A Method for Optimal Allocation of Regional Rail Transit Emergency Resources Based on Resource Sharing

Lei Xu\textsuperscript{1,2}, Chuanjiang Wang\textsuperscript{1,*}, Wei Dong\textsuperscript{2,3} and Xinya Sun\textsuperscript{2,3}

\textsuperscript{1}College of Electrical Engineering and Automation, Shandong University of Science and Technology, Qingdao 266590, China
\textsuperscript{2}Beijing National Research Center for Information Science and Technology (BNRist), Tsinghua University, Beijing, China.
\textsuperscript{3}Department of Automation, Tsinghua University, Beijing, China.

*Corresponding author: cxjwang@163.com

Abstract. Regional rail transit is a composite rail transit system that includes multiple types of rail transit. Compared with single-standard rail transit, the types of risks increase, the risk impact is greater, and the consequences are more serious. Therefore, it is urgent to optimize the allocation of regional rail transit emergency resources to improve the overall efficiency of emergency operation and maintenance. Aiming at the characteristics of regional rail transit, this paper proposes a method for optimal allocation of regional rail transit emergency resources based on resource sharing. Firstly, according to the overall requirements of emergency services, the number of emergency stations is set, and then an emergency resource optimization allocation model for regional rail transit is built based on the p-median model. Secondly, through the multi-standard emergency resource sharing, the overall efficiency improvement of emergency operation and maintenance is achieved. Finally, a case study was carried out using Chongqing regional rail transit as an example to verify the effectiveness of the method.

1. Introduction

With the development of economic integration of urban agglomerations, the regional rail transit system has gradually developed. It refers to a composite rail transit system that includes high-speed railways, intercity railways, subways, and monorails. The regional rail transit system has the characteristics of heterogeneity, integrity, interaction, and coordination, and each type of rail transit undertakes high-density and high-intensity transportation tasks, making the scale and importance of emergency maintenance work continue to increase. Therefore, it is of great significance to optimize the allocation of emergency maintenance resources for regional rail transit, which directly determines the timeliness and overall efficiency of emergency operation and maintenance. At present, some traditional emergency resource allocation methods do not meet the operational management requirements of regional rail transit. For example, the emergency resource allocation of different lines in the subway system is managed by the corresponding line operating company. Each line is self-contained and independent, and there are many problems such as repeated resource allocation, waste of resources, and long emergency rescue time, etc.

By optimally selecting a specific number of emergency rescue points from the candidate stations of various standards in the area, the average emergency rescue time is minimized. In this way, the unified optimized allocation of multi-standard rail transit emergency resources in the region can be achieved, and the overall efficiency of regional rail transit emergency response and disposal can be effectively improved. Based on this idea, this paper constructs a multi-standard emergency resource allocation
model based on the p-median model. At the same time, through the sharing of multi-standard emergency resources, the emergency response and disposal efficiency of regional rail transit is improved compared to the single-standard system. And the average emergency rescue time for emergency rescue is reduced, thereby improving the overall safety of regional rail transit.

2. Research Status

One of the most important functions of a rail transit emergency rescue station (hereinafter referred to as "emergency station" or "emergency point") is to provide sufficient emergency resources to the station of a rail transit emergency demand (hereinafter referred to as "demand station" or "demand point") in a timely manner, and the first problem that decision makers face is the location of emergency stations. Reasonable location of emergency stations can not only reduce costs, but also ensure the timeliness of emergency supplies, thereby avoiding possible greater losses.

The location problem was first proposed by the German scholar Alfred Weber [1] in 1909 to solve the shortest total distance from a single warehouse to multiple customers, marking the beginning of the location research.

