Study on integrated optimization model of inventory and routing problem and its application in China’s online agricultural products logistics

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Abstract

China's online shopping market developed rapidly in the last ten years. More and more companies focus on the performance of the supply chain instead of their own performance. Relatively short agricultural products shelf life leads to low profit. According to the characteristics of the online agricultural products logistics, the way how to control inventory cost and transportation cost in order to increase profits has become a serious and urgently solved problem. In order to solve the shortage of the practical application of the VMI mode under online shopping environment, the paper makes the combination of the VMI and 3PL. Firstly, the inventory routing model of a three-level distribution system with a vendor, a third party logistics company and multiple geographically dispersed retailers based on VMI-3PL and fixed partition policies is built. The goal is to minimize the total cost including the transportation cost and the inventory cost with no allowing storage. Secondly, the paper proposed a heuristic algorithm which is based on Matlab7.5 and ant colony algorithm. Lastly, Computational results show the performance of the solution approach.

Keywords: 3PL, Fixed Partition Policies. Inventory and Routing. Ant colony algorithm. Agricultural products online

1. Introduction

In recent decades, with the rapid development of China's e-commerce industry, online shopping has been more and more acceptable to many consumers and its market scale is continually expanding. By the end of 2015, the size of China's online shopping market has reached RMB 3.8 trillion. The scale of China’s online shopping user has reached 0.361 billion, the penetration rate of online shopping in the Internet reached 55.7%, online retail
transaction volume reached RMB 2789.8 billion, the scale of China's online shopping is more
than the United States. China has become the world's largest online retail market. According
to the Ministry of Agriculture recently predicted that in 2016 China's total online retail sales
of agricultural products will reach RMB 220 billion, an increase of more than 2015 of 46%. In
recent years, China's agricultural e-commerce has entered a stage of rapid growth, in 2015 the
retail price of agricultural products online more than RMB 150 billion, an increase of more
than 2 times more than in 2013.

With the increasingly intensified competition and the reduction of the margin, more
and more companies focus on the performance of the supply chain instead of their own
performance. Competition between companies has been changed into the competition
between the supply chains. As we all know, transportation and inventory control are the main
parts of the online agricultural products shopping supply chain management and the costs of
this two parts accounted for 66 percentage of the logistics costs. However, for the
transportation sector and inventory sector, they have different goals. There exists antinomy
between transportation and inventory. As a result, the way how to control inventory cost and
transportation cost in order to reduce the total cost has become a serious problem which needs
to be solved urgently. In addition to the inventory and transportation integration, the logistics
system should also coordinate the supply chain. In order to control the cost of the inventory
(Zhao et al., 2008; Diabat 2014; Ekici et al. 2015), vendor-managed inventory (VMI) is
concerned more and more by enterprises and scholars, According to the theory research and
application, VMI can always bring benefits to downstream enterprises (Pasandideh et al.,
2010; Govindan 2015). But for the vendor, the effect of VMI can not be ensured due to the
constraint of logistics ability. As a result, with the integration of VMI and 3PL, supplier can
focus on their core competitiveness and the efficiency of the supply chain will be increased
with the entry of the third party logistics (Guo and Hou 2010; Xu 2012; Niknamfar 2015).
However, the theory and the practices of inventory and routing problem are not very mature.
In this context, the paper studies the theory and the key technologies of inventory and routing
problem with the integration of VMI and 3PL. The paper has important theoretical and
practical significance.

Scholars (Zhong et al., 2011; Vansteenwegen and Mateo 2014) did a lot research on
the inventory routing problem. They constructed the model of inventory and routing problem
which can make the decision of retailer cycle replenishment, the replenishment quantity,
replenishment path, the goal of the model is to minimize the inventory and transportation
costs in the supply chain (Xu 2012). Huang and Lin (2014) considered the inventory and routing problem with the stochastic demand and it is not allowed out of stock, he built a model of inventory and routing problem which contained the shortage cost, transportation costs and resource costs (Huang and Lin 2014). Leandro and Cordeau (2012) considered a two layer inventory and routing problem with transshipment which is not only from the supplier to the retailers but also between the retailers, and it is not allowed out of stock (Leandro and Cordeau 2012; Coelho et al., 2014).

