Research on Route Optimization Based on Drop and Pull Transport

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Abstract. Many logistics enterprises in China have some problems, such as low transportation efficiency, long waiting time for loading and unloading, low mileage rate. These problems not only increase the operation cost of enterprises, but also hinder the development of logistics and transportation industry to a certain extent. As a new mode of transportation organization, drop and pull transport is widely used because of its advantages of reducing transportation costs, improving transportation efficiency, increasing mileage, reducing environmental pollution, and reducing waiting time for loading and unloading. By studying the advantages and organizational mode of drop and pull transport, this paper analyses the efficiency of full-trailers and semi-trailers. On this basis, combined with the actual transportation of R company, LINGO software is used to establish the transportation model, and the best route scheme based on the trailing transport is obtained.

1. Introduction
With the continuous growth of economy, China’s logistics industry is also developing rapidly. Its increasing freight volume and turnover has played an important role in promoting the development of the logistics industry.

With the rapid development of road transport industry, many problems have arisen. The backward mode of transportation and the increasing mileage of vehicle transportation in China have resulted in the phenomenon of low efficiency, high cost and high pollution. Therefore, the development of road transport modernization has put forward higher and higher requirements for the transport equipment of goods and the form of transport organization. As a kind of modern transportation mode, drop and pull transport not only meets the needs of modern logistics transportation, but also changes the traditional transportation mode to modern transportation. It plays a certain role in promoting the development of social economy and environmental protection.

2. Analysis on the Organization Model of drop and pull transport
According to the number of vehicles and trailers, the characteristics of the line network and the loading and unloading capacity of the loading and unloading points, there are different organizational forms for the drop and pull transport. Generally speaking, there are four forms of organization.

- Two Points and One Line Transportation Model

This form of organization is suitable for reciprocating transport lines, the specific process is: the vehicle train works in a cycle between loading and unloading operation points at both ends of the line,
in which loading and unloading operation points are equipped with a certain number of trailers, as shown in Figure 1.

![Figure 1. Two Points and One Lin Transportation Model.](image1)

- Circulating Transport Mode
  This form of organization is based on the vehicle traveling along the circular route, and further organizes the work of dropping and hanging, as shown in Figure 2.

![Figure 2. Circulating Transport Mode.](image2)

- Line multi-point, along the way dropping and hanging operation
  This form of organization requires that the trains should be arranged in the order of the unloading operation place at the starting point, as shown in Figure 3.

![Figure 3. Line multi-point, along the way dropping and hanging operation.](image3)

- Multi-point line, alternate towing.
  This kind of organization means that a certain number of trailers are equipped in the places where loading (unloading) points are concentrated. Loading(unloading) the goods of the Trailer in advance during the time when the train does not arrive. When a train on a certain line arrives first, throw off the trailer and concentrate on loading and unloading the main truck, then hang up the trailer which has been pre-loaded (unloaded) and return to the original unloading (unloading) point. The organizational form of drop and pull transport is shown in Figure. 4.

![Figure 4. "Multi-point, one-line, alternate towing" schematic.](image4)

3. Efficiency Comparison of drop and pull transport
At present, the combination forms of drop and pull transport vehicles are generally composed of truck + full trailer, tractor + semi-trailer and tractor + semi-trailer + full trailer.

Following is a case study to compare the transport efficiency of drop and pull transport. R company has a logistics transport service project, the specific situation is: to transport bulk goods on one-way reciprocating route, one-way transportation distance is 100 km, technical speed is 50 km/h, loading operation time is 10 min/t, unloading operation time is 8 min/t, pick-up and trailer operation is 5 minutes each time. The rated loads of main truck, full trailer and semi-trailer are 5, 5 and 10 t respectively.
According to the organizational principle of drop and pull transport, the formula of transport efficiency is deduced as follows:

\[
\text{Transport efficiency} = \frac{\text{Transport tonnage}}{\text{Transportation time}}
\]

\[
= \frac{\text{Driving time} + \text{loading and unloading operation time} + \text{lifting and hanging time}}{\text{Transport tonnage}}
\]

\[
= \frac{\text{Transportation distance}}{\text{Running speed}} + \text{Total Transportation Quantity} \times \text{Handling Time Quota} + \text{Hanging Time}
\]