In 1964, Hakimi [2] first proposed the p-center problem and p-median problem on the service facility network. The purpose of the p-center problem is to minimize the maximum distance between facilities and demand points by determining the location of p facilities. And the p-median problem can minimize the sum of the product of the distance between the facility and the demand point and the demand. The study of site selection in that paper is a milestone in the research history of site selection problem. In 1971, C. Toregas et al. [3] gave the initial form of the set cover model. This model minimizes the number of service facilities or construction costs on the premise of covering all demand points. Later, Church et al. [4] proposed the maximum coverage model. The model studies how to set up P facilities to maximize the number of acceptable service demand points under the condition that the number of service facilities and service radius are known. Other site selection models (reserved coverage model, maximum availability model, random set coverage model, etc.) are basically extensions of the above-mentioned site selection models.

There are relatively few studies on the location of railway emergency points. Zhang G [5] believes that railway demand points exist in the form of intervals. Aiming at the problem of location selection of railway emergency points with unknown locations and a given number, a two-stage comprehensive location model was established with the minimum construction cost, the minimum sum of the weight distance from the emergency point to the demand point and the minimum emergency rescue radius as the optimization goals. Taking into account the hierarchical characteristics of railway emergency points, Wu Y H [6] abstracted the demand characteristics by analyzing the influencing factors of railway demand points. On the premise that the hub emergency points and the fast emergency points have different maximum coverage radii, a multi-objective optimization model for hierarchical site selection of railway emergency points is proposed. After carrying out emergency resource demand estimation based on uncertain information theory, Gao X Y [7] established the optimization model of emergency stations location under dynamic demand conditions by restricting the total construction cost of emergency stations, limiting the number of emergency stations and ensuring the fairness of emergency rescue at each demand point.

Regarding the allocation of urban rail transit emergency resources, the research focuses on the relationship between emergency facility layout and urban rail transit network topology. Sun X L [8] optimized the urban rail transit emergency rescue site selection strategy under the conditions of urban rail network operation and emergency resource sharing, established multiple optimal planning models, and determined the location of the emergency rescue station by comparison of multiple optimal schemes. And a case study was conducted with the Beijing subway network. Ran L Y [9] and others built a model for selecting urban P-center emergency rescue stations based on complex network theory. At the same time, they considered space, cost, and rescue time, so that the maximum emergency rescue distance in the rail network was minimized and ensure that every demand station is covered.

In summary, although research on the location of rail transit emergency rescue points has achieved certain results, such as the proposed staged location, qualitative and quantitative combined location etc., only the location of emergency rescue points for single-standard rail transit is considered. In
terms of emergency resource sharing, only the internal sharing of urban rail transit by different operating companies is considered, and the barriers between different standards have not been broken. It can be seen that the research on the location of multi-standard emergency rescue points for regional rail transit has not yet formed a system, and further research is needed to establish theories and models consistent with reality.

3. Optimal Allocation Model of Regional Rail Transit Emergency Resources

After an accident, the shorter the time it takes for emergency personnel and supplies to arrive at the scene of the accident, the shorter the overall time spent on emergency response and disposal, and the smaller the impact and loss caused by the accident [10]. Since the emergency rescue time accounts for a large proportion of the overall time of emergency response and disposal, and is not greatly affected by the specific type of accident, it is convenient for overall optimization through resource allocation. Therefore, minimizing the emergency rescue time is the primary goal of the location of the regional rail transit emergency station. (In this paper, "emergency rescue time" refers to the time it takes for emergency personnel and supplies to reach the demand point from the emergency point.)

3.1. Mathematical Model

In this paper, the optimal allocation model of regional rail transit emergency resources is based on the P-median model [2]. The P-median model is to optimize the location of emergency points to minimize the average time required for emergency supplies to reach the various demand points from the nearest emergency point when the number of emergency points is limited.

The general idea of building the model is as follows: The number of emergency stations is determined in advance according to certain rules. The constraint is that all demand stations have to be covered by the corresponding emergency station within the specified maximum emergency rescue constraint time. In principle, every station in the rail transit network has the possibility of failure. Therefore, each station should be regarded as a demand station. (To simplify the model, this paper does not consider the demand points outside the stations such as the sections). The optimization goal is that the average time for emergency maintenance personnel to reach the demand station from the corresponding emergency station is the shortest, that is, the shortest average emergency rescue time.