2. Inventory and Routing Problem based on VMI-3PL

2.1 Basic assumption of this model

The inventory routing problem (IRP) in the VMI setting considers inventory control and vehicle routing decision simultaneously for reducing the cost of the logistics system which contains inventory costs and transportation costs significantly. Three decisions can be made: delivery frequency, the route and the delivery quantity.

In the VMI-3PL distribution system considered, there are a single outside supplier, a single third party logistics and n geographically dispersed retailers (Figure 1). Each retailer faces a deterministic demand rate, which is fulfilled without any delay by a fleet of homogenous vehicles with limited capacity w. The supplier serves the 3PL warehouse using big vehicles of capacity W. The objective of the paper is to make a decision of the inventory and transportation simultaneously in order to minimize the long-run average costs including holding cost, fixed and variable transportation costs of the supply chain.

![Figure 1: VMI-3PL distribution system](image)

In order to make the simplification of the practical situation, the common assumptions of the model are made as followings: each retailer is served by a vehicle for their services
each time; Initial inventory of the third party logistics warehouse is zero; Shortage is not allowed; Ordering costs and scheduling costs of the retailer to the supplier are not considered; The retailer's demand is determined (Guo and Hou 2010).

Hereafter, we use the following notations:

- \( h_0 \): Inventory holding cost per unit time and per unit stock at the 3PL warehouse
- \( h_i \): Inventory holding cost per unit time and per unit stock at the retailer \( i \) \((i=1,2,3\ldots n)\)
- \( N \): The number of all retailers
- \( D_i \): Demand per unit time at retailer \( i \) \((i=1,2,3\ldots n)\)
- \( D_l \): Total demand rate of the retailers within region \( l \), \( D_l = \sum_{i=1}^{n} D_i \)
- \( d_i \): Distance between the supplier and the 3PL warehouse
- \( d_l \): Distance between the 3PL warehouse and the retailer \( i \) \((i=1,2,3\ldots n)\)
- \( W \): Capacity of each big vehicle
- \( w \): Capacity of each small vehicle
- \( C \): Fixed cost of starting a big vehicle
- \( c \): Fixed cost of starting a small vehicle
- \( V \): Variable transportation cost per unit distance of each big vehicle
- \( v \): Variable transportation cost per unit distance of each small vehicle
- \( T_0 \): Time interval of delivery from the supplier to the 3PL warehouse
- \( T_l \): Time interval of delivery for region \( l \) from 3PL warehouse
- \( M_l \): Replenishment number of region \( l \) within \( T_0 \)
- \( \chi \): A fixed partition of the retailers replenished from the warehouse under an FPP, \( \chi = \{ \chi_1, \chi_2, \chi_3, \ldots, \chi_l \} \)
- \( \theta_l \): The length of the TSP route for region \( l \)'s shortest route on which all retailers within the region are visited
- \( T \): Time interval of the planning cycle
- \( K \): Number of third-party logistics replenishment cycle contained in Time interval of the planning cycle, \( K = T / T_0 \)

2.2. IRP model based on VMI-3PL

In this paper, the third-party logistics supplier replenishment cycle \( T_0 \) is called the planning period. According to the Integer-ratio which means \( T_l \) is an integer multiple of \( T_0 \), that means

\[
M_l = \frac{T_0}{T_l} \in \left\{ \ldots, \frac{1}{3}, \frac{1}{2}, 1, 2, 3, \ldots \right\} \quad \forall l \in (1, 2, 3, \ldots l) \quad (2.1)
\]
2.2.1 Inventory costs

In this paper, we consider the inventory holding costs of the 3PL warehouse and the retailer. The average inventory of 3PL warehouse is \( \sum_{k=1}^{K} \sum_{M_j=1}^{M} (M_j - 1) \cdot T_i \cdot D_i \). The retailers are divided into \( l \) fixed partition and each partition can be seen as a large retailer, the inventory cost of partition \( l \) is \( T_i \cdot \frac{\sum_{k=1}^{K} \sum_{M_j=1}^{M} (h_i \cdot D_i \cdot T_i)}{2} / \forall l = 1, 2, 3, \ldots \). Therefore, this system can be drawn on the comprehensive inventory total cost is:

\[
\sum_{k=1}^{K} \sum_{M_j=1}^{M} (M_j - 1) \cdot T_i \cdot D_i + \sum_{l=1}^{L} \sum_{i \in E_l} (h_i \cdot D_i) = \sum_{k=1}^{K} \sum_{M_j=1}^{M} \left( h_i \cdot T_i \cdot D_i \right) / \forall l = 1, 2, 3, \ldots \]

