Evaluation method of effect of marshalling operation process based on DEA

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Abstract. Based on the marshalling station transfer operation process, this paper divides the marshalling transfer operation process into three sub-processes: arriving-disintegrating, disintegrating-marshalling and marshalling-dispatching. Considering the input of the facilities of the marshalling station, the intermediate output of the operating time and the final output of the number of transfer trains, an evaluation index system is constructed and a slacks-based network DEA model is established. For purposes of illustration, the model is applied in a design calculation example, the efficiency of the marshalling station transfer operation process is analysed, and the results show that the model is effective.

1 Introduction

Marshalling station is a station that handles the disintegrating and marshalling of freight trains on the railway network which is equipped with relatively complete shunting equipment. According to the operation process of the trains in the station, the marshalling station system can be divided into three systems: arriving-disintegrating, disintegrating-marshalling and marshalling-dispatching. Each system cooperates with each other and restricts each other, jointly complete a series of work of assignments, disintegration, assembly, marshalling, and departure of the train. In accordance with the requirements of the market-oriented development of transportation enterprises, the marshalling operation process should not only increase the individual operation time and reduce the intermediate waiting time and other indicators that reflect the efficiency of the transfer process, but also reflect the number of final transfer trains. Therefore, the study of the degree of coordination between subsystems starts with the quantitative indicators of inputs and the qualitative indicators of outputs, and analyse the operating efficiency of the entire transit system. Therefore, to increase output with as little input as possible.

Based on the principle of input-output analysis, there are many methods to evaluate the efficiency of the system, most of which are to reduce input while the output is fixed, or to maximize output while the input is fixed. One of the well-known methods is data envelopment analysis(DEA). DEA measures the efficiency of each individual section by calculating a discrete piecewise frontier determined by the set of Pareto-efficient DMUs[1]. There have many applications of DEA in the transportation field, Lewis H. F.[2-3] combined the two-stage DEA and network DEA. The method is applied to the efficiency evaluation of the system, to split the operation process and study the

system's interior, to deepen the evaluation efficiency from the overall to the links, and to analyse the input and output effects from a micro perspective, which is more in line with the actual operation process. Gao Ying [4] used the network DEA model to evaluate the internal situation of China's railway transportation. Li Xiamiao [5] divided the wagon operation process into a network of loading and unloading, transit, travel activities, and established an input-output evaluation index system. Hamid [6] consider an IFT system as a multi-division transport chain and calculate its efficiency using a slacks-based DEA model.

This paper uses the network DEA method to design the input and output indicators of each subsystem, and establishes a system evaluation method oriented to the transfer effect of the marshalling station to provide the transfer efficiency evaluation method of the marshalling station.

2 Analysis of marshalling operation process

According to the work completion process in the marshalling station, the work process is divided into three relatively independent links: arriving-disintegrating, disintegrating-marshalling and marshalling-dispatching. These three links are independent but restrict each other, and there will be delays in spreading processes. In the past, the evaluation index was mainly based on the operation time, that is, the average transit time of the train at the technical station. The operation process was not analysed from the internal relationship, and it was impossible to judge which part was in trouble, and it was impossible to evaluate the comprehensive effect of the entire operation process. For example: some trains have longer transit time due to the long arrival operation time, some have long waiting time for disassembly, or long marshalling

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operation time, etc.; and the facilities and equipment conditions of different marshalling stations are different, which will affect the operation to a certain extent. effectiveness.

3 Methodology to evaluate the efficiency of process based on DEA

3.1 Relationship structure

Based on the analysis of the operation process of the marshalling station, the transfer operation process is

Figure 1. Relationship structure of marshalling operation process.

3.2 Model of evaluation

The most important for DEA model is the selection of input-output indicators, which has an impact on the evaluation results on the reliability and practicality. The indicator selection should reflect the reality. As for index

divided into the sub-processes of arriving-disintegrating, disintegrating-marshalling and marshalling-dispatching (Figure 1). Since the relevant data of the waiting process is difficult to obtain, the intermediate waiting time is not considered. X_{j1i} , X_{j2i} , X_{j3i} indicate resource input for each subsystem, Z_{j1p} , Z_{j2p} , Z_{j3p} indicate intermediate output for each subsystem, At the same time, it is also the input of the transfer operation, and the final output of the whole operation process is obtained through the entire transfer process system Y_j .

of input, the completion of sub-process involves investment in infrastructure, therefore, the number of lines corresponding to infrastructure equipment is the key, which showed in Table 1. As for index of intermediate output, we consider the time of every work. And the index of final output is the total number of transit trains, which showed in Table 2..

Table 1. Index of input.

Input categories	Index
X_{j1i}	Number of trucks in arriving yard
	Number of train inspection group-1
X_{j2i}	Number of shunting line
	Number of Shunter
X_{j3i}	Number of trucks in dispatching yard
	Number of train inspection group-2

Table 2. Index of production

Output categories	Index
Arriving-disintegrating Z_{j1p}	Number of arriving-disintegrating train
	Time of train inspection
	Time of disintegrating
Disintegrating-marshalling Z_{j2p}	Number of marshalling train
	Time of assembling
	Time of marshalling
Marshalling-dispatching Z_{j3p}	Number of dispatching train
	Time of train inspection