Based on the above ideas, the model assumptions and the main modelling points are as follows:

1) The rail network and stations are known. Each station in the area is a demand station, and the section between stations will not generate demand;
2) The total number of emergency stations is m, and the locations of the emergency stations can be selected from all stations. (The setting method of m is as follows: let the ratio of the number of demand stations to the number of emergency stations is q (5≤q≤10). To ensure that the number of emergency stations meets the minimum requirements, the number of emergency stations needs to be determined by rounding up when it is not an integer);
3) Each demand station belongs to only one emergency station, and this affiliation relationship is determined by human configuration, and belongs to the decision content of optimal configuration. Each accident only requires rescue from one emergency station, and does not consider the situation that multiple accidents occur simultaneously within the coverage of one emergency station;
4) When an emergency occurs, the emergency personnel of the corresponding emergency station will choose the shortest path of ground traffic to rush to the demand point at a certain average speed;
5) It is required that the emergency rescue time of emergency personnel and supplies from the emergency station to the demand point does not exceed the maximum emergency rescue constraint time $T_{\text{max}}$ given in advance.
Table 1. Symbol explanation of mathematical model.

| Symbols | Explanation |
|---------|-------------|
| i       | Demand station subscript |
| j       | Emergency station subscript |
| n       | Number of rail transit stations in the area (i.e. number of demand stations) |
| m       | Number of emergency stations |
| q       | Ratio of number of demand stations to number of emergency stations |
| $t_{ij}$ | Rescue time from emergency station j to demand station i |
| $x_{ij}$ | Decision variable, 1 if demand station i belongs to emergency station j, otherwise 0 |
| $y_j$   | Decision variable, 1 if candidate point j (i.e. station j) is selected as the emergency station, otherwise 0. |
| $T_{max}$ | Maximum emergency rescue constraint time |

(1) Objective function:

$$\text{min}Z = \sum_{i=1}^{n} \sum_{j=1}^{m} t_{ij} x_{ij}$$  \hspace{1cm} (1)

The optimization goal is that the average emergency rescue time from the emergency station to each demand station is the smallest (equivalent to the minimum total emergency rescue time).

(2) Constraints:

$$\sum_{j=1}^{m} x_{ij} = 1$$ \hspace{1cm} (2)

$$n:m = q, \ (5 \leq q \leq 10)$$ \hspace{1cm} (3)

$$x_{ij} \leq y_j, \forall i, j$$ \hspace{1cm} (4)

$$x_{ij}(t_{ij} - T_{max}) \leq 0, \forall i, j$$ \hspace{1cm} (5)

$$x_{ij}, y_j \in \{0,1\}, \forall i, j$$ \hspace{1cm} (6)

Among them:
Equation (2) indicates that each demand point belongs to only one emergency station;
Equation (3) indicates that there is a certain limit on the number of emergency stations;
Equation (4) indicates that an emergency station should be established before providing emergency rescues, that is, station i can be rescued by station j only when station j is selected as the emergency rescue station;
Equation (5) indicates that all emergency rescues must meet the maximum emergency rescue constraint time;
Equation (6) represents the 0-1 constraint of the variable.

(3) Decision variables

$$y_j = \begin{cases} 
1, & \text{Station j was selected as the emergency station} \\
0, & \text{otherwise} 
\end{cases}$$

$$x_{ij} = \begin{cases} 
1, & \text{Demand point i belongs to emergency point j} \\
0, & \text{otherwise} 
\end{cases}$$

The value of $y_j$ determines the location of the emergency station, and the value of $x_{ij}$ determines the relationship between the emergency station and the demand station.
3.2. Solving Method

In order to solve this model, the nature of the optimization problem needs to be analyzed first. The optimization variable in this paper is $x_j$ and $y_j$, and its related constraints are linear functions, so the feasible region is a convex set. For the optimization objective function, it can be known that $Z$ is a linear combination of $x_j$, so the objective function is a convex function, and the optimization problem in this paper is a convex optimization problem.

