Research on Transportation Organization Optimization on Port Station of Sea-rail Combined Transport

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Abstract. The port station on Sea-rail combined transport is the connection of railway and waterway transportation, but also the source of railway transportation on sea-rail combined transport. To improve the handling capacity of China's major ports, and strengthen the work of container sea-rail combined transport, the research of the transportation organization optimization of sea-rail combined transport port stations has been put on the agenda. This paper uses gray prediction method to predict the amount of transportation borne by sea and railway; Then, the transport capacity of sea transportation and railway joint transportation organization is taken as a research object. It mainly includes the following aspects: the ability of loading and unloading process, the ability of picking up and delivering vehicles, and dispatch, etc. Based on the actual case, the adaptability analysis, obtained the feasibility of transportation organization optimization; Finally, the problems need to be solved in the optimization of port station.

Keywords: Sea-rail combined transport, Port station, Transportation organization, Gray forecast

1 INTRODUCTION

Using sea transport and rail two forms of transport, and through containers to complete the shipment of goods, the organization formed is called sea-rail combined transport. In the sea-rail combined transport, containers can carry more goods, and have a lower transportation cost. Sea-rail combined transport is a more common way of transportation organization in the world. At the same time, it can rely on the port stations jointly established by railway and port, which has a strong radiation to the inland. At present, China has begun to improve the joint transportation of containers by sea and railway to promote the rapid development of container sea-rail combined transportation. China actively carries out the work of sea rail combined transport, makes reasonable planning for the infrastructure of container transport, and improves the overall level of container sea rail combined transport system [1].According to the survey, the rapid growth of container iron and water combined transport volume is mainly based on the launch of new facilities at the port and railway terminals, the continuous promotion of railway entry, and the establishment of a multimodal transport joint venture company to expand the business scope.

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The optimization of transport organization on sea-rail combined is an important link to improve the efficiency of sea-rail combined transport. China's index to judge the development level of multimodal transport is not only the volume of multimodal transport, but also focuses on the efficiency of changing gear and connection. According to the Outline of the National Comprehensive Three-dimensional Transportation Network Plan, the development goal for 2035 is that "the completion rate of multimodal transport replacement in one hour is above 90%".We have gradually abandoned the quantity-based indicators and strengthened the quality indicators. In the development of multimodal transport, the "one single system", information technology, network and other important issues have been further paid attention to [2].The research on the transportation organization of the port station at the multimodal transport junction has become the next breakthrough point for the increase of the freight volume.

2 THE FORECAST OF TRANSPORT VOLUME ON PORT AND STATION SEA-RAIL COMBINED

Scientific prediction of sea-rail intermodal transport volume at port stations can promote the development of multimodal transport. There are many ways to predict the combined transport volume. Among the many methods, the gray prediction method is the most effective. The advantages of the gray prediction method are that there is no large number of samples, no regular distribution, the calculation workload is small, and the quantitative and qualitative analysis is consistent, so it is more suitable for the prediction of sea-rail combined transport volume [3].

2.1 Historical data of sea-rail combined transport on Port A

Port A is an important node for transport between Asia and Europe and a corridor between East Asia and West Asia. It has great advantages in developing sea-rail combined transport. It is the most potential port in northern China, and has been selected as the railway container center station and the sea-rail combined transport channel demonstration project .At present, the land area of Port A has reached 132km^2, with a total of 160 berths of various types, 103 berths above 10,000-ton class, and 120 container routes. Port A is the shipping hub center in northern China. Port A is expected to become a world-class port by 2035.

By viewing the data provided by the Port A Group, the number of multimodal transport types in Port A in 2016-2021 is shown in Table 1.

