Research on Competitiveness of Haoji Railway Compared to Traditional Multimodal Transportation Organization

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Abstract—This paper gives a brief introduction of coal transportation layout in China, and analyzes Haoji Railway using SWOT analysis method, establishes a model to calculate the comprehensive transportation cost of coal by Haoji Railway, Sea-river Combination and highway transport respectively, and the model takes time value and price cuts into consideration. The results show that Haoji is favorable under certain conditions. Finally, some relevant suggestions are put forward accordingly.

1. INTRODUCTION
China consumes over 4 billion tons of coal every year and has formed the transportation pattern of “transporting coal in the West into the East” and “transporting coal in the North into the South” since the coal is mainly reserved in “3 West” area, namely Shanxi, Shaanxi, western Inner Mongolia, and consumed in the eastern coastal and southern regions[1]. Besides, railway, waterway and highway all deeply participate in the transportation of coal. Due to the “supply side reform” of the coal industry, China’s coal production is more concentrated in “3 West” area[2-3]. In 2018, China transported 2.38 billion tons of coal, and Datong-Qinhuangdao Railway, Shuohuang Railway, Mengji Railway and Fengshada Railway, Jingyuan Railway, etc. composite the “North Channel”, which transported 880 million tons accounting for 73.1% of the total coal transported volume of “3 West” area, by linking with coastal shipping and Yangtze River, this organization mode satisfies a large proportion of coal demand in East and Yangtze River region. The coal export volume of Hebei, Tianjin and Rizhao ports corresponding to the four railway channels reach 780 million tons. Haoji Railway[4], China's first specific north-south freight channel for coal came into operation in Sep, 2019. The above mentioned five railway lines reach 1.35 billion tons, which forms the basic layout of coal railway transportation in China. This paper establishes a model to compare the comprehensive costs by using Haoji Railway, the traditional rail-sea-river combination and highway transportation to see whether Haoji Railway could reduce the logistics costs and offer a favourable choice.

2. SWOT ANALYSIS OF HAOJI RAILWAY
After a detailed field visit, the SWOT analysis is summarized as follows.

2.1. STRENGTHS
(1) Sufficient Capacity. Haoji Railway is built according to the high standard dedicated railway requirements and utilized much advanced technology and can provide sufficient transportation
capacity. In addition to transporting coal, it will also attract container cargoes along the region relying on the logistics parks to improve profitability.

2) Shareholder resources. Haoji Railway has a diversified composition of shareholders. Many shareholders are large coal generating companies and can reduce coal prices to improve its competitiveness, the coal price transported by Haoji is 50 yuan lower than that by other transportation mode.

3) Time-saving. It shortens transportation time substantially and provides fast turnover and high reliability for power plants compared with rail-sea-river transportation.

4) Transportation can be completed in only 1-2 days, while the latter takes 15-20 days.

5) Coal storage and transportation base. As an important part of energy security, coal storage and transportation bases, such as Jingzhou, Xinyu and Huarong, connect coal mining enterprises and electric power enterprises along the line.

2.2. WEAKNESSES
(1) Lack of coal supply. At present, the supply capacity of coal mines along the line needs to be further increased, and the cost of these new coal fields are higher than the existing ones.

(2) Transportation price: the current transportation line pricing is relatively high, which has no advantage over the traditional sea to river transportation organization mode.

(3) “The last kilometer” connection to Haoji still lags behind. Only six of the 81 connecting stations have been completed simultaneously. The railway and local governments still have different understandings of the construction of the connecting stations, and there are still many obstacles in practice.

(4) Different transportation standards from the National Railway Standard. The main line of Haoji Railway applies the C96 models, which costs more than the surrounding national railway C70 construction standard. The capacity of customer dedicated rail sidings and dumpers are insufficient, which restricts the transfer capacity and efficiency of Haoji Railway.

