Optimization Study of Transportation Assignment for Oil Product Secondary Distribution

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Abstract

This paper proposes an optimization scheme of the transportation assignment for the oil product secondary distribution. Firstly, for the multi-variety oil product a cost model of the secondary distribution system for the oil product is established. Then a transportation assignment scheme is designed with the table-manipulation method. Based on the proposed transportation assignment scheme, total transportation cost can be optimized. Finally, the results of a numerical example verify the effectiveness of this scheme.

Keywords: Optimization, Transportation Assignment, Oil Product

1. Introduction

With the rapid development of the economics, oil product market has maintained rapid growth. In the process of oil product sales, the oil product logistics process is very important. It is a very popular research topic that the gradually maturing information technology manages and improves logistics process because logistics process is very complex and changeful. The sale process of oil product has twice logistics distributions from oil refinery to oil station mainly. The distribution of oil product from oil refinery to oil depot distribution center is called as the first distribution. And the distribution of oil product from oil depot distribution center to oil station is called as the secondary distribution.

The optimization problem of the distribution is the most important problem which can reduce distribution cost, therefore, the optimization research has caused the concern of many scholars increasingly [1-4]. Based on the analysis of the status quo of refined oil product distribution and the contributing factors in the distribution optimization, Reference [5] provided theoretical foundation for the effective integration of the primary and secondary product distribution through the establishment of a combined optimization model. Based on the optimized routing of regional logistics delivery system, Reference [6] discussed the optimized strategies and relative suggestions of the system in the aspects of delivery networks and nodes, delivery activities and delivery information. In Reference [7] the model of the harbor oil distribution scheduling was given based on the theory and method of the vehicle routing problem with time windows. Then a series of heuristics strategies were proposed by considering the constraints of time, space and weight of oil ships. The optimal harbor oil distribution scheduling routes was obtained. Reference [8] redesigned oil product distribution network for a large oil company. Reference [9] planned the distribution center and vehicle scheduling, and studied transportation cost, transportation distance and order-placing frequency. Reference [10] established the shortest path and the minimum cost model of oil product secondary distribution. This model was solved and optimized by solver software. Reference [11] established the demand forecast model and forecasted demand quantity and transportation demand of every oil station combined with characteristics of oil product secondary distribution. Reference [12] studied the refined oil distribution business, and brought forth a solution for marketing forecast, auto-replenishment and distribution optimization, and then a refined oil distribution management system was designed.

The integration of oil product is realized recently, and oil product logistics distribution system is in preliminary stage. Research references of oil product logistics distribution proposed some viewpoints, which were the establishment of oil company modern logistics system and the practice operation, but lacked quantitative analysis of system plan and feasible scheme. In this paper, the total transportation cost model of oil product secondary distribution is established with multiple oil depot distribution centers and multiple oil stations. Transportation assignment optimization of oil product secondary
distribution is studied. A transportation assignment scheme that cost can be optimized is obtained by the table-manipulation method. An example is given to verify the effectiveness of the transportation assignment scheme.

2. The basic model

This paper considers oil product secondary distribution problem of from \( m \) oil depot distribution centers to \( n \) oil stations, and the basic model can be shown in Figure 1.

2.1. Notation description of the model

Some notations are employed in the paper, which can be seen as follows:

- \( C \) —— total transportation cost;
- \( M_i \) —— oil depot distribution center \( i \) \((i = 1, 2, \ldots, m)\);
- \( N_j \) —— oil station \( j \) \((j = 1, 2, \ldots, n)\);
- \( Q_q \) —— the variety of oil product \( q \) \((q = 1, 2, \ldots, r)\);
- \( D_d \) —— the decision date of distribution quantity \( d \) \((d = 1, 2, \ldots, s)\);
- \( H_{ij} \) —— distance from the oil depot distribution center \( i \) to the oil station \( j \);
- \( P \) ——freight of oil product (Yuan/Ton·Kilometer);
- \( Z_{ij} \) —— distribution quantity from the oil depot distribution center \( i \) to the oil station \( j \);
- \( Z_{ij,q,d} \) —— distribution quantity of oil product \( q \) from the oil depot distribution center \( i \) to the oil station \( j \) on the \( d \) day.