Table 1. Overview of sea-rail combined Transport volume of Port A from 2016-2021

year	2016	2017	2018	2019	2020	2021
Transport volume on Sea-rail combined of Port A (ten thousand TEU)	31	32	34	49	48	80

2.2 Gray prediction method for measurement

According to the traffic volume data of sea-rail combined transport in Port A from 2016 to 2021 and the forecast content of the grey prediction method, the following calculation is carried out:

In the first step, construct the cumulative generation column:

Eliminate the randomness and volatility of the data, and we can know that:

$X^{(0)}$=[31, 32, 34, 49, 48, 80];

$X^{(1)}$=[31, 63, 97, 146, 194, 274];

In the second part, we construct the matrix B and the data vector Y_n

Establish the data matrix to obtain:

$$B=\begin{pmatrix} -47 & 1 \\ -80 & 1 \\ -121.5 & 1 \\ -170 & 1 \\ -234 & 1 \end{pmatrix} \qquad Y_n=\begin{pmatrix} 32 & 1 \\ 34 & 1 \\ 49 & 1 \\ 48 & 1 \\ 80 & 1 \end{pmatrix}$$

In the third step, the B^TB, $(B^TB)^{-1}$and B^TY_n are calculated

$$B^TB=\begin{pmatrix} 107027.25 & -652.5 \\ -652.5 & 5 \end{pmatrix} \qquad (B^TB)^{-1}=\begin{pmatrix} 0.0000457 & 0.005965 \\ 0.005965 & 0.978490 \end{pmatrix}$$

(By the formula) $\hat{a}=(B^TB)^{-1}B^TY_n=(a,b)^T$ acquirability $\hat{\alpha}=\begin{pmatrix} -0.2443774 \\ 16.70875 \end{pmatrix}$

a=-0.2443774 b=16.70875

The fourth step is to derive the prediction model:

$$\frac{dX^{(1)}}{dt}-0.2443774X^{(1)}=16.70875$$

$$X^{(0)}(1)=31 \qquad \frac{b}{a}=-68.37272722$$

$$X^{(0)}(1)-\frac{b}{a}=99.37272722$$

$$X^{(1)}(k+1)=99.37272722e^{0.2443774k}-68.37272722$$

The fifth step, the residual test:

(1) Subtracted to generate the $\hat{x}^{(0)}$ sequence.

$\hat{X}(0)=\{31, 58.50896589, 93.6331319, 138.4805843, 195.7429826, 268.8571082\}$

(2) Calculate the absolute error sequence and the relative error sequence.

The absolute error sequence is:

$\delta(k)=\{0, 4.491034111, 1.124166009, 4.152547616, 9.262398339, 6.885874466\}$

The relative error sequence is: $\varepsilon(k)=\{0, 14.03\%, 3.31\%, 8.47\%, 19.30\%, 8.61\%\}$

Step 6, the posterior difference test:

(1) Calculation of the variance of the original sequence $X^{(0)}$. $\bar{X}^{(0)} = 45.66667$ $S_1^2 = 288.8889$

(2) Calculation of the variance of the residual difference. $\bar{\delta}(k) = 4.31934$ $S_2^2 = 9.99068$

(3) Calculation of C-value. $C = \frac{S_1^2}{S_2^2} = 0.18597$

(4) Calculation of the small error probability. $S0 = 0.6745 \times 16.9967 = 11.4643$

$e_i = \{4.31934，0.17170，3.19517，0.16679，4.94306，1.59420\}$

All e are less than S_0, so P=1 and C <0.35.

Through a series of tests, the final results are small in error, which can be seen from the data that the prediction simulation has high accuracy.

In Step 7, the model can be used for prediction after testing. When k=7,8,9, the annual sea-rail combined freight volume of Port A from 2022 to 2024 can be predicted. The calculation results are shown in Table 2.

Table 2. The volume forecast of sea-rail intermodal transport on Port A from 2022-2024

year	Sea-rail combined transport volume Port A (ten thousand TEU)
2022	94
2023	120
2024	153

3 STUDY ON TRANSPORTATION ORGANIZATION CAPACITY OF PORT STATION

When studying the combined transport capacity of railway and sea route, the subject of the study needs to be identified. To match the comprehensive railway transportation capacity in the port station with the comprehensive transportation capacity of the port, and the comprehensive transportation capacity of the port can support the total port business. The calculation can be done by using the following formula[4].

$$M_{GX} < M_{GZH} < M_{LZH} \tag{1}$$

$$M_{GX} = \frac{Q_T K_B}{365 W_J K_Z} \times \alpha_T \tag{2}$$

In the formula:

