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Optimization Model of Extension of Classification Station

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Abstract: Classification station plays an important role in railway transportation. It faced various possible schemes when marshaling station would be extended. Decision makers were concern to how to choose feasible extension scheme so as to minimize the total investment. Based on the actual development, optimization model of extension of classification station is built. The objective function is to minimize the total investment, subject to three groups: First is the sorting capacity is to meet the demand, second is the utilization of sorting capacity is not too low, the last is the capacity of feasible scheme should e is larger than former. In order to reduce the difficulty of solving model directly, this model is transformed into shortest path model. The specific solution is expounded through an example application. The use area of the model is described in the end. The model can be used in the macro-control by high-level leader. The specific micro-operation can be done in this decision.

Key words: Railway transportation, extension of marshalling station, capacity of marshalling station, optimization model, the shortest path

INTRODUCTION

Classification station plays an important role in railway transportation and too many freight trains are broken and classified. To ensure the normal order of whole railway transportation, the capacity of marshalling station should meet the demand the development of railway freight volume and cars which are gradually increasing. To avoid the situation that the capacity of marshalling station is much larger than the needed by the freight volume, the classification yard should be extended according to the planning freight volume. If the number of extension is over many, normal order of railway transportation will be affected and the transportation efficiency will be reduced, if over few, the investment funds will be used in early stages and the waste will appeared.

To reduce investment cost and improve organization efficiency, the number of marshalling yard is less and the scale of classification station is larger in the world. The number of equipment is very large and the modernization is very high, so the investment funds about construction or extension of marshalling station is very high. To avoid wasting, the final scale of marshalling station was come into being after multi-time extensions.

When the classification yards are extended, some factors should be taken into consideration as follow:

- The feasible extension schemes and its number

The number is large, so the difficulty to select the most suitable is large.

- The cost and capacity of every feasible extension scheme

The capacity should meet the transportation demand and the cost should minimize.

Therefore, the decision maker needs to make a reasonable decision to solve the problem of extension of marshalling station.

Over the past years, several models have been established to evaluate the investment of marshalling station in different ways, among which the bi-level programming model is more representative. The bi-level programming model can better solve the marshalling station's layout issue, but the calculation will be quite complex when the number or the scale of marshalling station increases (Yin and Zhu, 2009).

An optimization decision which make the total investment is minimal on the basis of meeting the gradual enhanced freight volume was found. According to the situation of the extension or establishment of marshalling yards in China, the feasible extension schemes of marshalling stations and its number was provided. After

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some parameters and variable were introduced, Optimization Model of Extension of Classification Station (OMECS) was built. Taking into the consideration of the trouble from model solving, the transition to the shortest route model for solving was used. The concrete solving method by examples was explained, as well as the application range of the model.

ESTABLISHMENT OF OMECS

Setting up m is the number of extensions of marshalling station, so m is the investment phase, In theory, the value of m can be any positive integer, However, taking the Chinese railway's actual into account, the value of m is not more than 5 (Li *et al*., 2011). Setting up C_k is the needed breaking and marshalling capacity in the k extension of the marshalling stations, k = 1, 2, ..., m. S_i is extension schemes provided in Table 1, i = 1, 2, ..., 10 (Chen *et al*., 2006). The number of extension schemes is not exactly 10, so the exact number is not explored (Table 1).

Setting up $F_{i\ min}$ is the minimize breaking and marshalling capacity for classification yard of i extension scheme and $F_{i\max}$ is the maximum breaking and marshalling capacity. F_i and S_i has a discrete function can be expressed as Table 2 (Wang *et al*., 2008).

F_i is an interval from $F_{i\ min}$ to $F_{i\ max}$, some intervals are overlap, such as the overlap of S_1 and S_2 is the interval (3500 4000), the overlap of S_5 and S_6 is the interval (7000 8000). The difference between the largest and the smallest capacity is very big to some marshalling yards, such as the difference of S_8 is 4000. The reason is organization mode and equipment utilization of stations, such as the number of shunting locomotive, the number of shunting lines in hump, the leading tracks where are used in marshalling trains and so on.

Table 1: Extension scheme of marshalling station

i	S_i
0	No marshalling station
1	Single directional lateral-type marshalling station with three yards in one stage
2	Single directional combination-type marshalling station with three yards in two stages
3	Single directional combination-type marshalling station with four yards in two stages
4	Double directional combination-type marshalling station with five yards in two stages
5	Double directional combination-type marshalling station with six yards in two stages
6	Single directional longitudinal-type marshalling station with three yards in three stages
7	Single directional combination-type marshalling station with four yards in three stages
8	Double directional combination-type marshalling station with five yards in three stages
9	Double directional longitudinal-type marshalling station with six yards in three stages
10	Double directional combination-type marshalling station with seven yards in three stages

According to the practice of development for China's marshalling yard, some extension schemes are not suitable to some classification yards (Yang, 1998; Jing *et al*., 2012), such as S_6 is not feasible extension scheme to S_4. It mainly takes account of the terrain, the utilization of the device and so on. Use $g(S_i)$ as the candidate set that feasible extension scheme for S_i (i = 1,2,..., 10). The details are follow as Table 3.

