

Capacity Optimization of Haolebaoji-Ji'an Railway Freight Transportation



Kai Xu and Xiaoning Zhu

Abstract Under the guidance of national policies, China Railway tries to take advantages of Haolebaoji-Ji'an railway, one of the north-to-south heavy-haul railway in China, to carry out "freight increment" and "road to railway" target. Based on the analysis of Haolebaoji-Ji'an railway, this paper analyzes the influence on the transportation corridor capacity from three perspectives. First, the service area covered by traffic flow path is limited and the trains make a detour in some areas. Second, the capacity of the collection and distribution system cannot fit the demand of railway coal transportation. Third, the management of the empty wagon dispatching is still disorganized leading to the lack of empty wagon in some stations. According to the drawbacks, this paper proposes some strategies and suggestions for enhancing the transportation capacity.

Keywords Haolebaoji-ji'an Railway · Capacity Optimization · Traffic Flow Path · Collection and Distribution System · Empty Wagon Dispatching

1 Introduction

In China, coal production is mainly located in the northwest, while consumption is distributed in the east and south. Due to the unbalanced layout of resource and industry, the supply and demand of coal are separated geographically, resulting in the transportation situation of "Coal from the north to the south" and "Coal from the west to the east". As the main mode of coal transportation in China, railway has formed seven vertical and five horizontal transportation corridors. The seven vertical

K. Xu (✉) · X. Zhu

School of Traffic and Transportation, Beijing Jiaotong University, Beijing, China

e-mail: 21114031@bjtu.edu.cn

X. Zhu

e-mail: xnzhu@bjtu.edu.cn

© Beijing Paiké Culture Commu. Co., Ltd. 2023

X. Dong et al. (eds.), *The proceedings of the 10th Frontier Academic Forum of Electrical Engineering (FAFEE2022)*, Lecture Notes in Electrical Engineering 1054, https://doi.org/10.1007/978-981-99-3408-9_118

1315

corridors include Jiaozuo-Liuzhou Railway, Beijing-Kowloon Railway, Beijing-Guangzhou Railway, Baotou-Xi'an Railway, Haolebaoji-Ji'an Railway, Nanning-Kunming Railway, the part of Lanzhou-Chongqing Railway and Lanzhou-Xinjiang Railway in Xinjiang. The five horizontal corridors include northern corridor, middle corridor and southern corridor in "San Xi" area, Shanghai-Kunming Railway, the part of Xilinhaote-Wulahaote Railway and Bayanwula-Xinqiu Railway in Inner Mongolia. As a vital north-to-south heavy-haul railway, Haolebaoji-Ji'an Railway catches more and more attention with the growing freight volumes.

The researches mainly concentrate on the analysis of Haolebaoji-Ji'an Railway transportation organization and system, including how to reduce the cost and improve the capacity. Based on the transportation market of Haolebaoji-Ji'an Railway, Li analyzed the factors and challenges on constructing collection and distribution system. Then the strategies were proposed from four aspects: accelerating the construction of strategic loading sites along the line, building the coordinated system for multi-modal transportation, improving the yard distribution and facilities and building the fourth-party logistics platform, so as to promote further development of the collection and distribution system for Haolebaoji-Ji'an Railway [1]. Wu et al. analyzed the current situation of Haolebaoji-Ji'an Railway transportation capacity from the loading station and corridor capacity, rolling stock and unloading equipment, collection and distribution system, impact of restricted sections. In order to further release the transportation capacity, this research put forward some suggestions such as improving the construction of infrastructure, promoting disciplinary operation of freight transportation, focusing on the restricted section including Jingbian-Shenmu Railway and Xiangyangbei station [2]. Based on the analysis of Haolebaoji-Ji'an Railway attraction area and the coal freight market status, Dong and Fu proposed the influence of Haolebaoji-Ji'an Railway on China's coal freight market from the following three aspects: the existing layout of coastal coal transportation, the change in the coal transportation pattern, and the new trend of the coal transportation reform. As a result, Haolebaoji-Ji'an Railway has intensified competition in some regions. According to the statistics of China Energy Investment, this research studied on two main coal transportation modes including "sea-to-river" transportation and through railway transportation. Then this research analyzed the potential transfer of coal transportation volume of these two methods to Haolebaoji-Ji'an Railway [3].