The method for solving the convex optimization problem is relatively mature. This paper uses MATLAB's CVX toolbox to solve it. CVX converts MATLAB programming language into a modelling language that allows MATLAB expressions to specify constraints and goals to efficiently solve convex optimization problems.

4. Case Study

4.1. Scenario

This paper uses Chongqing regional rail transit as an example to verify the optimization method of regional rail transit emergency resource allocation. The A of Figure 1 is a schematic diagram of Chongqing’s mid-to-long-term railway network planning [11], and the B of Figure 1 is a schematic diagram of urban rail transit in Chongqing [12]. This paper considers various types of rail transit systems, that is, high-speed rail, ordinary railway, and subway. In terms of high-speed rail and ordinary railway, due to the large scale of the rail network, here are selected partial stations of the Chengyu Railway, Lanyu Railway, and Suiyu Railway from the high-speed railway lines, and partial stations of the Xiangyu Railway from the ordinary railway lines. In terms of subway, the stations of line 1 and line 6 of Chongqing subways are selected for instance verification.

![Figure 1. Schematic diagram of Chongqing's Rail Transit Network](image)

For high-speed rail and ordinary railway, the selected demand stations are shown in Table 2.

| Line          | Station                          |
|---------------|----------------------------------|
| Chengyu Railway | Bishan, Shapingba, Geleshan, Chongqing North * |
| Lanyu Railway  | Chongqing West*, Chongqing North*, Caijia*, Beibei* |
| Suiyu Railway  | Hechuan, Beibei*, Caijia*, Chongqing North* |
| Xiangyu Railway| Chongqing, Chongqing West*, Tuanjiecu, Beibei* |

Among them, Chongqing North Station, Chongqing West Station, Beibei Station and Caijia Station are repeated (marked with an asterisk in Table). Although they are different lines, the stations are the same. After removing the duplicates, there are a total of 10 high-speed railway and ordinary railway
demand stations selected. In terms of subways, Chongqing subway line 1 has a total of 25 stations and line 6 has a total of 28 stations. Among them, Xiaoshizi Station is a common station of two lines. After removing the duplicates, a total of 52 subway demand stations were selected, so a total of 62 high-speed rail, ordinary railway and subway demand stations were selected.

4.2. Related Parameters
According to the mathematical model of site selection designed above, the following parameters need to be determined:
(1) The spatial location of all stations and the spatial distance between them (based on which the travel time $t_{ij}$ between all stations can be calculated).
(2) Number of demand stations
In the example, there are 10 high-speed railway and ordinary railway stations and 52 subway stations, so a total of 62 demand stations are selected.
(3) Number of emergency stations
According to the ratio formula between the number of demand stations and the number of emergency stations, $n : m = q$, ($5 \leq q \leq 10$), take $q = 6$, so the number of emergency stations is 11.
(4) Emergency rescue speed
It is assumed that the average speed of emergency personnel and resources from the emergency rescue station to the demand station is 30Km / h [13]. The emergency rescue time can be obtained by dividing the straight-line distance between the emergency station and the demand station by this average speed.
(5) Maximum emergency rescue constraint time
Constraint on emergency rescue time is based on "High-speed Railway Emergency Response Plan (Trial) (Rail Transport [2012] No.33)" [14] and "Chongqing Rail Transit Subway System Operation Emergency Response Plan (2017 Edition)" [15], combining the service capacity of regional rail transit, the maximum emergency rescue constraint time for emergency rescues is set to 60 minutes.

