Cost Analysis of Multimodal Transport on Refrigerated Container

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Abstract. Refrigerated container multimodal transport is a long-distance interprovincial transportation, which effectively ensures the quality of agricultural products. The application of refrigerated containers and other means of transportation in the long-distance transportation of perishable agricultural products can reduce the cost of multimodal transport of agricultural products and improve the logistics efficiency. Therefore, it is of practical significance to study the multimodal transport cost analysis of refrigerated containers for perishable agricultural products. The article classifies the applicable goods in refrigerated containers and refrigerated containers; Erishable agricultural products have short shelf life and high damage rate. Refrigerated transportation tools have the particularity; In the cold chain logistics environment, in addition to considering the transportation cost, transit cost and time penalty cost of normal temperature multimodal transport, we should also consider the loss cost of perishable agricultural products in transit and the energy loss cost of refrigerated container refrigeration in transit.

1. Introduction
Most refrigerated goods on the market are transported in refrigerated containers. Refrigerated containers can ensure the best transport quality of goods, reduce wastage rate, and freight prices are low. Refrigerated containers account for 7% of the total container volume. Demand for refrigerated containers has grown at an average rate of 5-6% per year, much higher than the 2-3% growth rate for ordinary containers.

Perishable agricultural products are the main transport cargo of refrigerated containers. With the improvement of quality of life, consumers are demanding higher and higher freshness, color and delivery time of perishable agricultural products. At the same time, the demand for agricultural products and the flow of freight are also increasing, prompting production and transport enterprises to come up with better solutions. In order to meet the changing needs of consumers and realize the stable development of enterprise economy, it is necessary to complete the transportation of the best cost and the most efficient distribution service in the cold chain logistics distribution, so as to improve customer satisfaction and establish brand image. In addition, with the rapid development of the Internet, the continuous progress of cold chain logistics technology, coupled with the opportunity of new retail, China's fresh e-commerce industry has maintained a rapid development speed.

China needs to export large quantities of frozen vegetables to Japan, Germany and other countries. These agricultural products are mainly transported through Dalian, Qingdao, Shanghai, Shenzhen,
Guangzhou Island and other ports. With the development of economy in the east and west of China, cargo transportation will become more and more frequent, and the freight volume of long-distance refrigerated agricultural products increase greatly. Despite the slow development of multimodal and cold chain transport in China, the future development potential is still great.

2. Multimodal transport on refrigerated container

2.1. Classification of refrigerated containers
Refrigerated container is a special container with good heat insulation and can keep the temperature in the box in a certain low temperature range, which is suitable for transporting all kinds of perishable agricultural products. When refrigerated container multimodal transport is adopted, there is no need to replace the goods in the middle to maximize the internal low temperature environment. When refrigerated container multimodal transport is adopted, there is no need to replace the goods in the middle to maximize the internal low temperature environment. Refrigerated containers provide the best transportation environment to ensure the freshness and nutritional value of all kinds of agricultural products.

Refrigerated containers can be used as active cold storage to store perishable agricultural products in order to regulate the supply of agricultural products in the market and bring certain economic income to sellers. The existing new refrigerated containers are more environmentally friendly and scientific and practical in construction and temperature control performance. The classification of refrigerated containers is shown in Table 1.

| Type of refrigerated container | Definition |
|--------------------------------|------------|
| Mechanical refrigerated containers | The refrigeration unit and the main body of the container are two completely independent devices connected by hoses, and the refrigeration device is powered by a fuel engine. |
| Refrigerated containers on refrigerated panels | The frozen plate is equipped with eutectic liquid, which uses the low temperature characteristics of eutectic liquid to reduce the temperature in the container. |
| Refrigerated containers on Liquid nitrogen or dry ice | Provide refrigeration to containers using the special properties of objects such as liquid nitrogen or dry ice. |
| Air-conditioned refrigerated containers | In the refrigerated container suitable for cold temperature, to inhibit the breathing and ripening action of fruits and vegetables, to adjust the concentration of ethylene and other gas in the air in the box. |