At present, the researches about Haolebaoji-Ji'an Railway are just at the beginning. The specific optimization still need to refer to the existing researches about heavy-haul railway transportation. Bondin et al. established a nonlinear integer programming model based on the through traffic flow marshalling problem caused by high traffic density and inefficient transportation capacity to solve the optimal problem of the through traffic flow direction [4]. Marin et al. studied the interaction between traffic flow and train, also defined train operation frequency and the method of traffic flow path segmentation [5]. Zhang, based on the situation of Baotou-Shenmu Railway, established an optimization model for the multi-path traffic flow organization to calculate the optimized train operation plan [6]. Zhou analyzed the defects of the collection and distribution system of Datong-Qinhuangdao Railway, and put forward the plan of rebuilding and constructing the corridor to improve

the capacity [7]. Wang studied the collection channel and the construction of loading station based on Datong-Qinhuangdao Railway transportation organization mode, and proposes a suitable construction scheme for the collection system [8]. According to the background of German railway, Cordeau et al. regarded the empty wagon allocation problem as a job-shop scheduling problem and established a model with the goal of minimizing the dispatching cost of empty wagons [9]. Haghani [10] and Beaujon et al. [11] regards the empty wagon allocation problem as an inventory problem for each freight operation station to calculate the number of the empty wagons needed in the operation.

How to guarantee the utilization of corridor capacity has become the most important issue for Haolebaoji-Ji'an Railway. In this paper, we provide some specific suggestions on the optimization of Haolebaoji-Ji'an Railway transportation, on the basis of problem analysis. We divide the problem analysis into three parts. In Sect. 2, we focus on the traffic flow path. In Sect. 3, the collection and distribution system are studied. In Sect. 4, we concentrate on the dispatching of empty wagon. Section 5 provides strategies for the issues and Sect. 6 includes the paper.

2 Traffic Flow Path

Haolebaoji-Ji'an Railway originates from Haolebaojinan railway station in Ordos, Inner Mongolia and terminates at Ji'an station on the Beijing-Kowloon Railway, which passes through seven provinces and regions, including Inner Mongolia, Shanghai, Henan, Hubei, Hunan and Jiangxi. It is one of the Class I railway lines in Chinese national railway system and the possesses the total length of 1813.5 km. With the operation of Haolebaoji-Ji'an Railway, "San Xi" area and "Liang Hu Yi Jiang" area is directly connected by railway which result in more convenient coal supply. However, the problems in traffic flow path will lead to insufficient capacity. The main problems are as follows.

2.1 Limited Service Coverage

Based on the loading statistics in 2022, Haolebaoji-Ji'an Railway covered 15 railway bureaus and 22 provinces. The specific proportion of train destination is shown in the Table 1 below.

As shown in the table, the central regions in China, such as Hubei, Jiangxi, Hunan and Henan, is the main direction of Haolebaoji-Ji'an Railway transportation. The provinces surrounding the railway corridor, such as Anhui, Jiangsu, Chongqing and Sichuan, is the secondary direction. While some provinces far away from the line, such as Qinghai, Gansu, Jilin, Heilongjiang, Hainan and Tibet, have not been covered yet. Therefore, Haolebaoji-Ji'an Railway still has great potential in the coal transportation with further development through the optimization and adjustment of traffic flow path.