(5) The control of cargo sources is not enough. Xi’an Bureau and Wuhan Bureau have their own interests when using the entrusted transportation mode. The cargo transportation organization is not completely determined by the Haoji Railway, and the coordination efficiency is low.

(6) Lack of self owned carriages. Haoji Railway is short of its own carriages, causing serious damage to goods, with a loss rate of 5%, larger than the 2-3% of rail-sea-river transportation.

2.3. OPPORTUNITIES
(1) Requirements to adjust transportation structure. Since 2018, a policy to adjust the transportation structure so as to improve the rail and waterway proportion in cargo transport has been implemented. Hence, China Railway Group may transfer part of the traffic volume to Haoji Railway under this background.

(2) Adjustment of traffic volume of Datong-Qinhuangdao Railway: Datong-Qinhuangdao Railway is also a shareholder of Haoji Railway and its capacity has been fully utilized. Nowadays Datong-Qinhuangdao Railway is still relocating some of its coal transport, and may transfer some cargoes on Haoji Railway.

(3) Development of containers and other sources of goods. Due to the economic development around the area, more high-value cargoes might need to be transported through this passage.

(4) The cost of ship operation has increased a lot. Since 2020, the fuel oil standard for ships along the coastal area and the Yangtze River has been further improved, and ship operating costs have increased, which has led to a rigid increase in freight rates. After the renovation of the Yangtze river barge, the port handling costs also have some room to rise.

2.4. THREATS
(1) Slow production of collieries. Due to the supply side reform of the coal industry, collieries along the line will be slow and must obey more restrictions.
(2) Thermal power industry reform. The number of extra-high voltage is increasing, and the new construction of coal power plants may be less than expected. Some the power plants in Hunan, Hubei and Jiangxi area, as the peak adjusting power plants of the Three Gorges hydropower station, may not be able to operate at full load throughout the year.

(3) The growth of macro demand slows down: the power of macro-economic growth is insufficient, especially after Covid-19 hit, and the operating rate of thermal power plants is low.

(4) Competition of surrounding national railway lines: after the opening of high-speed railway lines, the original passenger transport capacity will be released, and Haoji railway will face more fierce competition with other national railway lines such as Jiaolui line and Beijing-Jiulong line.

(5) Impact of imported coal: the price of imported coal has advantages. If the state liberalizes imported coal to reduce the cost of power plants, it will bring certain impact on the railway transportation of Haoji.

Based on the above analysis, a model is established as follows to compare the comprehensive costs by using Haoji Railway and multimodal transport.

3. REALISTIC COAL MINE AND POWER PLANT DISTRIBUTION

In the early stage of operation for Haoji Railway, there are only limited suppliers of coal in the upstream region, mainly gathering in Erdos of Inner Mongolia and Yulin in Shaanxi. The typical mining factories are Xiaobaodang Colliery, Hongqinghe Colliery etc. For power plants, basically they lie in river region in Hunan, Hubei and Jiangxi Province.

Table 1. Major Collieries Along Haoji Railway

| Mining Area        | Coal Field | Total Number | Number in Operation | Capacity (million tons per annum) | Local Railway       |
|--------------------|------------|--------------|---------------------|-----------------------------------|---------------------|
| Erdos, Inner Mongolia | Huerjite   | 13           | 5                   | 110                               | New Entao Railway   |
|                    | Nalinhe    | 12           | 2                   | 112                               | railway siding      |
| Yulin, Shaan Xi    | Yuheng     | 20           | 4                   | 132.3                             | Jingshen Railway    |
|                    | Yushen     | 35           |                      | 155.2                             | Jingshen Railway    |

At present, 15 collieries have come into operation. Xiaobaodang Colliery, Baijiuhaizi Colliery and has come into operation. In 2019, over 13 million tons of coal can be transported by Haoji Railway and approximately 60 million tons can be transported in 2020.