2.2. Hypothesis of the model

The oil product is conveyed from \( m \) oil depot distribution centers \( M_1, M_2, \ldots, M_m \) to \( n \) oil stations \( N_1, N_2, \ldots, N_n \). The traffic volume of the oil depot distribution center \( M_i \) is \( a_i \), sales volume of the oil station \( N_j \) is \( b_j \), and the constraint conditions that must be met are shown as follows:

\[
\sum_{j=1}^{n} Z_{ij} = a_i \quad i = 1, 2, \ldots, m, \\
\sum_{i=1}^{m} Z_{ij} = b_j \quad j = 1, 2, \ldots, n.
\]
In an operation cycle, total traffic volume of the oil depot distribution center is assumed to be equal to total sales volume of the oil station.

\[ \sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \quad i = 1, 2, \cdots, m; \quad j = 1, 2, \cdots, n \]

The transportation model with balanced supply and demand relation is established, and shown in Table 1.

**Table 1. The balanced supply and demand relation table**

<table>
<thead>
<tr>
<th>Oil Station</th>
<th>Oil Depot Distribution Center</th>
<th>( N_1 )</th>
<th>( N_2 )</th>
<th>\cdots</th>
<th>( N_n )</th>
<th>Sales Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_1 )</td>
<td></td>
<td>( a_1 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M_2 )</td>
<td></td>
<td></td>
<td>( a_2 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \cdots )</td>
<td></td>
<td></td>
<td></td>
<td>( \cdots )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M_m )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( a_m )</td>
<td></td>
</tr>
<tr>
<td>Freight Volume</td>
<td></td>
<td>( b_1 )</td>
<td>( b_2 )</td>
<td>\cdots</td>
<td>( b_n )</td>
<td></td>
</tr>
</tbody>
</table>

Transportation distance \( H_{ij} \) from the oil depot distribution center \( M_i \) to the oil station \( N_j \) can be obtained, and shown in Table 2.

**Table 2. The transport mileage table**

<table>
<thead>
<tr>
<th>Oil Depot Distribution Center</th>
<th>Oil Station</th>
<th>( N_1 )</th>
<th>( N_2 )</th>
<th>\cdots</th>
<th>( N_n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_1 )</td>
<td></td>
<td></td>
<td>( H_{11} )</td>
<td>( H_{12} )</td>
<td>\cdots</td>
</tr>
<tr>
<td>( M_2 )</td>
<td></td>
<td></td>
<td>( H_{21} )</td>
<td>( H_{22} )</td>
<td>\cdots</td>
</tr>
<tr>
<td>( \cdots )</td>
<td></td>
<td></td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>\cdots</td>
</tr>
<tr>
<td>( M_m )</td>
<td></td>
<td></td>
<td>( H_{mj} )</td>
<td>( H_{m2} )</td>
<td>\cdots</td>
</tr>
</tbody>
</table>

2.3. Establishment of the model

Cost model of oil product secondary distribution includes total transportation cost and total inventory holding cost. Total transportation cost is transportation cost of all oil station all-year, which is denoted by product of quantity, distance of distribution and freight.

\[
C = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{q=1}^{r} \sum_{d=1}^{s} Z_{ijqd} H_{ij} P \quad i = 1, 2, \cdots, m; \quad j = 1, 2, \cdots, n; \quad q = 1, 2, \cdots, r; \quad d = 1, 2, \cdots, s. \tag{1}
\]

The smallest cost model of total transportation cost is established.

\[
\min C = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{q=1}^{r} \sum_{d=1}^{s} Z_{ijqd} H_{ij} P \quad i = 1, 2, \cdots, m; \quad j = 1, 2, \cdots, n; \quad q = 1, 2, \cdots, r; \quad d = 1, 2, \cdots, s. \tag{2}
\]

2.4. Solution of the model

The table-manipulation method is used to solve the oil product secondary distribution transportation assignment problem with balanced supply and demand. A primary scheme is obtained by
minimum element method. The basic idea of the minimum element method is supplied nearby.