4.3. Emergency Resource Allocation Schemes
The examples in this paper are analyzed and compared according to the following three emergency resource allocation schemes.

| Scheme name                                      | Scheme explanation                                                                                                                                 |
|--------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Allocation without Optimization (status quo)     | In this scheme, the emergency resources of rail transit are allocated according to manual experience (the mathematical method is not used for optimization). The high-speed railway and the subway handle emergency rescue by themself, and emergency resources cannot be shared. There are 10 demand stations and 2 emergency stations for high-speed rail. There are 52 demand stations and 8 emergency stations for subway. |
| Optimized allocation without multi-standard sharing | According to the allocation model of this paper, the high-speed rail and the subway are individually optimized for single-standard emergency resources. The emergency resources of high-speed rail and the subway cannot be shared. The number of demand stations and emergency stations of each system is the same as above. When multi-standard rail transit emergency rescue stations are shared, the optimal allocation is carried out, that is, the emergency stations of high-speed rail and subway can be selected from the candidate stations of the two. Emergency stations can serve both high-speed rail demand stations and subway demand stations, and then optimize the allocation of multi-standard emergency resources according to the allocation model in this paper. |
4.4. Comparative Analysis of Results

4.4.1. Allocation without optimization (status quo). At present, rail transit emergency stations are allocated according to the experience of experts in various standards, and resources cannot be shared between the standards [16]. The high-speed railway and the general railway can be equipped with 2 emergency stations and the number of demand stations is 10. Chongqing subway line 1 and line 6 have a total of 52 demand stations and 8 emergency stations. (In order to distinguish between high-speed railway stations and subway stations, the following description of subway stations is only replaced by the station name. For example, Beibei refers to Beibei subway station on subway line 6, and Beibei Station refers to Beibei high speed rail station.)

Table 4. Emergency rescue level corresponding to allocation scheme without optimization (status quo).

| System Emergency station       | Number of Demand Stations | Covered stations                                      | Maximum Rescue Time (min) | Average Rescue Time (min) |
|--------------------------------|---------------------------|------------------------------------------------------|---------------------------|---------------------------|
| High-speed railway and ordinary railway Bishan station | 5                         | Bishan station, Shapingba station, Chongqing West station, Chongqing North station, Chongqing station | 50                        | 35.01                     |
| Hechuan station                | 5                         | Hechuan station, Beibei station, Geleshan station, Caijia station, Tuanjiecu station | 59                        | 37.27                     |
| Subway                         | Daxuecheng                | Daxuecheng, Weidianyuan, Bishan                      | 20                        | 13.44                     |
| Laijiaqiao                     | 6                         | Laijiaqiao, Shuangbei, Shijingpo, Ciqikou, Lieshimu, Yanggongqiao | 26                        | 20.35                     |
| Majiayuan                      | 7                         | Shapingba, Xiaolongkan, Majiayuan, Gaomiao, Xietaizi, Shiyou, Daping | 32                        | 22.56                     |
| Qixinggang                     | 5                         | Eling, Lianglukou, Qixinggang, Jiaochangkou, Chaotianmen | 22                        | 17.24                     |
| Longfengxi                     | 7                         | Beibei, Southwest University, Zhuangyuanbei, Longfengxi, Xiangjiagang, Caijia, Caojiawan, Jinsansi, Lijia, Jiuqhe, Kangzhuang, Dazhulin, Guangdianyuan, Dalongshan | 26                        | 19.23                     |
| Ranjiaba                       | 8                         | Jinshansi, Lijia, Juqhe, Kangzhuang, Dazhulin, Guangdianyuan, Dalongshan, Ranjiaba | 35                        | 26.10                     |
| Hongqihegou                   | 5                         | Huahuiyuan, Huangnibang, Hongqihegou, Hongtudi, Wulidian | 21                        | 17.33                     |
| Xiaoshizi                      | 8                         | Jiangbeicheng, Dajuyuan, Xiaoshizi, Shangxinjie, Liejiapi, Changshengqiao, Qijiawan, Changshengqiao, Qijiawan, Changshengqiao, Qijiawan | 30                        | 22.43                     |

It can be seen from Table 4 that Hechuan station and Bishan station have large coverage areas as emergency stations. They are far from Chongqing North station, and the longest rescue time is more than 50 minutes, resulting in a longer average rescue time. The number of demand points covered by
the emergency stations of subway line 1 and line 6 are different, and the longest rescue time for different emergency stations varies greatly.

