Analysis of the advantageous railway transportation distance compared with truck-only transportation

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Abstract: Intermodal transportation integrates the advantages of various modes of transportation. Railway transportation has the characteristics of low cost and environmental protection in medium and long distance transportation. Under the background of intermodal transportation, this paper focuses on the difference of generalized cost between truck-only door-to-door transportation and railway door-to-door transportation under the same OD, and analyzes the dominant transportation distance of truck-only transportation and railway transportation in intermodal transportation. We found that when the truck-only transportation distance is more than 400-700 km, it is more economical to convert it to railway transportation.

1. Introduction

Intermodal freight transport systems have the potential to perform better than unimodal systems in economic, especially China is facing the adjustment of transportation structure. It is crucial that researching that choosing railway is better under what conditions. This paper compares the broad cost of road door-to-door transportation and railway door-to-door transportation of 20ft container and 40ft container, and measures and calculates the advantages of the two transportation modes in intermodal transportation.

2. Construction of generalized cost model for road and railway

When railway transportation is adopted, the railway transportation cannot fully realize the door-to-door service, it is considered to calculate the short-distance drayage (i.e., pre- and post-haulage by trucks) of railway transportation. Therefore, the truck-only and railway flow diagram is shown in Fig. 1.

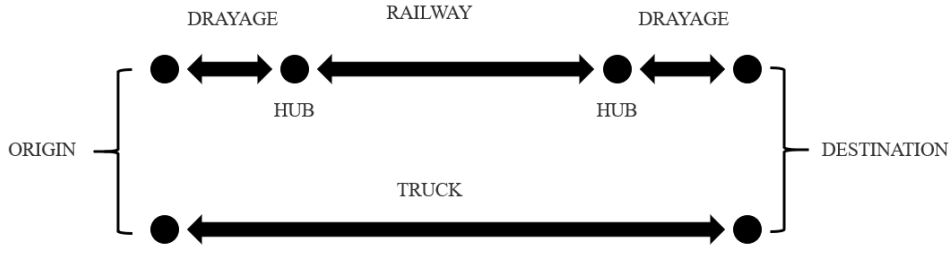

Fig. 1 The truck-only and railway flow diagram

2.1 The generalized cost of the railway transportation

There are two main factors in the generalized logistics cost of railway transportation. One part is the cost, including the drayage cost at both ends, the handling cost at both ends, and the railway transportation cost. The other part is the time, including the drayage time at both ends, railway transportation time, train assembly time, waiting time of drayage, etc.

The railway door-to-door transportation cost is determined as follows:

$$C_{rail} = C_{rail}^1 + 2C_{rail}^2 + 2C_{rail}^3 \tag{1}$$

C_{rail}^1 is the railway transportation cost, that is determined as follows:

$$C_{rail}^1 = c_{rail}^1 + c_{rail}^2 S_{rail} + c_{rail}^j S_{rail} \tag{2}$$

Where c_{rail}^1 is the first base rate of railway container transportation, which is the fixed cost(yuan/ Unit), c_{rail}^2 and c_{rail}^j are the variable cost of the second base rate of railway container transportation and the railway construction fund(yuan/ Unit/ km), and S_{rail} is railway container transportation mileage(km).

C_{rail}^2 is the railway container handling cost(yuan/Unit).

C_{rail}^3 is the drayage cost. If the "door-to-door" railway intermodal transportation is realized, the drayage at both ends must be completed by the logistics company that has signed an agreement with the railway company. Therefore, the cost charged is higher than that of the truck-only transportation. The charging basis of the drayage fees at both ends: within 10 km of the starting mileage, 450 yuan / Unit is charged for 20 foot container, 675 yuan / Unit for 40 foot container, and 24 yuan /Unit-km for 20 foot container and 36 yuan / Unit-km for 40 foot container beyond exceeding the starting mileage.

$$C_{rail}^3 = \left(c_{road}^1 + \max\left\{0, c_{road}^2 (l_{rail-road} - 10\right\} \right) \tag{3}$$

Where c_{road}^1 is the starting mileage rate(yuan/Unit), c_{road}^2 is the rate beyond exceeding the starting mileage(yuan/ Unit/ km). And $l_{rail-road}$ means average distance of drayage in railway transportation (km).

The railway door-to-door transportation time is determined as follows:

$$T_{rail} = T_{rail}^1 + 2T_{rail}^2 + T_{rail}^3 + T_{rail}^4 \tag{4}$$

T_{rail}^1 is the railway transportation time. Due to the long transportation distance of container trains, the corresponding technical operations will be carried out in some technical stations on the way, but the operation time is short and can be ignored. Therefore, the transportation time of the train can be expressed as:

$$T_{rail}^1 = \frac{S_{rail}}{v_{rail}^1} \tag{5}$$

Where v_{rail}^1 is average speed of railway(km/h).

T_{rail}^2 is the drayage time, which is determined as follows:

$$T_{rail}^2 = \frac{l_{rail-road}}{v_{road}^2} \tag{6}$$

Where, v_{road}^2 is average drayage speed(km/h), which is the average speed of the truck in the urban area.

T_{rail}^3 is the waiting time after the container arrive at the station through the drayage until the train departs, which is average waiting time. T_{rail}^4 is the waiting time after the train departs until the container is transported out of the station by drayage, which is average waiting time.

2.2 The generalized cost of the truck-only transportation

There are factors in the generalized logistics cost of truck-only transportation, including the truck-only transportation cost, truck-only transportation time in the highway, truck-only transportation time in urban area, etc.