(2-2)

2.2.2 Transportation costs

Transportation costs including vehicle fixed costs and variable transportation costs. The transportation costs of big vehicle is \( (C + 2V \cdot d_i) \cdot K \), while the transportation costs of small vehicle is \( \sum_{k=1}^{K} M_j (\theta_i \cdot v + c) \), this system can be drawn on the comprehensive transportation total cost is:

\[
\sum_{k=1}^{K} M_j (\theta_i \cdot v + c) + (C + 2V \cdot d_i) \cdot K
\]

(2-3)

2.2.3 IRP model

With formula 2-2 and 2-3, the IRP can be formulated as the following mathematical programming model:

\[
\text{Min} TC = \frac{1}{T} \left[ h_i \cdot T_0 \cdot \sum_{k=1}^{K} \sum_{M_j=1}^{M} (M_j - 1) \cdot T_i \cdot D_i / 2 \right] + \sum_{k=1}^{K} \sum_{M_j=1}^{M} h_i \cdot D_i / 2
\]

\[
+ \frac{1}{T_0} \left[ \sum_{k=1}^{K} M_j (\theta_i \cdot v + c) + (C + 2V \cdot d_i) \cdot K \right]
\]

(2-4)

Substituting \( T_i = \frac{T_0}{M_i} \) and \( T = K \cdot T_0 \) into the above equation 2.4, we can get the formula 2.5

\[
\text{Min} TC = \frac{1}{K} \left[ h_i \cdot T_0 \cdot \sum_{k=1}^{K} \sum_{M_j=1}^{M} (M_j - 1) \cdot T_i \cdot D_i / 2K \right] + \sum_{k=1}^{K} \sum_{M_j=1}^{M} h_i \cdot D_i / 2K
\]

\[
+ \frac{1}{T_0} \left[ \sum_{k=1}^{K} M_j (\theta_i \cdot v + c) + (C + 2V \cdot d_i) \right] / K
\]

(2-5)
Study on integrated optimization model of inventory and routing problem and its application in China’s online agricultural products logistics  
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\[ S, \ t. \quad W \geq T_0 \ast \sum_{i \in X_1} D_i \]  \quad (2-6) \quad M_i \ast_w \geq *D_i \ast T_0

(2-7)

\[ T_0 \text{ is a positive integer and } M_i \in \{1/3, 1/2, 1, 2, 3, \ldots\}, \ \forall i \in \{1, 2, 3, \ldots, l\} \]  \quad (2-8)

In this model, constraint 2-6 indicates the vehicle capacity constraints ensuring that the load of big vehicle is more than or equal to the vehicle capacity. Constraint 2-7 indicates the vehicle capacity constraints ensuring that the load of small vehicle is more than or equal to the vehicle capacity. Constraint 2-8 ensured that \( T_0 \) is a positive integer.

2.3. A solution approach to the IRP based on VMI-3PL

2.3.1. The algorithm process framework

![Image of the algorithm process framework](image)

**Figure 2. The algorithm process framework of the IRP on VMI-3PL**

According to Figure 2, in order to solve the three level inventory routing problem based on VMI-3PL, the paper presents a solution approach that decomposes the problem into two sub-problems: the 3PL warehouse--retailer transportation and inventory sub-problem and the supplier--3PL warehouse transportation and inventory sub-problem. The first problem is solved by ant colony algorithm and the fixed partition of the retailers can be obtained. Then the second problem can be solved at the same time, according to the fixed partition given by the first problem, we can get replenishment cycle from supplier to a third party logistics and replenishment number from the 3PL warehouse to the retailers. Finally, the total cost and the fix partition can be obtained (Leandro and Cordeau 2012).
2.3.2 The solution process based on Integer-Ratio

According to Constraint 2-6, the range of \( T_0 \) is \( (0, W / \sum_{l \in L_i} D_l] \), \( M_l \) can also be obtained at the same time. In this paper, we introduced a parameter \( \lambda_i \) which represents the \( l \) th partition ratio of distribution costs and inventory costs. Formula about \( \lambda_i \) can be represented as follows:

\[
\lambda_i = \frac{M_i (\theta_i * v + c) / T_0}{D_i * T_0 / (2M_i)} = \frac{2M_i^2 (\theta_i * v + c)}{D_i * T_0^2}
\]

