)\]

\[\sum_{k=1}^{K} x_{ij}^k = 1 \quad \forall i, j \]

\[(2)\]

\[\sum_{j=1}^{N} x_{ij}^k = 1 \quad \forall i, k \]

\[(3)\]

\[\sum_{j=0}^{N} x_{ij}^k \leq y_{ik} \quad \forall i, j, k \]

\[(4)\]

\[\sum_{j=0}^{N} x_{ij}^k = y_{jk} \quad \forall i, j, k \]

\[(5)\]

\[\sum_{j=0}^{N} x_{ik}^j - \sum_{j=0}^{N} x_{ij}^j = 0 \quad \forall i, k \]

\[(6)\]

\[\sum_{k=1}^{K} y_{0k} \leq K \quad \forall k \]

\[(7)\]

\[\sum_{p=1}^{P} \sum_{i=1}^{N} q_{ip} y_{ik} \leq G \quad \forall i, k \]

\[(8)\]

\[a_j = t_{ij}, \text{if } x_{ij}^k = 1 \quad \forall i, j, k \]

\[(9)\]

\[a_j = a_i + s_i + t_{ij}, \text{if } x_{ij}^k = 1 \quad \forall i, j, k \]

\[(10)\]

\[a_j = \begin{cases} a_i + s_i + d_{ij}/v_i, & a_i + s_i + d_{ij}/v_i \leq T_i \\ T_i + (d_{ij} - (T_i - a_i - s_i)v_i)/v_{i+1}, & a_i + s_i + d_{ij}/v_i > T_i \end{cases} \quad \forall i, j \]

\[(11)\]

\[\theta_{ip}(t_i) = \theta_{0p} e^{-\eta a_i} \quad \forall i, p \]

\[(12)\]
Objective function (1) indicates that customers' satisfaction with delivery time and product freshness is maximized. Constraints (2) ~ (6) are transportation flow constraints; (7) indicates that allow a portion of the vehicle to be idle; (8) indicates that the total distribution weight of each vehicle does not exceed the load limit; (9) ~ (11) are vehicle delivery time; (12) is the freshness change with time; (13) ~ (14) are customer satisfaction with the delivery time and product freshness; (15) are 0-1 variables.

Case Analysis

This paper adapts an example of 50 customers in CAB dataset. Genetic algorithm is applied to solve the complex VRP problem for fresh agricultural products based on the versatility and strong robustness. On the basis of the first round of the optimal solution, to resort distribution customers of each vehicle to get the second round optimization, shown in Table 1 and Figure 1. After the first round of optimization, the maximum customers' satisfaction is 0.929. Then the second round of optimization increases it to 0.937, customers satisfaction has been significantly improved.

### Table 1. Example results.

<table>
<thead>
<tr>
<th></th>
<th>First round optimization</th>
<th>Second round optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer satisfaction</td>
<td>0.929</td>
<td>0.937</td>
</tr>
<tr>
<td>Distribution path</td>
<td>(0,32,25,5,21,14,39,0)</td>
<td>(0,14,21,32,23,5,39,0)</td>
</tr>
<tr>
<td></td>
<td>(0,4,7,3,6,4,49,47,0)</td>
<td>(0,17,3,7,6,4,49,47,0)</td>
</tr>
<tr>
<td></td>
<td>(0,33,19,10,8,11,37,43,0)</td>
<td>(0,19,8,11,33,44,43,37,0)</td>
</tr>
<tr>
<td></td>
<td>(0,20,16,9,50,27,46,45,35,32,38,0)</td>
<td>(0,20,16,9,27,22,34,35,50,46,40,45,38,0)</td>
</tr>
<tr>
<td></td>
<td>(0,12,15,1,30,42,0)</td>
<td>(0,30,15,12,1,42,0)</td>
</tr>
<tr>
<td></td>
<td>(0,28,13,26,31,24,18,29,41,48,2,0)</td>
<td>(0,28,13,26,2,31,24,18,29,41,48,0)</td>
</tr>
<tr>
<td>Distribution distance</td>
<td>993</td>
<td>954</td>
</tr>
<tr>
<td>Customer quantity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time window=1</td>
<td>36</td>
<td>37</td>
</tr>
<tr>
<td>Time window(0,1)</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Time window=0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Freshness=1</td>
<td>37</td>
<td>38</td>
</tr>
<tr>
<td>Freshness(0,1)</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Freshness=0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The satisfaction after adjustment is slightly lower than that initial path without traffic congestion, but much larger than the condition with traffic congestion, which is consistent with the actual situation. At the same time, the sudden traffic congestion reduces the customers’ satisfaction and the adjustment based on the real-time traffic information weakens the influence of congestion and improves the customers’ satisfaction.

The initial distribution path (0,19,8,11,10,33,44,43,36,37,0) (Figure 2) is affected by traffic congestion and adjusted path is (0,19,8,11,36,43,33,44,37,10,0) (Figure 3). It can be found that the farmer distribution path (0,19,8,11) remains unchanged due to traffic congestion between customer 11 and 10, the latter distribution path (10, 33, 44, 43, 36,37,0) has changed.

Figure 4 displays the customers’ satisfaction with time window. Through the comparison and analysis of the three curves, it is found that for most customers, the satisfaction with the time window under the initial distribution path without congestion is greater than the adjusted path under the condition of traffic congestion, and the satisfaction without change under congestion is lowest.
Figure 5 represents the customers’ satisfaction with the product freshness before and after the route adjustment. Among them, the satisfaction level is still the lowest without adjustment after the impact of traffic congestion.

Since the conclusion from Figure 4 and 5 only applies to most customer points and does not apply to all customers, so it is difficult to get the total satisfaction level. Therefore, the introduction of sensitive coefficient of time window and product freshness of all customers are necessary, results are shown in Figure 6. The customers’ satisfaction level in initial path with traffic congestion is still the lowest in comparison with other situations. However, for the initial path and adjusted path, if the initial distribution path of the genetic algorithm is not unique, then satisfaction with dynamic adjustment will be less or equal to the initial distribution path, otherwise, the satisfaction with dynamic adjustment is less than the initial distribution path.

Summary

The perishability of fresh agricultural products and the complexity of traffic increase the difficulty of distribution for fresh agricultural products and greatly reduce the customers’ satisfaction with delivery time and product freshness. In this paper, a dynamic vehicle distribution model of fresh agricultural products based on dynamic traffic is established. The genetic algorithm is used to solve the initial routes and dynamic routes adjustment to maximize customers’ satisfaction. The results show that the real-time traffic reduces the customers' satisfaction level, and the optimization of the dynamic distribution routing effectively reduces the influence of the road traffic condition on the product distribution and improves the customers' satisfaction with time and product freshness.

References