"M_{GX}" means that the port enterprise needs the transportation organization capacity annually; *"M_{GZH}"* means the port comprehensive operation capacity; *"M_{LZH}"* means the comprehensive railway transport capacity in the port station; *"Q_Z"* said that the annual cargo volume of the

port enterprises; "W_J" indicates the net load of goods of railway vehicles; "K_Z" indicates the payload factor; "K_B" indicates the fluctuation coefficient; "α_T" indicates the carrying coefficient.:

3.1 Capacity calculation of transportation organization of port enterprises one year

Through the collection of relevant data on Port A, the net load of goods of railway vehicles (W_J) is 66.5 tons, and the payload factor (K_Z) is 0.95; The floating volume of goods in port A railway area is not much floating. According to the floating status of port A throughput from 2016 to 2021, the maximum data (Q_Z) is 550.56 million tons. The fluctuation coefficient (K_B) is 1.1, the bearing factor (α_T) is 0.65.

$$M_{GX} = \frac{Q_T K_B}{365 W_J K_Z} \times \alpha_T$$ =(550560000×1.1)×0.65/(365×66.5×0.95)=17072

3.2 Calculation of the pickup and delivery vehicle operation capacity at the port station

Operation capacity (M_1) is the maximum number of vehicles completed by the locomotive within one day at the port. It covers the vehicle mobilization situation and the vehicle loading and unloading operations. In having your own equipment into the port, operation capacity [2] can be calculated by the following formula:

$$M_1 = \frac{n T_T \alpha M_C}{T_{ZY} + t_{QS}} \tag{3}$$

In the formula:

"M_1" indicates the pickup operation capacity; "T_T" means the total time of daily operation; "M_C" represents the maximum pickup number of vehicles; "α" indicates the double operation coefficient, the general value is 1; "T_{ZY}" is the batch operation time; "t_{QS}" is the pickup batch operation time; "n" is the shunting number.

According to the investigation of the operation status of Port A, the operation time, the average value, the dual operation coefficient, the operation time of each batch of vehicles, and the delivery time of each batch of vehicles are analyzed and calculated:

T_T=20.0(h), M_C=154.5, α=1, T_{ZY}=3.2(h), t_{QS}=0.8 (h)

There are 22 shunting locomotives in Port A, among which all the shunting locomotives in Port A are operated daily. The relevant values are brought into formula (3) for calculation, and the limit transport capacity M_1 of Port A party can be obtained.

M_1=22× (20×154.5)/ (3.2+0.8)=16995

3.3 Calculation of port pickup and departure operation capacity

Handling capacity (M_2) force refers to the sum of the handling capacity, calculated according to the following formula:

$$M_2 = \frac{(1440N - \sum t_G)(1 - y_K)}{t_{DF}} \times n_L \tag{4}$$

In the formula:

"N" is the total number of positive lines and incoming lines; *"Σt_G"* is the time for all fixed operations; *"y_K"* is the main line and the incoming line idle work coefficient; *"t_{DF}"* is the average time spent in handling a delivery assignment; *"n_L"* is the average number of vehicles per train.

The data was collected from the A City Railway Bureau Group Company for 160 columns, averaging 106 vehicles per column, totaling about 16,960 vehicles.

3.4 Calculation of port handling operation capacity

Handling capacity (M_3) refers to the maximum number of handling vehicles available at the port within one working day. The calculation formula is as follows:

$$M_3 = \sum M_J + \sum M_R \tag{5}$$

In the formula:

"ΣM_J" represents the sum of the daily loading capacity of the loading tool; *"ΣM_R"* is the sum of the loading capacity of the daily handling operators.

The machine loading and unloading capacity of Port A is composed of the forklift truck, crane, gantry crane, forklift truck, grip machine, front door crane, crane and bucket wheel of the loading and unloading company. Human loading and unloading personnel of loading and unloading Company with data available by Port A.