2.2. Type of suitable cargo in refrigerated containers
Refrigerated containers not only have the function of ordinary containers, but also have their unique heat insulation and temperature control functions. The goods applicable to refrigerated containers include perishable goods and special goods. This paper studies perishable agricultural products. Perishable agricultural products mainly refer to agricultural products that need refrigerated containers to use their heat insulation and temperature control technology to keep them at a specified temperature to ensure their transport quality. The types of perishable goods shipped in refrigerated containers are shown in Table 2.

| Type | Definition | Citing |
|------|------------|--------|
| Uncooled goods | Transport temperature in 0-10°C refrigerated goods, inhibit respiratory action. | Including fresh fruits, vegetables, etc. |
2.3. Characteristics of multimodal transport of refrigerated containers

In container multimodal transport, containers are used as means of delivery and multiple modes of transport are linked together. This form can bring convenience to customers and transportation enterprises to a great extent, and has great advantages in improving transportation efficiency. During container transportation, goods of different nature and batches are collected in fixed containers. According to the above definition and the classification of perishable agricultural products, it can be seen that the refrigerated container multimodal transport of perishable agricultural products has the following characteristics.

(1) High transport requirements: R perishable agricultural products are easy to damage and mold under the conditions of high temperature and multiple humidity in summer, so in the process of transportation and storage, we need to provide a stable low temperature environment. In the refrigerated container multimodal transport, the general long transportation distance of agricultural products is large, and the corresponding external temperature is unstable, which requires a more precise temperature control inside the refrigerated container.

(2) Freight is affected by seasonal factors and volume fluctuates greatly: Fresh fruits and vegetables are the main transport of perishable agricultural products. The transportation of fruits and vegetables in China is obviously affected by seasonal influence, and the freight volume fluctuates greatly under the influence of the season. For example, the northern fruits of our country are mostly picked in summer and autumn, while the southern vegetables are transported in winter and spring.

(3) Long haul: The shelf life of perishable agricultural products itself is limited, and the time limit for transportation is relatively strict. Refrigerated container multimodal transport due to long distance costs more time. This contradiction increases the difficulty of organizing the multimodal transport of perishable agricultural products.

3. Analysis of transport cost of refrigerated container multimodal transport

Transportation cost refers to the cost between the two nodes, related to the refrigerated container freight rate, transportation distance, etc. The total cost is represented by the $C_1$, and the cost composition of the road, railway and waterway container transportation cost in the transportation cost is analyzed in detail. Total cost $C_1$ as expressed in formula 1.

$$C_1 = \sum_{h \in H} \sum_{i \in I} \sum_{j \in J} \sum_{k \in M} X_{ij}^h C_{ij}^{kh} q^h$$

(1)

3.1. Transport costs of road container

The transportation cost of containers on roads in China is the charging unit. According to the national requirements, empty box and heavy boxes of different specifications and models are charged according to the unified national basic freight rate, and all regions formulate the requirements that meet the basic freight rates according to the actual situation. Container freight rates include not only basic freight and box fees, but also some other fees such as delay fees, road blocking parking fees, transportation change fees, etc. Highway container transportation costs are expressed as $C_{11}$.

$$C_{11} = \sum_{m} D^m + m \times c_1 \times L_1 + n \times c_3 \times L_1 + (m + n) \times c_3$$

(2)

$D^m$: Carriers have fixed costs for the $m$ vehicle;

$m$: Number of transport vehicles dispatched by carriers;

$n$: Number of outsourced cargo containers;
3.2. Transport costs of railway container
There are two rules for calculating the cost of railway container transportation in China. One is to open up the railway container transport market, the establishment of railway container transport price rules; the other is the conventional calculation method, which consists of basic freight, railway container cargo handling operation costs, container cargo transportation fees and other costs. The conventional calculation method is the box as the unit of measurement, and the basic freight is divided into two parts: delivery to base price and operation base price. Depending on the transport situation, the head office may also levy a surcharge on railway electrification, a railway construction fund and other expenses. Conventional calculation of railway container transport costs $c_{12}$ expressed as:

$$C_{12} = n \times (c_{j1} + c_{j2} \times L_2) + n \times f_{dq} \times L_2$$

$n$: Number of containers;
$c_{j1}$: The base price of railway containers;
$c_{j2}$: Operating base price of the railway container;
$L_2$: Transport distance of railway containers;
$f_{dq}$: Rate of electrification surcharge for railway containers.