Final output Y_j

Number of transfer train

The model is constrained by the input-output relationship of the arriving-disintegrating, disintegrating-marshalling, marshalling-dispatching and the entire transfer process. Taking the operating efficiency value of the k -th marshalling station E_k as the goal, a slack-based network DEA evaluation model is established:

$$\min E_k = e_k^1 + e_k^2 + e_k^3 + e_k^4$$

$$s.t. \begin{cases} \sum_{j=1, j \neq k}^n \lambda_j^1 x_j^i + s_k^{1i} = e_k^1 x_k^{1i}, \forall i = \{1, 2\} \\ \sum_{j=1, j \neq k}^n \lambda_j^2 x_j^i + s_k^{2i} = e_k^2 x_k^{2i}, \forall i = \{3, 4\} \\ \sum_{j=1, j \neq k}^n \lambda_j^3 x_j^i + s_k^{3i} = e_k^3 x_k^{3i}, \forall i = \{5, 6\} \\ \sum_{j=1, j \neq k}^n \lambda_j^1 z_j^p - s_k^{1p} = z_k^{1p}, \forall p \in \{1, 2, 3\} \\ \sum_{j=1, j \neq k}^n \lambda_j^2 z_j^p - s_k^{2p} = z_k^{2p}, \forall p \in \{4, 5, 6\} \\ \sum_{j=1, j \neq k}^n \lambda_j^3 z_j^p - s_k^{3p} = z_k^{3p}, \forall p \in \{7, 8, 9\} \\ \sum_{j=1, j \neq k}^n \lambda_j^4 z_j^p + s_k^{4p} = e_k^4 z_k^p, \forall p \in \{1, 2, \dots, 9\} \\ \sum_{j=1, j \neq k}^n \lambda_j^4 y_j - s_k = y_k \\ \lambda_j^l \geq 0, \forall l \in \{1, 2, 3, 4\} \end{cases}$$

Where e_k^l represents the l -th ($l = 1, 2, 3$) sub-process of the k -th marshalling station,

respectively represents the sub-process of arriving-disintegrating, disintegrating-marshalling, marshalling-dispatching, x_j^i represents the i -th input of the j -th marshalling station, and z_j^p represents the p -th intermediate output at the k -th marshalling station, y_k represents the final output of the k -th marshalling station; λ_j^l represents the weight coefficient of the l -th ($l = 1, 2, 3$) sub-process of the j -th marshalling station, s_k^{li} and s_k^{lp} are the corresponding slack variables.

If the optimal solution satisfies $e_k^l \geq 1$, then the l -th ($l = 1, 2, 3$) sub-process of the k -th marshalling station is DEA valid, otherwise, it is DEA invalid.

4 Illustrative case

Through the statistics of the existing marshalling stations, the data such as train inspection time are normally distributed or exponentially distributed. Randomly generate data based on this. And based on statistics from existing literature, number and time data are obtained. Table 3. shows the statistics and Table 4. shows the result of the illustrative case.

Table 3. statistics of transfer operation process

Index	A	B	C	D	E
Number of trucks in arriving yard	6	4	5	6	6
Number of train inspection group-1	4	3	2	4	2
Number of shunting line	10	8	8	10	6
Number of Shunter	2	2	2	2	2
Number of trucks in dispatching yard	5	5	5	5	5
Number of train inspection group-2	5	4	3	4	3
Number of arriving-disintegrating train	1755	1784	1872	1654	1929
Time of train inspection/min	30	33	27	31	35
Time of disintegrating/min	15	11	13	13	17
Number of marshalling train	1652	1344	1500	1483	2020
Time of assembling/min	45	50	55	45	60
Time of marshalling/min	20	25	20	25	25
Number of dispatching train	1856	2386	3751	4065	3999

Time of train inspection/min	34	33	30	25	27
Number of transfer train	2985	3398	4959	5993	4582

Table 4. Efficiency of transfer operation process

Station	e_k^1	e_k^2	e_k^3	e_k^4	E_k
A	0.934	1.034	1.276	0.877	1.098
B	0.886	0.692	1.098	1.334	0.994
C	1.653	1.573	1.215	1.366	1.487
D	1.367	1.467	1.196	1.198	1.365
E	0.655	0.798	0.772	1.277	0.856

From the result, we can know the main factor is the total time. Station C's total time is shortest and it ranks first. In the arriving-disintegrating, disintegrating-marshalling, marshalling-dispatching and the entire transfer process, Station C and Station D are all DEA valid. Overall, for each station, we can know the shortest sub-process, which mean that the efficiency of input and output is low, and it is time to reduce the transit time of trains at the marshalling station.

freight transport chains using a modified network DEA approach. Transportation Research Part E, 129: 66-86.

5 Conclusion

Based on the traditional time-based evaluation method, this paper divides it into three subsystems considering the transfer operation process of the marshalling station, and uses the network DEA model to evaluate the efficiency of its internal operation process. The results of the calculation example show that the constructed model is effective, the relative efficiency of each operation process can be obtained. The evaluation indicators need to be further refined in the future.

References

1. Charnes, A., Cooper, W. W., Lewin, A. Y., Seiford, L.M., (1994) Data envelopment analysis: theory, methodology, and applications. Dordrecht: Spring Netherlands.
2. Lewis H. F., Sexton T. R., Network DEA: Efficiency analysis of organization with complex internal structure. Computers and Operations Research. 31(9): 1365-1410.
3. Marchetti D., Wanke P. (2016) Brail's rail freight transport: Efficiency analysis using two-stage DEA and cluster-driven public policies. Social-Economic Planning Sciences. 59(9):26-42.
4. Gao Ying, Li Weidong. (2011) Research on the efficiency evaluation of China's Railway transport enterprises with network DEA. China soft Science, 5:176-182.
5. Li Xiamiao, Guo Wang, et al. (2019) Evaluation method of relative effect of wagon utilization process based on network DEA. Journal of Railway Science and Engineering, 16:2107-2113..
6. Hamid Saeedi, Behzad Behdani, et al. (2019) Assessing the technical efficiency of intermodel