Table 1 Loading direction of Haolebaoji-Ji'an Railway in 2022

Index	Province	Percentage(%)	Index	Province	Percentage(%)
1	Hubei	38.51	12	Ningxia	0.54
2	Jiangxi	20.88	13	Shanxi	0.39
3	Hunan	14.84	14	Fujian	0.25
4	Henan	12	15	Yunnan	0.21
5	Anhui	2.88	16	Zhejiang	0.19
6	Jiangsu	2.32	17	Shaanxi	0.1
7	Chongqing	1.77	18	Guangdong	0.09
8	Sichuan	1.4	19	Hebei	0.02
9	Shandong	1.1	20	Shanghai	0.01
10	Guizhou	1.09	21	Liaoning	0.01
11	Guangxi	0.72	22	Xinjiang	0.005

2.2 Angular Wagon Flow

The connecting line between Baotou-Xi'an Railway and Haolebaoji-Ji'an Railway has a negative influence on the traffic flow path. If a train from Baotou-Xi'an Railway want to get to Haolebaoji-Ji'an Railway, it need go to Taiyuan-Zhongwei-Yinchuan Railway by transferring at Suide station first and then pass through Yangqiaopan station and Jingbiandong station. The whole traffic flow path produces a large number of detours and generates serious angular wagon flow problems.

(1) Repeated occupation of equipment.

The angular wagon flow means that the circuitous transportation exists which will occupy the up and down equipment respectively and have an impact on the transportation capacity. The more angular wagon flow in the traffic flow path, the more waste of railway station capacity.

(2) Affecting other traffic operations in the rail exchange yard.

Railway stations generally have lines dedicated to special operations in the rail exchange yard, such as filling the refrigerated truck with ice. The occupation of the rail exchange yard by the angular wagon flow will interfere with these operations and increase the dwell time of these vehicles at the station.

(3) Increasing the station transit time and reducing transport efficiency.

The operation procedures of adapting the angular wagon are as below: arrival, disintegration in the first system before the transition, aggregation before transition, transition, second disintegration, aggregation, grouping and departure. Therefore, the vehicle operation time is additional.

(4) Increasing transportation costs and consuming railway station adaptation capacity.

Angular wagon flow makes the shunting operation and dwell time increased which will bring substantial cost such as operation expenses, cargo detention fees and Infrastructure costs in railway stations. If there are many angular wagon flows, the economic losses in operation and engineering can be considerable.

3 Collection and Distribution System

The concept of “insisting on integrated planning and supporting the construction of the collection and distribution system” was proposed in the beginning of Haolebaoji-Ji'an Railway project. In fact, the construction of the collection and distribution system is obviously slower than the main line. The slow construction progress of the special railway lines and coal bases around the railway line leads to the lack of the capacity.

3.1 Inadequate Supply in Collection

The main coal supply for Haolebaoji-Ji'an Railway comes from "San Xi" area. Inner Mongolia has a coal production capacity over 70 million tons, but most of the volume is transported by water rather than railway. It is estimated that the coal supply will be about 20 million tons in 2021 and about 35 million tons in the long term. Coal supply in Shaanxi is more than 100 million tons. While due to the relatively slow construction of coal mines, the actual production capacity is limited. It is estimated that in 2021, Yulin will supply about 40 million tons of coal for transportation by Haolebaoji-Ji'an Railway, and about 60 million tons in the long term. The annual output of Shanxi coal is about 6 million tons, which is mainly for local sales at present. After connecting with Haolebaoji-Ji'an Railway in the future, it is estimated that the coal supply will be about 3 million tons.

Because Haolebaoji-Ji'an Railway is a new planned coal transportation corridor, there are a lot of disadvantages such as development condition, coal supply and transportation distance. The slow construction progress of infrastructure leads to the loss of originally planned coal supply. At present, the construction of the main line and connecting line is at normal process. While the construction progress of the collection station and special railway line is obviously lagging, which results in the lack of collection capacity. In summary, it is necessary to speed up the development of direct connection projects of coal sources to ensure the long-term coal transportation indicators.