As to \( \lambda_i \), the closer to 1, the more accurate of the final result is. The solving strategies are as follows:

1) if \( \frac{2(\theta_i * v + c)}{D_i * T_0^2} > 1 \), then \( M_i \to \sqrt{\frac{D_i * T_0^2}{2(\theta_i * v + c)}} < 1 \), let \( z \in Z^+ \) which meets the following conditions:

\[
\frac{1}{z+1} \leq \sqrt{\frac{D_i * T_0^2}{2(\theta_i * v + c)}} \leq \frac{1}{z}, \text{ make a compare of the objective function value when } M_i \text{ is between } \frac{1}{z+1} \text{ and } \frac{1}{z}.
\]

2) if \( \frac{2(\theta_i * v + c)}{D_i * T_0^2} < 1 \), then \( M_i \to \sqrt{\frac{D_i * T_0^2}{2(\theta_i * v + c)}} > 1 \), let \( z \in Z^+ \) which meets the following conditions:

\[
z \leq \sqrt{\frac{D_i * T_0^2}{2(\theta_i * v + c)}} \leq z + 1, \text{ make a comparion of the objective function value when } M_i \text{ is between } z \text{ and } z + 1.
\]

(2) From formula 2-7, \( M_i > \frac{W}{D_i * T_0} \), so we can get the solution process as follows:

1) Generating \( T_0 \), which is a positive integer with the range is \((0, W / \sum_{l \in L_i} D_l] \).

2) Based on ant colony algorithm and \( T_0 \), we can get the optimal delivery routes and the total transportation costs in the period of time from the third-party logistics warehouse to retailers.

3) According to \( T_0 \), we can calculate \( k \) which can be represented as follows:

\[
k = \sqrt{\frac{D_i * T_0^2}{2(\theta_i * v + c + K)}}, \text{ let } z \leq k \leq z + 1, \text{ make comparion of } f(z) \text{ and } f(z + 1).
\]

If \( f(z) > f(z + 1) \), then \( M_i = z \). Otherwise, \( M_i = z + 1 \).
4) Based on formula 2.5, we can get $\text{Min} TC^*$ with regard to $T_0$ and $M_I$.

5) Let $T_0 = T_0 + 1$, to solve the above problems again, then we can get the other result which is $\text{Min} TC_2$.

(a) if $\text{Min} TC_2 > \text{Min} TC^*$, then we have got the best solution including the best route, $M_I$ and $T_0$.

(b) If $\text{Min} TC_2 < \text{Min} TC^*$, then $\text{Min} TC_2 = \text{Min} TC^*$.

(c) Let $T_0 = T_0 + 2$, repeating these steps until the system average total cost is lower when $T_0 = T_0^* + 1$ compared with $T_0 = T_0^*$.

(d) The best solution can be obtained including the best route, $M_I$ and $T_0$.

3. Computation results and computational analysis
3.1 Application model

In Hebei province, China, there is a large agricultural e-commerce enterprises, the company with a third party logistics companies to carry out agricultural products into the city logistics services. In order to explain the problem and not to disclose the business secrets, we take the enterprise logistics system as the background, the relevant data were properly modified. For example, there are a single supplier, a single third party logistics company, 20 geographically dispersed retailers in this example as follows, the retailer's location, demand rates and the unit inventory cost for each retailer are shown in Table 1.

<table>
<thead>
<tr>
<th>node</th>
<th>Coordinate</th>
<th>Demand rate</th>
<th>Unit inventory cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>3PL Delivery Center</td>
<td>(0,0)</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td>Customer 1</td>
<td>(0.3)</td>
<td>1.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 2</td>
<td>(-2,2)</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 3</td>
<td>(-3,-3)</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 4</td>
<td>(3,-1)</td>
<td>1.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 5</td>
<td>(-4,-1)</td>
<td>2.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 6</td>
<td>(1,-2)</td>
<td>3</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 7</td>
<td>(1,3)</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 8</td>
<td>(3,4)</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Customer 9</td>
<td>(-3,0)</td>
<td>3</td>
<td>0.2</td>
</tr>
</tbody>
</table>
The other basic parameters are set as follows Table 2.