"ΣM_J"=11009; *"ΣM_R"=5959*

and

$$M_3 = \sum M_J + \sum M_R = 11009 + 5959 = 16968$$

3.5 Calculation of the parking vehicle capacity of the port station

The capacity to stop vehicle in port station (M_4) is the total number of vehicles that each driving route can stay under the normal operation of cargo transportation. The replacement length of the convertible is 1.3 meters, and the route is calculated according to the actual length. The formula is as follows:

$$M_4 = \frac{\sum_{i=1}^{N} (L - L_J - 30)}{14.3} \tag{6}$$

In the formula:

"N" is the number of incoming lines; *"L"* is the effective incoming line length; *"L_J"* is the locomotive length. Through the above calculation formula, calculate the minimum transportation capacity under this mode of transportation is the port multiple transportation capacity.

$$M_{GZH} = \min(M_1, M_2, M_3, M_4) \tag{7}$$

The port and the railway both sides constantly mobilize the use of vehicles. The capacity level of port storage vehicles is calculated by the sum of traffic routes between the two ports. Through the information provided by the enterprise, it can be judged that the vehicle storage capacity of the port enterprise is 8051 vehicles and the port station railway line vehicle storage capacity is 8788 vehicles.

Therefore, the M_4 is shown as follows:

$$M_4=8051+8788=16839$$

3.6 Matching analysis of railway comprehensive transportation capacity and port comprehensive transportation capacity

By comparing M_1, M_2, M_3, M_4 according to formula (7), the comprehensive port operation capability is obtained:

$$M_{GZH} = \min(M_1, M_2, M_3, M_4) = 16839$$

To calculate the operation capacity of Port A station, the disassembly capacity of port station, and the operation capacity of port station, etc.,

$$M_{LZH} = 16906$$

Available by comparison:

$$M_{GZH} < M_{LZH} < M_{GX}$$

Given that 16839<16906<17072, the port rail transport capacity can match the port transport capacity, but not the demand capacity. Because the demand capacity far exceeds the transportation capacity and organizational capacity of the organization, a deeper research on the form, infrastructure, mechanical equipment, personnel matching and other issues of the organization is needed. It is also necessary to study the work handover links of both sides, aiming to reduce unnecessary operation, improve the overall work efficiency and reduce the operation costs. So as to improve the organizational capacity of both sides and increase the total amount of cargo jointly transported by Port A.

4 DIFFICULT PROBLEMS URGENTLY NEEDED IN THE PROCESS OF TRANSPORTATION ORGANIZATION OPTIMIZATION

4.1 Strengthen the construction of infrastructure and equipment

First, we set up a unified information management platform. The information platform includes port A, cargo operation center, customs, station in the port, etc., which can jointly maintain the information on the platform. Secondly, all information on railway transport vehicles, cargo loading and unloading vehicles, electronic documents are integrated on the platform. The platform forms a system of unified operations. The parties can use the system to do the work more efficiently. Thirdly, the infrastructure in the port station is optimized and transformed [5].

4.2 Establish a unified working standard

The work standards shall be unified in management, and the work standards of both sides shall be set uniformly. Replan the post responsibilities, work content and safety management of the staff under the two modes of transportation. On the one hand, to formulate unified operation standards suitable for both parties to conduct standardized operations and ensure safety. On the other hand, to establish a common liquidation mechanism applicable to both parties. The two sides agreed in disputed places, such as operation content, property ownership and safety supervision responsibility. Under the unified system, the work objectives of both sides are consistent, the assessment methods are consistent, and the coordination degree of the two sides is improved. At the same time, the two sides will conduct centralized management. Port station dispatch management duty station master, dispatcher, duty officer, freight center dispatch freight duty officer, port dispatch party dispatcher, duty officer and other personnel, together set up the command center.

4.3 Realize the information sharing of land-port information

Port enterprises are responsible for sorting out the effective information provided by each department and forming an information sharing platform.Port enterprises update the data of each department in time, and each department performs its own duties, and shares information on the platform to improve the original phenomenon of information uncirculation.

5 CONCLUSION

Through the analysis of the relevant data of Port A, it shows that Port A attaches great importance to the joint transportation mode of railway and sea route. In 2019 and 2020, due to the impact of the epidemic, the overall operating conditions of Port A port and the total amount of jointly transported goods showed a downward trend. Excluding the impact of the epidemic, the growth trend of Port A is still increasing every year.

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