4.4.2. Optimized allocation without multi-standard sharing. According to the allocation model of this paper, the high-speed rail and the subway are individually optimized for single-standard emergency resources [17]. The emergency rescue level corresponding to optimized allocation scheme without multi-standard sharing is shown in Table 5.

Table 5. Emergency rescue level corresponding to optimized allocation scheme without multi-standard sharing.

| System               | Emergency station | Number of Demand Stations | Covered stations                                                                 | Maximum Rescue Time (min) | Average Rescue Time (min) |
|----------------------|-------------------|---------------------------|----------------------------------------------------------------------------------|---------------------------|--------------------------|
| High-speed railway and ordinary railway | Chongqing West station | 5                         | Bishan station, Shapingba station, Chongqing West station, Chongqing North station, Chongqing station | 42                        | 31.45                    |
|                      | Geleshan station  | 5                         | Hechuan station, Beibei station, Geleshan station, Caijia station, Tuanjiecun station | 50                        | 34.17                    |
| Subway               | Chenjiaqiao       | 6                         | Jiandingpo, Daxuecheng, Chenjiaqiao, Weidianyuan, Bishan, Laijiaqiao              | 17                        | 12.19                    |
|                      | Ciqikou           | 6                         | Shuangbei, Shijingpo, Ciqikou, Lieszimu, Yanggongqiao, Shapingba                  | 21                        | 16.25                    |
|                      | Xiestaizi         | 6                         | Xiaolongkan, Majiyan, Gaomiaocun, Xiestaizi, Shiyoulu, Daping                     | 25                        | 18.12                    |
|                      | Jiaochangkou      | 6                         | Eling, Lianglukou, Qixinggang, Jiaochangkou, Chaotianmen, Xiaoshizi                | 20                        | 15.46                    |
|                      | Xiangjiagang      | 7                         | Beibei, Southwest University, Zhuangyuanbei, Longfengxi, Xiangjiagang, Caijia, Caojiawan | 24                        | 17.09                    |
|                      | Dazhulin          | 7                         | Jinshansi, Lijia, Jiuqhe, Kangzhuang, Dazhulin, Guangdianyuan, Ranjiaba           | 31                        | 21.32                    |
|                      | Hongtudi          | 7                         | Dalongshan, Huahuiyuan, Hongqihegou, Huangnibang, Hongtudi, Jiangbeicheng, Wulidian | 20                        | 15.11                    |
|                      | Liujiaping        | 6                         | Dajuyuan, Shangxinjie, Liujiaping, Changshengqiao, Qiujiaowan, Chayuan            | 22                        | 16.43                    |

4.4.3. Optimized allocation with multi-standard sharing. High-speed rail, ordinary railway and subway emergency rescue stations can be selected from the candidate stations of all and emergency rescue stations can serve high-speed railway, ordinary railway demand stations and subway demand stations.
According to the mathematical model constructed in this paper, the emergency rescue level corresponding to optimized allocation scheme with multi-standard sharing is shown in Table 6.