Table 2: Other basic parameters

<table>
<thead>
<tr>
<th>W</th>
<th>w</th>
<th>G</th>
<th>V</th>
<th>v</th>
<th>h₀</th>
<th>d₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>9</td>
<td>100</td>
<td>1</td>
<td>2</td>
<td>0.1</td>
<td>50</td>
</tr>
</tbody>
</table>

3.2 Computation results and analysis

3.2.1 Computation results

The solution approach described in previous section was programmed with MATLAB 7.6 (2008a). All numerical experiments were done with a PC of RAM 512M based on Windows XP system. The best results are as follows in Table 3.

Table 3: Best partition

<table>
<thead>
<tr>
<th>Partition</th>
<th>Vehicle Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1—2—8—9—14—11—1</td>
</tr>
<tr>
<td>2</td>
<td>1—17—3—4—6—10—1</td>
</tr>
<tr>
<td>3</td>
<td>1—18—13—5—15—12—7—1</td>
</tr>
<tr>
<td>4</td>
<td>1—20—19—16—21—1</td>
</tr>
</tbody>
</table>

From the results shown in Table 3 and Fig. 3, we can get the delivery time $M_i$ as follows in Table 4.
Table 4: Best result

<table>
<thead>
<tr>
<th>Partition</th>
<th>Partition 1</th>
<th>Partition 2</th>
<th>Partition 3</th>
<th>Partition 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retailer i</td>
<td>1 7 8 13 10</td>
<td>2 3 5 9 16</td>
<td>17 12 4 14 11</td>
<td>19 18 15 20</td>
</tr>
<tr>
<td>$M_t$</td>
<td>3 3 3 3 3</td>
<td>4 4 4 4 4</td>
<td>5 5 5 5 5</td>
<td>2 2 2 2 2</td>
</tr>
<tr>
<td>Total cost</td>
<td>172</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T$</td>
<td></td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.2 Computation analysis

Through adjustment of the fixed parameters, this paper observed changes of the results. There are two main fixed parameters, the first one is the maximum load of the vehicle from the third-party logistics company. The second one is stock rate (Li et al., 2011; Ivanov et al. 2014; Park et al., 2015). Results are shown as follows:

Table 5: Adjustment of w

<table>
<thead>
<tr>
<th>w</th>
<th>T</th>
<th>M</th>
<th>Total -cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>W=9</td>
<td>12</td>
<td>[3 4 5 2]</td>
<td>151</td>
</tr>
<tr>
<td>W=6</td>
<td>8</td>
<td>[2 4 4 6 4]</td>
<td>103</td>
</tr>
<tr>
<td>W=10</td>
<td>10</td>
<td>[2 2 3 1]</td>
<td>123</td>
</tr>
</tbody>
</table>

From Table 5, we can get the conclusion that vehicles of small load which can improve the distribution frequencies and reduce the total-cost of the whole supply chain. In order to improve the total benefit of the supply chain, more vehicles of small load should be used.

Table 6: Adjustment of Stock rate

<table>
<thead>
<tr>
<th>Stock rate</th>
<th>$T_0$</th>
<th>$M_t$</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h_0=0.1$; $h_i=0.2$</td>
<td>12</td>
<td>[3 4 5 2]</td>
<td>151</td>
</tr>
<tr>
<td>$h_0=0.05$; $h_i=0.1$</td>
<td>10</td>
<td>[2 2 4 2]</td>
<td>120</td>
</tr>
<tr>
<td>$h_0=0.2$; $h_i=0.4$</td>
<td>8</td>
<td>[2 2 3 2]</td>
<td>168</td>
</tr>
</tbody>
</table>

From Table 6, we can get the conclusion that adopting lower distribution efficiency can reduce the cost of the whole supply chain if stock rate of the third party logistics warehouse and the retailer are low.
3.3 The effects of ant colony algorithm parameter settings

3.3.1 Information strength parameters $\alpha$ and Visibility parameters $\beta$

Information intensity index $\alpha$ refers to the global pheromone update when all ants complete one cycle while visibility parameters $\beta$ reflects the priori and definite nature of ant path search.

This paper observes the effect to the optimal path length with the different value of $\alpha$ and $\beta$. From Table 7, we can get the conclusion that we can get the best result when the value of $\alpha$ is 0.5; What’s more, With increase of $\beta$, optimal solution obtained is smaller and smaller.