Table 2. Major Coal Fields Along Haoji Railway

| Consumption (mil tons) | Transferred Volume (mil tons) | Transferred Volume by Waterway (mil tons) | Transferred Volume by Railway (mil tons) | Transferred Volume by Railway (mil tons) | Major Consumers                                      |
|------------------------|-------------------------------|------------------------------------------|----------------------------------------|----------------------------------------|-----------------------------------------------------|
| Hubei                  | 118.67                        | 115.54                                   | 38                                     | 58                                     | Jiangling Power Plant in Hubei, Jingzhou Coal Storage and Transport Base |
| Hunan                  | 127                           | 110                                      | 36                                     | 65                                     | Huarong Coal Storage and Distribution Base            |
Jiangxi 80 74.57 27.12 28.17 20 Xinyu Steel Mill, Xinyu Coal Storage and Distribution Base

|   |   |   |   |   |
|---|---|---|---|---|
| Sum | 325.67 | 300.11 | 101.12 | 151.17 |

4. MATHEMATICAL MODEL

4.1. Model Hypothesis

- Coal can be transported by Haoji Railway, by traditional rail-sea-river combination or by highway, regardless of imported coal.
- The quantity of coal transported by rail and boat is different, and both can meet the requirements of the power plant, considering the time value and liquidity occupation cost [5].
- Regardless of port congestion in the loading and unloading ports
- The mining factory may cut their prices to improve their competitiveness
- The coal mine can connect to the power plant by road directly

4.2. Abbreviations and Acronyms

\( i \) : production site \( i \) of coal, \( i = 1, 2, \ldots, I \).
\( j \) : power plant \( j \) in Yangtze River Economic Belt, \( j = 1, 2, \ldots, J \).
\( k \) : loading point of Haoji Railway
\( l \) : unloading point of Haoji Railway
\( p \) : loading port of coal in North China
\( q \) : unloading port of coal in Yangtze River Delta
\( \alpha \) : mode choice, when \( \alpha = 1 \), coal is transported through Haoji Railway; when \( \alpha = 2 \), coal is transported through rail-sea-river combination; when \( \alpha = 3 \), coal is transported by highway
\( C_{ij}^{\alpha} \) : total cost from site \( i \) to power plant \( j \) by mode \( \alpha \)
\( L_a \) : wastage rate, proportion of wasted coal during transport by mode \( \alpha \)
\( u_{ij} \) : unit cost of transport by railway or by highway per kilometer, applicable to each separate legs, for \( i = 1, 2, \ldots, I \), \( j = 1, 2, \ldots, J \)
\( \text{LEN}_{ik} \) : railway length from point \( i \) to point \( k \), for \( k = 1, 2, \ldots, K \).
\( \text{INT} \) : demand deposit interest rate (%)
\( P_i^\alpha \) : coal price in site \( i \) when the mining company chooses mode \( \alpha \)
\( F_{ik}^{\alpha} \) : Fixed cost when using railway transportation, such as loading cost and picking cost
\( T_{ik}^{\alpha} \) : time to transport coal from site \( i \) to \( k \) by mode \( \alpha \)

So the modal choice is simplified as follows. The most economical route has to be found by calculating the comprehensive cost by these two different routes. When \( \alpha = 1 \), there are \( k*l \) routes altogether. When \( \alpha = 2 \), there are \( p*q \) routes altogether. When \( \alpha = 3 \), there are \( i*j \) routes altogether.

The model is transformed to a directed network problem and it is our duty to find out the minimum total cost for each origin and destination.
4.3. Equations

\[ C_{ij}^1 = \min \left( C_{ik}^1 + C_{kl}^1 + C_{lj}^1 + P_i^1 + V_{ij}^1 \right) \left( 1 - L_i^1 \right), \text{ for } k=1,2,...,K; \text{ for } l=1,2,...,L \] (1)

\[ C_{ij}^2 = \min \left( C_{ip}^2 + C_{pq}^2 + C_{qj}^2 + P_i^2 + V_{ij}^2 \right) \left( 1 - L_i^2 \right), \text{ for } p=1,2,...,P; \text{ for } q=1,2,...,Q. \] (2)