3.1 Full Trailer Transportation Efficiency

The truck train consists of the main truck and the full trailer. The loading and unloading operations and lifting operations of the main truck are carried out at the loading and unloading site, and the loading and unloading operations of the full trailer are carried out at the same time as the transportation operations. Assuming that the main truck loads \( x_1 \) and the trailer loads \( x_2 \), the case shows that the train:

\[
\text{Transport efficiency} = \frac{\text{Transport tonnage}}{\text{Transportation time}} = \frac{x_1 + x_2}{240 + \frac{1}{6}R_1(10 + 8) + \frac{1}{6}0 + \frac{1}{6}250} \text{ (t/h)}
\]

Because \( 0 \ll x_1 = x_2 \ll 5 \), \( 0 \ll \text{Transport efficiency} \ll 1.76 \text{ t/h} \).

3.2 Transportation efficiency of semi-trailer

Trailers consisting of tractors and semi-trailers only carry out pick-up operation at the loading site, while the loading and unloading operation and driving process of trailers are carried out simultaneously. Assuming that the semi-trailer loads \( x_3 \), the case shows that the train:

\[
\text{Transport efficiency} = \frac{\text{Transport tonnage}}{\text{Transportation time}} = \frac{x_3}{240 + 0 + \frac{1}{6}0 + \frac{1}{6}250} \text{ (t/h)}
\]

Because \( 0 \ll x_3 \ll 10.0 \), \( 0 \ll \text{Transport efficiency} \ll 2.4 \text{ t/h} \).

By comparison: it is concluded that the semi-trailer is better than the full-trailer when it is used to transport goods of the same load quality.

4. Route optimization of suspension transport

4.1 R Company Transportation Status Analysis

R company is a logistics brand of household appliances manufacturing company. It has established a three-level logistics network layout that radiates the whole country. At present, the company has 15 shipping bases in China, 100 distribution centers, with a total storage area of more than 5 million square meters, 100,000 transferable vehicles, more than 6,000 service outlets covering the whole country, and has established cooperative relations with dozens of domestic and foreign companies. As a third-party logistics company, R company's main task is to complete the customer's transportation requirements in the shortest time. The main goods transported by R company are large electrical equipment, such as air conditioning, refrigerators, color TV, etc. At present, the transportation projects carried out by R company are mainly vehicle transportation, but also in the direction of zero-load transportation. The mode of transportation has changed from the traditional mode of bicycle transportation to the mode of swap trailer transport.

4.2 Problem Description

R company mainly carries out transportation services for small and medium-sized enterprises in China, mainly by land transportation. Taking Tianjin Transport Base, Lianyungang Transport Base and Qingdao Transport Base as examples, the main distribution centers are Jinan, Qingdao, Shenyang, Xi’an, Changsha and their subordinate jurisdictions.
Recently, the company’s profits have declined. Some people have analyzed the reasons for the decline in transportation efficiency, which is mainly caused by the long loading and unloading time and the improper choice of transportation routes. In order to improve the company’s operating profit and reduce transportation costs, this paper applies LINGO to optimize transportation network according to its distribution distance and cost.

4.3 LINGO Path Optimization Model
Firstly, after fully understanding the local economic development, we calculate the cost of each shipping base to five distribution centers, and then calculate the cost of transportation to specific locations according to the actual transportation situation. Table 1 shows the cost of shipping base to five distribution centers, and Table 2 shows the cost of five distribution centers to major customers.

| Table 1. Distribution Cost. | Jinan | Qingdao | Shenyang | Xi’an | Changsha |
|-----------------------------|-------|---------|----------|-------|----------|
| Qingdao Shipping Base       | 319   | 10      | 987      | 1011  | 1200     |
| Lianyungang Shipping Base   | 352   | 260     | 930      | 831   | 897      |
| Tianjin Shipping Base       | 360   | 679     | 726      | 901   | 1310     |