C_{ROAD} is truck-only transportation cost, which can be expressed as:

$$C_{ROAD} = c_{road}\left(S_{road} + 2l_{road}\right) \tag{7}$$

Where c_{road} is the rate of truck-only transportation (yuan/km), S_{road} is the truck-only transportation distance in the highway(km), and l_{road} is the truck-only transportation distance in urban area(km).

The truck-only transportation time is determined as follows:

$$T_{ROAD} = T_{road}^{1} + 2T_{road}^{2} \tag{8}$$

T_{road}^{1} is truck-only transportation time in the highway, which can be expressed as:

$$T_{road}^{1} = \frac{S_{road}}{v_{road}^{1}} \tag{9}$$

Where, v_{road}^{1} is average speed of truck-only transportation time in the highway(km/h).

T_{road}^{2} is truck-only transportation time in urban area, which can be expressed as:

$$T_{road}^{2} = \frac{l_{road}}{v_{road}^{2}} \tag{10}$$

Where, v_{road}^{2} is average speed of truck-only transportation time in urban area (km/h).

2.3 Generalized cost model of road and railway door-to-door transportation

This paper constructs the generalized cost of truck-only door-to-door transportation and railway door-to-door transportation by transforming time value into cost. It is determined as follows:

$$\begin{aligned} &C_m^{G} = C_m + VOT \cdot T_m \\ &m \in (RAIL, ROAD) \end{aligned} \tag{11}$$

Where C_m^{G} is the generalized cost of the road or railway(yuan), C_m is the cost of the road or railway(yuan), T_m is the time of the road or railway(hour), VOT is value of time(yuan/h).

3. Calculation model of the advantageous railway distance

By calculating and comparing the difference of the generalized cost and actual cost of a container through road door-to-door transportation and railway door-to-door transportation, the dominant transportation distance range of the two modes can be obtained.

Based on Eq.1, Eq.7, the critical transportation distance of two kinds of door-to-door transportation under the actual cost can be determined as follows:

$$C_{rail} = C_{road} \tag{12}$$

$$S_{rail} = \lambda S_{road} \tag{13}$$

Based on Eq.11, the critical transportation distance of two kinds of door-to-door transportation under the generalized cost can be determined as follows:

$$C_{rail}^{G} = C_{road}^{G} \tag{14}$$

$$S_{rail} = \lambda S_{road} \tag{13}$$

Where λ is the detour coefficient. The highway network is relatively developed, and the railway needs to bypass a long distance, so it is necessary to change the value of railway distance. The two

modes have the critical value of transportation distance with the same generalized cost. Taking the critical point as the division, by comparing the difference of generalized cost in different transportation distance range, the dominant transportation distance interval of the two modes is obtained.

4. Case analysis

4.1 Parameter value analysis

As shown in Table 1, by comparing the relationship between the mileage of several railway ODs and the corresponding highway mileage and taking the average value, the value of λ should be 1.13.

Table 1 Comparison between the railway distance and road distance

OD	Railway distance(km)	Road distance(km)	λ
Baoji-Chengdu	673	631	1.066561
Shanghai-Kunming	2690	2330	1.154506
Beijing-Guangzhou	2284	2115	1.079905
Beijing- Shanghai	1463	1224	1.195261
Xinxiang-Rizhao	635	626	1.014377
Yingtan-Xiamen	694	575	1.206957
Chengdu-Kunming	1108	856	1.294393
Baotou-Lanzhou	1006	952	1.056723
Average			1.133585

Based on the information that is shown on website and actual investigation, the rest of parameters should value as shown in Table 2.

Table 2 The value of parameter list

parameter	20ft	40ft	unit
c_{rail}^{1}	440	532	yuan/ Unit
c_{rail}^{2}	3.185	3.918	yuan/ Unit/km
c_{rail}^{j}	0.264	0.264	yuan/ Unit/km
C_{rail}^{2}	195	292.5	yuan/ Unit
c_{road}^{1}	450	675	yuan/ Unit
c_{road}^{2}	24	36	yuan/ Unit/km
$l_{rail-road}$	30	30	km
v_{rail}^{1}	35	35	km/h
v_{road}^{2}	40	40	km/h
T_{rail}^{4}	8	8	h
T_{rail}^{5}	8	8	h
c_{road}	9.24	11.58	yuan/ Unit/km
v_{road}^{1}	90	90	km/h
VOT	40	76.18	yuan/h
λ	1.13	1.13	

4.2 The analysis of the advantageous railway distance and sensitivity

According to the Eq.12 and Eq.14, considering the actual cost and transportation of 20ft containers, when the truck-only transportation distance exceeds 398 km, it is more economical to convert it to railway transportation. Similarly, the advantageous railway distance under other conditions is shown in Table 3.

Table 3 The advantageous railway distance under different conditions (km)

	Actual cost	**Generalized cost**
20ft	398	614
40ft	449	703

It can be seen that the advantageous railway distance of different types of goods is different, and the advantageous railway distance should be determined in a range rather than an accurate value. Based on the above results, the advantageous railway distance should be about 400-700 km.

5. Conclusion

We found that when the truck-only transportation distance exceeds about 400-700 km, it is more economical to convert it to railway transportation. Though we aimed to discuss more factors that influence advantageous railway distances , we do not present a full overview of all factors that could be considered, nor did we include those factors in all possibly rel-evant ways. As a result, there are some limitations to our analyses. Finally, future analyses could include more kinds of goods that influence the the advantageous railway distance.

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