First, after the freight of per ton oil product per kilometer has been given, the minimum transportation distance \( H_{ij} \) is found in the transport mileage table, and \( H_{ij} = \min H_i j \).

Second, we assume \( G_{ij} = \min(a, b) \), and \( G_{00} \) ton oil product is conveyed from the oil depot distribution center \( M_1 \) to the oil station \( N_i \), then \( G_{ij} \) is filled in the intersecting space \( (M_1, N_i) \) of the balanced supply and demand relation table.

Third, if \( G_{ij} = a \), the demand of the oil station \( N_i \) is reduced to \( b_i - a \); if the formula \( G_{ij} = b \) is set up, the demand of the oil station \( N_i \) is satisfied. The demand of oil station \( N_i \) can be cancelled in the balanced supply and demand relation table.

The minimum element is found in the transport mileage table once again. According to the step mention above, the minimum element method is continued until all elements of the transport mileage table are cancelled. A primary scheme is obtained in the balanced supply and demand relation table.

3. Verification of the model optimality

The primary transportation assignment scheme is verified by the closed circuit method. The objective function values of the primary scheme are judged, if the objective function values are not optimal, and the scheme should be adjusted.

The basic idea of the closed circuit method is: the starting point of the closed circuit starts from a space that represents non-base variable along the horizontal direction or the vertical direction in the primary transportation assignment scheme table, then turns left or turns right 90 degree when meet non-space until return to the space of the starting point. A closed circuit is formed.

In the closed circuit of the table, we assume the distribution quantity \( G_{11} = 1 \) of the starting point \((M_1, N_i)\), therefore, the distribution quantity of space \((M_1, N_a)\) is \( G_{1a} = y - 1 \), the distribution quantity of space \((M_1, N_a)\) is \( G_{2a} = Z + 1 \), the distribution quantity of space \((M_1, N_i)\) is \( G_{0a} = X + 1 \), and transportation distance of every intersecting space is added or subtracted 1 which is called the test number, then the modified numbers are filled up to the position \((M_1, N_i)\) of the test table relatively.

The test number of all non-base variables is counted in the table in turn following the above way. If all test number above zero or equal to zero, the primary scheme is the optimal. If there is any test number below zero, the primary scheme has to be adjusted.

4. Example analysis

In the economic region, oil depot distribution centers are ruled by three branch company which belong to the same oil company respectively, the oil products are supplied to the oil station of corresponding region: \( M_1(N_1,N_2), M_2(N_3,N_4), M_3(N_5,N_6) \). We assume that the freight of oil product is five (Yuan/Ton·Kilometer), the freight volume of every oil depot distribution centers and the sales volume of every oil station are shown in Table 3 (Suppose each unit is 10 ton), and the distance from the oil depot distribution center \( i \) to the oil station \( j \) is shown in Table 4.

<table>
<thead>
<tr>
<th>Oil Depot Distribution Center</th>
<th>( N_1 )</th>
<th>( N_2 )</th>
<th>( N_3 )</th>
<th>( N_4 )</th>
<th>( N_5 )</th>
<th>( N_6 )</th>
<th>Sales Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_1 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>( M_2 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>( M_3 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Freight Volume</td>
<td>20</td>
<td>16</td>
<td>8</td>
<td>40</td>
<td>12</td>
<td>12</td>
<td>108</td>
</tr>
</tbody>
</table>

Table 3. The balanced supply and demand relation table
The distribution scheme is decided according to the maximum benefit of every branch company completely. According to the data of Table 3 and Table 4, the total transportation cost is calculated as follows:

\[
\begin{align*}
\min C &= \sum_{i=1}^{n} \sum_{j=1}^{n} H_{ij} G_{ij} P = H_{11} \times G_{11} \times P + H_{12} \times G_{12} \times P + H_{13} \times G_{13} \times P \\
&\quad + H_{21} \times G_{21} \times P + H_{22} \times G_{22} \times P + H_{23} \times G_{23} \times P \\
&= 9 \times 20 \times 5 + 17 \times 16 \times 5 + 26 \times 8 \times 5 + 18 \times 40 \times 5 + 8 \times 12 \times 5 + 42 \times 12 \times 5 \\
&= 9900
\end{align*}
\]

The system is optimized. A primary transportation assignment scheme is obtained by the table-manipulation method, as shown in Table 5.