| Table 2. Costs of five distribution centers reaching major customers. | Jinan | Qingdao | Shenyang | Xi’an | Changsha |
|-----------------------------|-------|---------|----------|-------|----------|
| Zhangqiu                    | 22    | 280     | 521      | 410   | 621      |
| Shanghe                     | 63    | 436     | 501      | 399   | 595      |
| Jiaozhou                    | 255   | 63      | 611      | 537   | 712      |
| Jimo                        | 314   | 50      | 617      | 556   | 736      |
| Pingdu                      | 242   | 101     | 638      | 603   | 754      |
| Dadong                      | 368   | 421     | 12       | 802   | 921      |
| Huanggu                     | 396   | 410     | 9        | 837   | 930      |
| Lianhu                      | 421   | 433     | 711      | 21    | 506      |
| Lantian                     | 435   | 412     | 721      | 34    | 497      |
| Changan                     | 422   | 411     | 699      | 31    | 499      |
| Liuyang                     | 621   | 721     | 854      | 497   | 42       |
| Ningxiang                   | 622   | 766     | 875      | 465   | 26       |
| Wangcheng                   | 697   | 798     | 912      | 463   | 13       |

Establishment of Logistics Network Optimization Model
Minimize:

\[
\sum_{i \in P} \sum_{j \in Q} c_{ij} x_{ij} + \sum_{j \in Q} \sum_{k \in R} c_{jk} x_{jk} + \sum_{j \in Q} f_{j} y_{j}
\]

Subject to

\[
\sum_{j \in Q} x_{ij} \leq \sigma_{i}, \quad \forall i \in P; \quad \sum_{i \in P} x_{ij} \leq \rho_{j}, \quad \forall j \in Q
\]

(1)

\[
\sum_{i \in P} x_{ij} - \sum_{k \in R} x_{jk} = 0, \quad \forall j \in Q
\]

(2)

\[
\sum_{j \in Q} x_{jk} = \mu_{k}, \quad \forall k \in R
\]

(3)

\[
\sum_{k \in R} \mu_{k} z_{jk} \leq \rho_{j} y_{j}, \quad \forall j \in Q
\]

(4)

\[
\sum_{k \in R} \mu_{k} z_{jk} \leq \rho_{j} y_{j}, \quad \forall j \in Q
\]

(5)
\[
\sum_{j \in Q} y_{jk} \geq 1 \quad \forall k \in R \quad (6)
\]
\[
x_{ij} \geq 0 \quad \forall i \in P, \forall j \in Q \quad (7)
\]
\[
x_{jk} \geq 0 \quad \forall j \in Q, \forall k \in R \quad (8)
\]
\[
y_{j} \in \{0,1\} \quad \forall j \in Q ; \quad z_{jk} \in \{0,1\} \quad \forall j \in Q, \forall k \in R \quad (9)
\]

In the above formula:
- \(P\): Collection of shipping bases;
- \(Q\): Collection of distribution centers;
- \(R\): Collection of customers;
- \(C_{ij}\): the transportation cost from the shipping base to the distribution center;
- \(X_{ij}\): the volume of transportation from the shipping base to the distribution center;
- \(C_{jk}\): transportation cost from distribution center to customer;
- \(X_{jk}\): the volume of transportation from distribution center to customer;
- \(\sigma_{i}\): supply capacity of shipping base, \(\sigma_{i} \in \{71951,39843,61562,45125,76250\}\);
- \(\rho_{j}\): turnover capacity of distribution centers, \(\rho_{j} \in \{71951,39843,61562,45125,76250\}\);
- \(\mu_{k}\): customer demand,
- \(\mu_{k} \in \{468.75,437.5,2238,1562.5,468.75,1796,2238,937.5,937.5,1755,1796,1875,937.5\}\);
- \(\gamma_{j}\): if the distribution center \(J\) serves customer \(K\) 1, otherwise 0;
- \(F_{j}\): fixed operating cost of distribution center \(J\), \(F_{j} \in \{1031,949,2643,2743,3407\}\).

### 4.4 Scheme Analysis

Input the above model into LINGO and connect the transportation route between distribution center and customers according to the operation results, as shown in Figure 5.

![Figure 5. Distribution Route Planning.](image-url)
Drop and pull transport saves the time of loading and unloading operation, uses LINGO program to plan the route, saves the time and cost of cargo transportation, improves the efficiency of transportation and distribution, rationally arranges the two-way transportation relationship between factory and distribution center, and between distribution center and customers, so as to make the distribution of cargo more reasonable.

5. Conclusion
Drop and pull transport has shown great economic and social benefits, under the current policy background of energy saving and emission reduction in China, more and more scholars and logistics enterprises are paying attention to it. It plays an important role in promoting the transformation of logistics transportation mode in China, reducing the cost of logistics transportation, improving the efficiency of transportation and developing green logistics.

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