3.2 Inadequate Capacity in Distribution

With the decline of the coal production capacity in “Liang Hu Yi Jiang” area, the coal consumption demand has gradually increased. The annual coal consumption in Hubei Province is about 120 million tons, with 115 million tons imported from other provinces, of which about 57 million tons are imported by railway. The annual coal consumption in Hunan Province is about 100 million tons, with 82 million tons imported from other provinces, of which about 33 million tons are imported by railway. The annual coal consumption of Jiangxi Province is about 82 million tons, with 78 million tons imported from other provinces, of which about 33.5 million tons are imported by railway.

The coal bases supporting the line are mostly in the stage of planning, design and construction because of the aspects such as land and environmental, resulting in the lack of capacity in the short term. As of 2020, only Hubeihuadianjiangling Electric Power Plant and Guodiantoufenyi Electric Power Plant have been opened in the distribution system. While the demand requires the coal to be transferred to other lines in order to get to the destination, the current capacity cannot satisfy the demand of “Liang Hu Yi Jiang” area. Restricted by the existing railway line capacity, Haolebaoji-Ji’an Railway cannot be utilized fully.

4 Empty Wagon Dispatching

In the process of railway transportation production, transportation organization must insist on the principle of “unloading-Wagon plan-loading” which means sending out loaded wagons and recycling empty wagons. Therefore, empty wagon is an important factor affecting transportation efficiency. Empty wagon dispatching involves the whole links of the transportation system including rolling stock, unloading equipment and so on.

The collection and distribution system of Haolebaoji-Ji’an Railway is relatively scattered which may bring challenges on transportation organization. At present, the empty wagon dispatching plan of Haolebaoji-Ji’an Railway is given by China State Railway Group. The empty wagons mainly come from Wuhan Bureau, Nanchang Bureau and Guangzhou Bureau to meet the demand of Taiyuan Bureau and Xi’an Bureau through some boundary stations such as Goulinnan, Yueyangbei and Xinyuxi. And Xi’an Bureau also offers some empty wagons to Hohhot Bureau. Without fixed train marshalling for empty wagons, the whole dispatching is filled with randomness which means the railway bureau can get the empty wagons in case of shortage without schedule. In another word, the unreasonable utilization of the empty wagon leads to the insufficient capacity.

And due to the inconsistent rolling stock model, there are all kinds of unloading equipment which may affect the unloading efficiency of the arrival station. Without the supporting of advanced equipment, just unloading by manual work or ordinary dumper will result in a backlog of the wagons at the station. For example, Jiangling Station use the single hook unloading dumper which can only unload one vehicle at a time in the initial stage. The low efficiency has a direct effect on the whole corridor capacity.

5 Capacity Optimization Strategy

In view of the above problems, this paper proposes the following constructive suggestions for the capacity optimization of Haolebaoji-Ji'an Railway freight transportation.

5.1 Traffic Flow Path Adjustment

(1) Expanding the scope of services

The premise of expanding the scope of services is to enhance the railway capacity. With the boom of the economic, railway freight transportation get the development opportunities. Haolebaoji-Ji'an Railway corridor can connect with Dongsheng-Wuhai Railway, Taiyuan-Zhongwei-Yinchuan Railway, Datong-Puzhou Railway, Lanzhou-Lianyungang Railway, Nanjing-Xi'an Railway, Jiaozuo-Liuzhou Railway, Beijing-Kowloon Railway, Shanghai-Kunming Railway, Beijing-Guangzhou Railway by the connecting line to cover the coal transportation network of "nine vertical and six horizontal".

And with the development of the connecting line, the traffic flow path will update. Haolebaoji-Ji'an Railway can get the coal from Shanggao-Xinyu Railway through Wushenqinan connecting line and Taolimiaoan connecting line. The traffic flow path is the coal mine in Ordos-Wushenqi station- Wushenqinan connecting line/Taolimiao station-Taolimiaoan connecting line-Haolebaoji-Ji'an Railway. The whole traffic flow path of Taiyuan-Zhongwei-Yinchuan connecting line is the coal mine in Ningxia- Taiyuan-Zhongwei-Yinchuan Railway-Yangqiaopan station-Jingbiandong connecting line-Haolebaoji-Ji'an Railway. And Baotou-Xi'an connecting line brings the coal mine in Shaanxi, Lanzhou-Lianyungang connecting line sends the coal from Haolebaoji-Ji'an Railway to the center and east of China, Zilin station connecting line connects Haolebaoji-Ji'an Railway and Jiaozuo-Liuzhou Railway.