\[ C_{ij}^3 = \min \left( \text{LEN}_{ij}^3 \ast \text{uc}_{ij}^3 \right) \left( 1 - L_i^3 \right), \text{ for } \alpha = 1,2,3, i=1,2,...,I, j=1,2,...,J. \] (3)

\[ C_{ij} = \min \left( C_{ij}^\alpha \right), \text{ for } \alpha = 1,2,3, i=1,2,...,I, j=1,2,...,J. \] (4)

\[ C_{ik}^\alpha = \text{uc}_{ik}^\alpha \ast \text{LEN}_{ik}^\alpha + F_{ik}^\alpha \] (5)

\[ C_{kl}^\alpha = \text{uc}_{kl}^\alpha \ast \text{LEN}_{kl}^\alpha + F_{kl}^\alpha \] (6)

\[ C_{lj}^\alpha = \text{uc}_{lj}^\alpha \ast \text{LEN}_{lj}^\alpha + F_{lj}^\alpha \] (7)

\[ C_{ip}^\alpha = \text{uc}_{ip}^\alpha \ast \text{LEN}_{ip}^\alpha + F_{ip}^\alpha \] (8)

\[ C_{ql}^\alpha = \text{uc}_{ql}^\alpha \ast \text{LEN}_{ql}^\alpha + F_{ql}^\alpha \] (9)

\[ T_{ik}^\alpha = \frac{\text{LEN}_{ik}^\alpha}{V_{ik}^\alpha} \] (10)

\[ T_{kl}^\alpha = \frac{\text{LEN}_{kl}^\alpha}{V_{kl}^\alpha} \] (11)

\[ T_{lj}^\alpha = \frac{\text{LEN}_{lj}^\alpha}{V_{lj}^\alpha} \] (12)

\[ T_{ip}^\alpha = \frac{\text{LEN}_{ip}^\alpha}{V_{ip}^\alpha} \] (13)

\[ T_{pq}^2 = \frac{\text{LEN}_{pq}^2}{V_{pq}^2} + T_p, T_{pq} \in 1, 2, ... N \] (14)

\[ T_{qj}^2 = \frac{\text{LEN}_{qj}^2}{V_{qj}^2} \] (15)

\[ V_i = \left( T_{ik}^1 + T_{kl}^1 + T_{lj}^1 \right) \ast \text{INT}/365 \ast P_i^1 \] (16)

\[ V_j = \left( T_{ip}^2 + T_{pq}^2 + T_{qj}^2 \right) \ast \text{INT}/365 \ast P_j^2 \] (17)

Calculation is carried out under three different scenarios.

Scenario 1: Regardless of Time Value, and collieries do not cut prices for Haoji Railway.

Scenario 2: Time Value is taken into account, collieries do not cut prices for Haoji Railway.

Scenario 3: Time Value and price cuts are both taken into account.

4.4. Calculation of the model

All the data are obtained from field research, or public information from China Railway Website and Erdos Coal Transportation Web.
Table 3. Result of comprehensive Costs Under Different Scenarios (yuan/ton)

| Route | Cost of each legs | Time Value | Total Cost |
|-------|------------------|------------|------------|
|       | $C_i$            | Size       | Time of Travel(days) | $L_i$ | $P_i$ | Scenario 1 | Scenario 2 | Scenario 3 |
| 1     | Freight          | 195        | 2           | 0.10  | 5%    | 379.44     | 796.43     | 796.53     | 746.55     |
|       | Freight          | 1205       | 15          | 0.78  | 2%    | 379.44     | 813.0      | 813.8      | 813.8      |
|       | Freight          | 344.1      | 2           | 0.10  | 3%    | 379.44     | 745.95     | 746.05     | 746.05     |

5. ANALYSIS OF CALCULATION RESULTS

It is shown that highway transportation costs least under Scenario 1 and 2, while Haoji Railway is more competitive in Scenario 3 considering the subsidy from the mine. Lack of sidings increase the total cost substantially. When the siding is finished, Haoji Railway could cut its cost by 50.48 yuan/ton. Haoji Railway is better than rail-sea-river combination. It is also found that time value in this case is almost negligible. Since coal is always transported in large amount, the unit cost is not high and power plants usually stock much coal, power plants do not pay much attention to the capital occupation value.