**Table 6.** Emergency rescue level corresponding to optimized allocation scheme with multi-standard sharing

| Emergency Rescue Station | Number of Demand Stations | Covered stations                                                                 | Maximum Rescue Time (min) | Average Rescue Time (min) |
|--------------------------|---------------------------|----------------------------------------------------------------------------------|---------------------------|---------------------------|
| Beibei station           | 6                         | Hechuang station, Beibei station, Beibei, Southwest University, Zhuangyuanbei, Longfengxi | 32                        | 19.27                     |
| Caojiawan                | 6                         | Caijia station, Xiangjiagang, Caijia, Caojiawan, Jinshansi, Lijia                | 17                        | 13.09                     |
| Xiaoshizi                | 6                         | Jiaochangkou, Chaotianmen, Shangxinjie, Dajuyuan, Jiangbei, Xiaoshizi             | 15                        | 12.15                     |
| Daxuecheng               | 6                         | Bishan station, Bishan, Jiangdingpo, Daxuecheng, Chenjiqiao, Shuangbei           | 18                        | 14.52                     |
| Laijiaqiao               | 6                         | Tuanjiecu station, Geleshan station, Weidianyuan, Laishanxi                       | 23                        | 17.47                     |
| Shapingba station        | 6                         | Shapingba station, Chongqing West station, Yanggongqiao, Lieshimu, Ciqikou, Chongqing station | 20                        | 16.12                     |
| Huangnibang              | 6                         | Chongqing North station, Huahuiyuan, Hongqihe, Huangnibang, Hongtudi, Wulidian   | 18                        | 15.32                     |
| Eling                    | 6                         | Lianglukou, Eling, Daping, Shiyou, Qixinggang, Liujia                           | 15                        | 12.47                     |
| Ranjiaba                 | 7                         | Guangdianyuan, Ranjiaba, Shijingpo, Dazhulin, Kangzhuang, Dalongshan, Chuyuan   | 20                        | 16.34                     |
| Gaomiaocun               | 7                         | Changshengqiao, Qiujiawen, Gaomiaocun, Shiqiaopu, Xietai, Majiayuan, Xialong    | 19                        | 15.26                     |

4.4.4. Comparison of indicators before and after optimization. The comparison of regional rail transit emergency rescue level indicators before and after optimization is shown in Table 7.
Table 7. Comparison of emergency rescue levels of different emergency resource allocation schemes

| Allocation schemes | Allocation without optimization (status quo) | Optimized allocation without multi-standard sharing | Optimized allocation with multi-standard sharing | Explanation |
|------------------|---------------------------------|-------------------------------------------------|--------------------------------------------|-------------|
| Number of demand stations | 62 | 62 | 62 | The number of demand stations involved in the three configuration schemes is the same. |
| Number of emergency stations | 10 | 10 | 10 | The number of emergency stations involved in the three configuration schemes is the same. |
| Maximum rescue time (min) | 59 | 50 | 32 | Reduced maximum rescue time. |
| Average rescue time (min) | 22.50 | 20.29 | 16.20(28% less than current status) | Reduced average emergency rescue time. |
| Number of stations whose emergency rescue time exceeds 80% of the maximum emergency rescue time constraint | 14 | 9 | 5 | The number of stations with large emergency rescue time has been significantly reduced, and the rescue capacity of the entire regional rail transit network has been greatly improved. |

As can be seen from Table 7, in the case of optimized allocation of multi-standard emergency resources, the maximum time for emergency rescue is shortened by 27 minutes compared to status quo, and the average rescue time is shortened by about 28% compared to status quo. Compared with the optimized allocation scheme without multi-standard sharing, it is shortened by about 20%. The number of stations with large emergency rescue time has been significantly reduced, which validates the effectiveness of the optimization method of the regional rail transit emergency resource allocation in this paper.

5. Conclusion

Aiming at the problems of unreasonable allocation of rail transit emergency resources and excessive emergency rescue time, this paper proposes a method for optimal allocation of regional rail transit emergency resources based on resource sharing, which realizes the coordinated allocation of rail transport operation and maintenance resources of multi-standard rail transit systems. The emergency rescue level of the three allocation schemes were compared in the example, which verified the effectiveness of the method proposed in this paper and improved the emergency rescue of multi-standard rail transit, thereby improving the overall operation and maintenance efficiency of regional rail transit. The next research should combine the different fault types of multi-standard rail transit and their corresponding failure rates to optimize the allocation of emergency resources, and further strengthen the emergency rescue capabilities of regional rail transit.

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