(2) Optimization of angular wagon flow

First, choose a reasonable location for the railroad station. Yan'andong station, an intersection between Baotou-Xi'an Railway and Haolebaoji-Ji'an Railway, can be set up as a technical station to eliminate the angular wagon flow. And select the direction of the line into the station appropriately for the angular wagon flow is generated by

mismatching between railway line and station. When setting up the line, we should not only pay attention to the safety and the capacity of the receiving operation but also reduce the conflict with other operation. In summary, use the straight line to replace the angular wagon flow in the traffic flow path.

Meanwhile, it is effective to enhance the capacity by planning long-distance through transportation and making long-distance through train marshalling. The long-distance through train need fewer number of uncoupling and less cost. In another word, with the sufficient line conditions, the long-distance through transportation can reduce the number of angular wagon and remarshalling operation. When the capacity is not enough, diversion of operation to other auxiliary stations is quite useful. This method is suitable for large and scattered traffic flow and the direction of the diversion should minimize conflict as much as possible.

5.2 Collection and Distribution System Construction

(1) Push forward the construction progress of collection and distribution project.

Among the planned collection and distribution projects, less than half of the projects have been started, and only a few have been completed. As to the collection system, it is necessary to accelerate the process of constructing collection station and special railway line projects such as Nalinhe and Yanguangyingpanhao. Meanwhile, it is also important to focus on the construction of the connecting line between Haolebaoji-Ji'an Railway and other railway such as Baotou-Xi'an Railway and Xilinhaote-Wulanhaote Railway. And the focus of the distribution system is the construction situation of Huarong coal railway-water intermodal logistics base, Yueyang coal railway-water intermodal base and Xinyu coal storage base and other projects. By putting the project into operation, Haolebaoji-Ji'an Railway can establish the connection with the existing railway to increase the transportation direction and volume.

With the construction of collection and distribution project, building a unified information platform for railway, coal supply and demand becomes more and more important. The transparent collection and distribution information can promote trade development, reduce coordination cost, realize the seamless connection and improve the efficiency.

(2) Focus on logistics system construction

Traditional railway station is difficult to adapt to the development of modern logistics if not considering warehousing, packaging, processing, distribution facilities and information system. In order to develop railway logistics, railway freight yards should be professionalized, standardized, scaled and marketed. The logistics station is capable of handling coal transportation, storage and processing operations, while also providing personalized service for costumers, with loading and unloading, measuring, safety testing, information systems and other equipment.

And relying on the stations around the coal mining areas, the pressure of single coal source from Jingbian-Shenmu Railway can be relieved by constructing strategic cargo-loading spots such as Haizetan and Wushenqinan. In the region with rich coal resources and output capacity such as Taolimiao, Jingbian, Yan'an and Hancheng, the construction of the collection and transportation facilities can stimulate the coal market demand and adapt to the future development.

5.3 Empty Wagon Dispatching Strategy

(1) Make a scientific empty wagon dispatching plan

China Railway Group need to make a scientific and effective empty wagon dispatching plan for solving the problem of random adjustment. Before formulating the plan, it is necessary to consider the daily loading demand and the difference between the loading station on the line in order to calculate the number of empty wagons that should be sent back more accurately from the perspective of the whole corridor. Under the premise of guaranteeing the number of the empty wagon and the transportation distance, empty wagon dispatching can consider proximity principle which means sending the empty wagons to the demand area from the stations around the line first.