In the current nurturing stage, Haoji is competitive and can win some market share.

Then Xiaobaodang Mine and Hongqinghe Mine are selected to represent collieries in Yulin and Erdos respectively, and Jiangling Power Plant, Xiangtan Power Plant and Jinggangshan Power Plant are selected to represent destinations. The results are shown in the following diagram. It is shown that Haoji Railway is the first choice when transporting coal from Xiaobaodang to Xiangtan even without coal price cut. It became the top choice to transport coal from Xiaobaodang to Jiangling under Scenario 3. Highway transportation performs better when the distance is relatively short. Rail-sea-river transportation performs better during long distance transfer.

By the end of 2020, Haoji Railway could attract more coal due to better connecting conditions. Further research will be carried out to investigate the competitiveness of Haoji and the remaining ones from different origins to various destinations.

Table 4. Result of comprehensive Costs under Different Scenarios (yuan/ton)

| Origin          | Destination | Scenario 1 | Scenario 2 | Scenario 3 |
|-----------------|-------------|------------|------------|------------|
|                 | Mode 1 | Mode 2 | Mode 3 | Mode 1 | Mode 2 | Mode 3 | Mode 1 | Mode 2 | Mode 3 |
| Xiaobaodang     | 796    | 813    | 746    | 797    | 814    | 746    | 747    | 814    | 746    |
| Xiaobaodang     | 805    | 943    | 831    | 806    | 850    | 831    | 756    | 850    | 832    |
| Xiaobaodang     | 898    | 989    | 831    | 899    | 980    | 833    | 894    | 980    | 833    |
| Hongqinghe      | 819    | 903    | 778    | 819    | 804    | 778    | 769    | 804    | 778    |
| Hongqinghe      | 922    | 918    | 965    | 922    | 919    | 965    | 972    | 919    | 965    |
6. CONCLUSIONS AND SUGGESTIONS

(1) Support Haoji railway to play a greater role in the national coal transportation layout.

With the opening and operation of Haoji Railway, the "North coal transported to the South " will be able to realize direct railway transportation, and the "three horizontal and five vertical" coal outward transportation channels will be basically formed in China. Haoji Railway has invested much, which is also one of the pilot projects during mixed ownership reform of railway and is of great significance in China's coal transportation layout for the economy and society. In the short term, Haoji Railway will not have a significant impact on the existing "North coal transported to the South" pattern. The transportation volume will increase slowly, forming a new balanced pattern of coal transportation. In order to further fulfill the potential of Haoji Railway as a large coal freight corridor, it is suggested that construction of connecting stations along the line and get through the "last kilometer" as soon as possible.

(2) Strengthening the management of the coastline along the Yangtze River

Jingzhou coal storage and transport base is the landmark storage and transportation project of Haoji railway. The construction of the national strong general wharf around it will form fierce competition, resulting in the waste of coastline resources. It is suggested to strengthen the management and approval of the coastline along the Yangtze River.

(3) The industry supervisors Should Support Haoji Railway to play the role of ensuring the safety of energy storage and transportation

Haoji railway has communicated with the main coal producing areas in China, power plants, steel plants and other demanders in two lakes and one river area, and has arranged high-specification storage and transportation bases such as Jingzhou and Xinyu along the line. It is suggested to support Haoji railway and key connecting stations along the line as national multimodal transport demonstration projects, so as to better play the storage and transportation capacity of the project. Support the coal storage base along the line to become a national energy storage and transportation base.

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