<table>
<thead>
<tr>
<th>Information intensity index $\alpha$</th>
<th>visibility parameters $\beta$</th>
<th>Length of best route</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>47.3599</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>46.6172</td>
</tr>
<tr>
<td>0.5</td>
<td>0.6</td>
<td>45.0446</td>
</tr>
<tr>
<td>0.5</td>
<td>0.7</td>
<td>44.8318</td>
</tr>
<tr>
<td>0.5</td>
<td>0.8</td>
<td>44.1133</td>
</tr>
<tr>
<td>0.5</td>
<td>0.9</td>
<td>43.9122</td>
</tr>
<tr>
<td>0.5</td>
<td>1.0</td>
<td>43.6248</td>
</tr>
<tr>
<td>0.5</td>
<td>1.5</td>
<td>43.2619</td>
</tr>
<tr>
<td>0.5</td>
<td>5</td>
<td>43.2619</td>
</tr>
<tr>
<td>0.5</td>
<td>20</td>
<td>43.2619</td>
</tr>
<tr>
<td>0.5</td>
<td>30</td>
<td>43.2619</td>
</tr>
<tr>
<td>0.6</td>
<td>1.0</td>
<td>43.2619</td>
</tr>
<tr>
<td>0.9</td>
<td>1.0</td>
<td>43.9122</td>
</tr>
<tr>
<td>0.99</td>
<td>1.0</td>
<td>44.1350</td>
</tr>
</tbody>
</table>

3.3.2 Analysis of pheromone evaporation coefficient $\rho$

The value of $\rho$ can represent the pheromone concentration left on the route and it can decide whether the other ants choose this path. When the value of $\rho$ is small, the route will be left more pheromone, and it will attract other ants to choose this path.
From Table 8, we can get the same conclusion that with the increase of $\rho$, optimal solution obtained is larger and larger.

Table 8: Analysis of $\rho$

<table>
<thead>
<tr>
<th>Pheromone evaporation coefficient $\rho$</th>
<th>Length of best route</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>43.2619</td>
</tr>
<tr>
<td>0.3</td>
<td>43.4848</td>
</tr>
<tr>
<td>0.5</td>
<td>43.6248</td>
</tr>
<tr>
<td>0.7</td>
<td>44.1133</td>
</tr>
<tr>
<td>0.99</td>
<td>44.1641</td>
</tr>
</tbody>
</table>

3.3.3 The number of ant colony $m$

The number of ant colony plays an important role in the efficiency of the searching best result. The larger the number of ants is, the faster the stronger the algorithm's global search ability and the stability of the algorithm are. From Table 9, we can get the same conclusion. However, the randomness and the rate of convergence of the search tend to be slow. As a result, we should balance the global search ability and convergence speed when deciding the number of ant colony.

Table 9: Analysis of $m$

<table>
<thead>
<tr>
<th>Number of Ant colony $m$</th>
<th>Length of best route</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44.1641</td>
</tr>
<tr>
<td>3</td>
<td>43.7794</td>
</tr>
<tr>
<td>6</td>
<td>43.4848</td>
</tr>
<tr>
<td>10</td>
<td>43.2619</td>
</tr>
<tr>
<td>30</td>
<td>43.2619</td>
</tr>
<tr>
<td>100</td>
<td>43.9122</td>
</tr>
</tbody>
</table>

4. Conclusion

Based on the Fixed Partition Policies (FPP), the paper built an inventory routing model including a single warehouse, a single 3PL warehouse and several retailers. Firstly, the thesis gives the definition of the VMI-3PL mode, expatiates the necessity and feasibility of the integration of VMI-3PL, the analysis of operation mode and most importantly, the value added of this mode. Secondly, the definition of inventory and routing problem and the
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importance of this problem are proposed, based on the study of the strategy of inventory and routing under VMI-3PL, the model of integrating inventory and routing under centralized control of VMI-TPL supply chain is built using the Fixed Partition Policies(FPP) and integer ratio cycle. At last, the paper proposed an ant colony algorithm which is based on Matlab7.5 (2008 a).

Future research can also do more research on the situation of more kinds of products and demand will be random. The research enriches the theory of inventory and routing problem based on VMI-3PL mode and provides a theoretical basis and implementation guide for the construction of inventory and routing problem at the same.

5. Reference


Study on integrated optimization model of inventory and routing problem and its application in China’s online agricultural products logistics
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