According to the unbalanced supply and demand, the empty wagon dispatching plan for Haolebaoji-Ji'an Railway can be based on the through empty wagon train and the empty and loaded wagon mixing composition train. The through empty wagon train can transport empty wagons quickly and in large quantity. The empty and loaded wagon mixing composition train need less assembly time and can also supplement some empty wagons.

(2) Reinforce the railway management

The railway bureaus operating the coal transportation network should divide the responsibilities clearly and exchange the relevant information fluently based on the existing management model. For example, the stations in the charge of Xi'an Bureau are mostly loading station, while the stations in the charge of Wuhan Bureau are mostly unloading station. Therefore, Xi'an Bureau need the empty wagons from Wuhan Bureau sufficiently and steadily.

(3) Improve infrastructure conditions

The capacity of the railway is determined by the restricted sections on the line which means some sub-lines may affect the capacity of the whole line. The cargo from Taiyuan-Zhongwei-Yinchuan Railway and Shanggao-Xinyu Railway account for about 40% of the collection volume and the cross-line cargo account for about 70% of the distribution volume. Therefore, the restricted sections of the other railway will still have an impact on the capacity of Haolebaoji-Ji'an Railway. It is necessary to improve the infrastructure conditions and upgrade the equipment. For example, building the double track railway, increasing the station track and use the same wagon model.

6 Conclusion

This paper discusses the issues of Haolebaoji-Ji'an Railway from three perspectives: traffic flow path, collection and distribution system, empty wagon dispatching. And then this paper analyzes the harm of each issue to the whole corridor. At last, some strategies and suggestions are put forward in order to optimize the freight transportation organization and enhance the corridor capacity for the further development.

References

1. Li, Z.: Current situation and strategies for the collection and distribution system of Haolebaoji-Ji'an coal railway. *Freight Logist.* **38**(10), 49–53 (2020). (in Chinese)
2. Wu, Q., Meng, K., Li, S., Li, D., Chen, G., Yang, J.: Countermeasures against elevating freight volume of Haolebaoji-Ji'an Railway. *Freight Transp. Organiz.* **39**(08), 06–11 (2021). (in Chinese)
3. Dong, D., Fu, T.: Analyzing the impact of opening of Haoji railway on coal freight market. *J. Transp. Eng. Inf.* **002**(020), 0145–0149 (2022). (in Chinese)
4. Bodin, L.D., Golden, A.D.: A model for the blocking of train. *Transp. Res. Part II: Mythol.* **14**(1), 115–120 (1980)
5. Marín, A., Salmerón, J.: Tactical design of rail freight networks. Part II: local search methods with statistical analysis. *Eur. J. Oper. Res.* **94**(1), 43–53 (1996). [https://doi.org/10.1016/0377-2217\(95\)00193-X](https://doi.org/10.1016/0377-2217(95)00193-X)
6. Zhang, S.: Study on the organization and optimization of baoshen railway traffic flow. Beijing Jiaotong University (2020). (in Chinese)
7. Xiaowen, Z.: The analysis and strategy of the collection and distribution corridor capacity of Datong-Qinghuangdao Railway. *Railway Econ. Res.* **01**, 35–37 (2005). (in Chinese)
8. Qiming, W.: Study on the construction of Datong-Qinghuangdao Railway collection and distribution system. *Taiyuan Railway Technol.* **02**, 8–11 (2009). (in Chinese)
9. Cordeau, J.F., Toth, P., Vigo, D.: A survey of optimization models for train routing and scheduling. *Transp. Sci.* **32**(4), 380–404 (1998)
10. Haghani, A.E.: Formulation and solution of a combined train routing and makeup, and empty car distribution model. *Transp. Res. Part B* **23**(6), 433–452 (1989)
11. Beaujon, G.J., Turnquist, M.A.: A model for fleet sizing and vehicle allocation. *Transp. Sci.* **25**(1), 19–45 (1991). <https://doi.org/10.1287/trsc.25.1.19>