3.3. Transportation costs of water transport containers
Waterway container transportation cost mostly uses the method of fixed shipping period freight rate, and its freight calculation method is based on the shipping container transportation rate and charging method issued by the state. Waterway container shipping costs $c_{13}$ indicated as:

$$C_{13} = n \times c_{4} \times L_3 + c_f$$

$n$: Number of containers charged;
$L_3$: Distance of transport of waterway containers;
$c_4$: Freight charges for shipping containers by water;
$c_f$: Surcharge for waterway container transportation.

4. Other cost analysis of refrigerated container multimodal transport

4.1. Transit costs
Transit cost refers to the cost of using different modes of transport when refrigerated containers are in transit nodes. Container transfer stations are mainly inland container transfer stations and port container transfer stations. The main operation of the transfer station includes container transshipment, loading and unloading, repair and storage, etc. Its operating expenses mainly include container handling fee, unpacking fee, port surcharge, berthing fee, repair fee and labor management fee. As mentioned above, container transit costs consist of loading and unloading costs related to container quantity, short distance vehicle transportation costs and related miscellaneous expenses. A transit fee $C_2$ may be expressed as:

$$C_2 = \sum_{h} \sum_{i} \sum_{k} Z_{ik}^{hl} c_{ak} q_k^h + c_d$$

$c_d$: Related incidentals of container transfer.
4.2. Mass loss costs
Mass loss cost refers to the loss caused by the decline in the quality of perishable agricultural products due to the microbial activity and the oxygen in refrigerated containers. The deterioration rate of perishable agricultural products at room temperature increases exponentially but not linear with microorganisms. When the environmental temperature of agricultural products decreases, the metamorphism rate will also decline, and when the lower temperature reaches, the metamorphism rate of agricultural products will present a certain value. Fig.1 shows the quality-time image of perishable agricultural products. The quality of the agricultural products remains in the normal state, when reached a certain time, the quality of the agricultural products will continue to decline with time.

![Quality Rule Diagram of Agricultural Products](image)

As shown from the figure above:

\[
\delta = \begin{cases} 
1 & 0 < t_h \leq t_A \\
1 - \frac{t_h}{t_B} & t_A < t_h \leq t_B \\
0 & t_h > t_B 
\end{cases}
\]

(6)

\(t_h: \) Time of goods transportation.
Mass loss cost \(C_3\) may be expressed as:

\[
C_3 = \theta P h q \beta (1 - \delta) \quad 0 < t_h \leq t_B
\]

(7)

4.3. Cooling costs
The energy required during transportation and transit is supplied by power. During transportation, the power generated by both roads and railways is powered by diesel generators. Refrigeration cost refers to the cost of a refrigerated container to maintain a stable low temperature environment in the container during transport.

The total refrigeration cost \(C_4\) may be expressed as:

\[
c_4 = p \times \frac{Q}{a\beta}
\]

(8)

\(Q: \) Total energy consumed;
\(a: \) Conversion coefficient of electric energy generated by unit volume in the generator;
\(\beta: \) Refrigeration amount generated by the unit of electric energy in the refrigerated container;
\(P: \) Price of the diesel fuel.
4.4. Penalty costs
During timely delivery, the customer usually limits the carrier and requires the carrier to deliver the goods within the specified time. When the goods arrive before the specified time, because the customer is too early to receive the goods, it will produce a great early penalty cost; Carrier arriving later than the specified time will produce a late penalty cost. The penalty cost of arriving at the produce after the specified time window should increase nonlinearity over time.

5. Conclusion
With the quality of life, consumers demand the freshness, nutritional value and delivery time of perishable agricultural products. At the same time, the demand and circulation of perishable agricultural products are also increasing, making the long-distance cold chain transportation of perishable agricultural products more frequent. Refrigerated container multimodal transport has the advantages of less pollution and low cost, which can meet the increasing demand of consumers. The characteristics of relatively broad production area and relatively short life cycle, refrigerated container multimodal transport needs cross-provincial and long-distance transportation to ensure the quality of agricultural products. Cost analysis includes transport cost, transit cost, refrigeration cost and mass loss cost.

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