There is no feasible extension scheme for S_5 and S_{10}. The number of feasible extension scheme is less with the breaking and marshalling capacity is larger.

x_k is the select feasible extension scheme to S_k which is variable, $x_k \in g(S_k)$. The investment funds $f(x_k)$ to accomplish the feasible extension scheme written as:

$$f(x_k)=\begin{cases} B_{S_k,x_k}, & \text{if } x_k \neq S_k \\ 0, & \text{if } x_k = S \end{cases}$$

where, $B_{sk,\ xk}$ is the investment funds that S_k to x_k. If $S_k = x_k$, this mean that there is no extension $B_{sk,\ xk}$ is 0, else the $B_{sk,\ xk}$ is not 0. According to the actual condition, there should have the relation $F(x_{k-1}) \le F(x_k)$ (Cheng *et al*., 2010). OMECS can be built as follows:

Table 2: Corresponding relationship between F_i and S_i

S_i	$F_{i\ min}$	$F_{i\ max}$
S_1	3200	4000
S_2	3500	4500
S_3	4500	5200
S_4	5000	6500
S_5	7000	9000
S_6	6500	8000
S_7	7000	9000
S_8	8000	12000
S_9	14000	16000
S_{10}	15000	19000

Table 3: Feasible extension scheme of every marshalling station

S_i	$g(S_i)$
S_0	S_i (i = 1, 2, ... 10)
S_1	S_i (i = 2,3, ... 10)
S_2	S_i (i = 3, 4, ... 10)
S_3	S_i (i = 4, 5, ... 10)
S_4	S_i (i = 5)
S_5	S_i (i = Ø)
S_6	S_i (i = 7, 8, ... 10)
S_7	S_i (i = 8, 9,10)
S_8	S_i (i = 9, 10)
S_9	S_i (i = 10)
S_{10}	S_i (i = Ø)

$$
\begin{aligned}
&\min z = \sum_{i=1}^{m} f(x_i) \\
&\text{s.t.}\quad \alpha F_i \geq C_i \\
&\qquad \beta F_i \leq C_i \\
&\qquad F(x_{i-1}) \leq F(x_i) \\
&\qquad x_i \in g(S_k) \\
&\qquad k=1, 2, \ldots, m
\end{aligned}
$$

The objective function is let the total investment to the smallest. The capacity constraints is consideration in the first group constraint, that is the capacity of marshaling station be chosen should provide the greater capacity than the needed, α is the highest utilization rates, which can cope with the impact of fluctuations of car or train flow, $\alpha<1$. The second group restraint show that capacity has a minimum utilization rate in order to avoid excessive early investments, β is the lowest utilization. The relation of $\alpha>\beta$ do exist.

According to the actual condition, $\alpha = 0.8$, $\beta = 0.5$ (Yin *et al*., 2007). The second constraint plays an important role in this model, there will be the fact that S_9 will be constructed in the first stage, it will be a very big waste because the early investment is too high. Some researchers think funds constraint can be added into the model, it is not a solution, the reason is the minimum investment maybe lead to any scheme can not be selected and there have no answer to the model. The third constraint tells us that the breaking and marshalling capacity is larger and larger.

This model can be transformed into the shortest road model for solving (Hu, 2008; Li *et al*., 2002).

EXAMPLE OF OMECS

An example is given to explain the model application. Known conditions about the example is follows: $m = 3$, $C_1 = 3000$ cars/d, $C_2 = 5000$ cars/d, $C_3 = 7000$ cars/d, x_1 is the first extension scheme, x_2 is the second extension scheme, x_3 is the third extension scheme, investment funds will be given in the Fig. 1.

According to the constraints of the model, the candidate scheme of extension is considered as follow. S_2, S_3 and S_4 in the first extension; S_4, S_5 and S_6 in the second extension; S_5, S_6, S_7 and S_8 in the third extension. Make the corresponding extension and the most the shortest road diagram is in Fig. 1 (the investment funds units is billion).

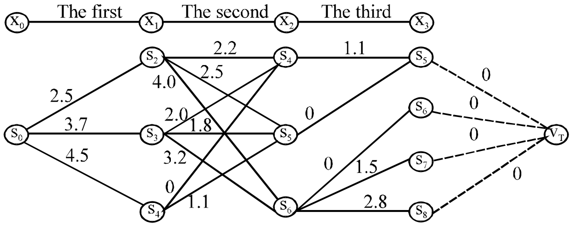

Fig. 1: Shortest road to solve the model

S_9 and S_{10} are disappeared in the Fig. 1, avoid the waste. The weight value of solid line is $B_{sk,\, xk}$, all needed $B_{sk,\, xk}$ can be found in Fig. 1.

Using the optimization software or direct calculation, The shortest road from S_0 to V_T in Fig.1 is acquired, the result is $S_0 \rightarrow S_2 \rightarrow S_5 \rightarrow S_5 (\rightarrow V_T)$. From it, in the first extension, S_2 is needed; in the second extension S_5 is needed; in the third extension, S_5 is needed, it shows in this extension that there is no investment. The minimize investment funds is $B_{S_0, S_2} + B_{S_2, S_5} = 5$ billion Yuan.

CONCLUSION

Optimization model of extension for classification station is built, it is very difficulty to solve the model directly The shortest road is used to solve it easily, even it has 5 extension, each extension has more than 6 options, the optimization solution are obtained easily. However, some complex situations are not considered when the model are built, such as the capacity can be enlarged from some technical organization measures to the same type station; the annual interest rate of investment funds; the operation cost of station; the difficulty of land expropriation and so on. So the model can be used in the macro-control by high-level leader, the specific micro-operation can be did in this decision.

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