The optimality of primary transportation assignment scheme is verified. The test number of all non-base variables is counted, as follows:

- \((M_1, N_1) = 9 - 22 + 18 - 2 = 3\)
- \((M_1, N_2) = 17 - 22 + 16 - 10 = 1\)
- \((M_2, N_3) = 12 - 18 + 16 - 10 = 0\)
- \((M_2, N_4) = 13 - 5 + 22 - 18 = 12\)
- \((M_2, N_5) = 28 - 20 + 22 - 18 = 10\)
- \((M_2, N_6) = 6 - 16 + 18 - 2 = 6\)
- \((M_3, N_1) = 18 - 16 + 22 - 40 = -16\)
- \((M_3, N_2) = 8 - 5 + 22 - 16 = 9\)
- \((M_3, N_6) = 42 - 20 + 22 - 16 = 28\)

The test result is shown in Table 6.
We can observe that the test number of intersecting space \((M_i, N_j)\) is below zero, so the primary scheme has to be adjusted. A modified transportation assignment scheme can be obtained, as shown in Table 7.

**Table 7. The modified transportation assignment scheme**

<table>
<thead>
<tr>
<th>Oil Depot Distribution Center</th>
<th>Oil Station</th>
<th>Oil Station</th>
<th>Oil Station</th>
<th>Oil Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_1</td>
<td>N_1</td>
<td>N_2</td>
<td>N_3</td>
<td>N_4</td>
</tr>
<tr>
<td>M_2</td>
<td>8(-8)</td>
<td>4(+8)</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>M_3</td>
<td>20</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 (+8)</td>
<td>8(-8)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The optimality of modified transportation assignment scheme is verified. The test result as shown in Table 8.

**Table 8. Test number of the modified scheme table**

<table>
<thead>
<tr>
<th>Oil Depot Distribution Center</th>
<th>Oil Station</th>
<th>Oil Station</th>
<th>Oil Station</th>
<th>Oil Station</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_1</td>
<td>N_1</td>
<td>N_2</td>
<td>N_3</td>
<td>N_4</td>
</tr>
<tr>
<td>M_2</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>M_3</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>10</td>
</tr>
</tbody>
</table>

We observe that all the test numbers are above zero or equal zero, so the modified transportation assignment scheme is optimal scheme, the total transportation cost of the modified scheme can be calculated according to the Table 8.

\[
\begin{align*}
\min C &= \sum_{i=1}^{n} \sum_{j=1}^{m} H_{ij} \cdot G_{ij} \cdot P \\
&= H_{14} \times G_{14} \times P + H_{15} \times G_{15} \times P + H_{16} \times G_{16} \times P + H_{21} \times G_{21} \times P + H_{24} \times G_{24} \times P + \\
&H_{32} \times G_{32} \times P + H_{33} \times G_{33} \times P \\
&= 12 \times 22 \times 5 + 12 \times 5 \times 5 + 12 \times 20 \times 5 + 20 \times 2 \times 5 + 28 \times 18 \times 5 + 16 \times 10 \times 5 + 8 \times 18 \times 5 \\
&= 7060
\end{align*}
\]

According to (3) and (4), the total transportation cost can be saved by the table-manipulation method. The saving cost is shown as follows: \(9900 - 7060 = 2840\).

5. Conclusions

This paper has studied the optimization problem of oil product secondary distribution. The total transportation cost of oil product secondary distribution has been established. A transportation assignment scheme in which cost can be optimized has been obtained by the table-manipulation method. In addition, a numerical example that includes six oil station and three oil depot distribution center is given to verify the effectiveness of this transportation assignment scheme.

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7. References


