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The Optimal Crew Allocation Scheme of Intercity Railway EMU: A Case Study of Guangzhou-Qingyuan Intercity

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Abstract

To improve the operational efficiency and service quality of intercity railways, this paper proposes a dynamic configuration optimization method for train crew based on workload. The study focuses on the Guangzhou Qingyuan Intercity Railway and the Guangzhou East Ring Intercity Railway. Through field research and task analysis, the crew work is divided into fixed and variable tasks, and the workload of key positions such as train conductors and cleaners is quantitatively analyzed under different passenger load factors. On this basis, a workload forecasting model was constructed, and a dynamic configuration scheme with hierarchical classification was developed based on the characteristics of the route. This plan takes "time occupancy rate" as the core indicator and establishes a trigger based personnel adjustment mechanism, achieving the optimal allocation of human resources while ensuring service levels. The research results provide a scientific basis for the refined operation of Guangqing and Guangzhou East Ring intercity lines, and also provide a reference paradigm for the crew configuration of other intercity lines in China.

Keywords

Intercity Railway, Crew Allocation Optimization, Passenger Load Factor, Grading and Classification, Task Analysis Method

1. Introduction

Intercity railway, as an important component of modern transportation systems, has shown diversity and contemporary characteristics in their development and definition on a global scale. From the high-speed railway network in Europe to the dense intercity transportation system in Asia, intercity railways, with their unique charm, connect cities and urban agglomerations, becoming an important artery for promoting regional economic development. In China, with the official release of the "Code for Design of Intercity Railway", intercity railway is clearly defined as a passenger dedicated line railway that serves adjacent cities or urban agglomerations, with a design speed of 200 km/h or less, and is characterized by speed, convenience, and high density. This definition not only clarifies the technical standards for intercity railways, but also lays the foundation for their position and role in national transportation strategies (Zhao et al., 2022).

However, despite the enormous potential of intercity railways in promoting regional economic integration and optimizing urban spatial layout, they still face many challenges in actual operation. One of the most significant issues is the generally low "load factor". The emergence of this phenomenon is partly attributed to the relative singularity of intercity railway lines, the short opening time, and the necessary stage of market cultivation. More importantly, the passenger flow of intercity railways is deeply influenced by multiple factors such as seasonal fluctuations, route characteristics, and passenger travel habits, presenting a high degree of dynamism and uncertainty. In this context, if the operating unit continues to use the traditional and fixed crew task configuration plan, it will undoubtedly be difficult to adapt to the rapid changes in passenger flow, which not only affects the smooth operation of daily operations, but may also lead to idle waste of human resources and rising operating costs (Zhang et al., 2025; Yang et al., 2025).

Therefore, exploring a scientific, flexible, and efficient configuration plan for intercity railway crew has become an important issue that urgently needs to be addressed. The solution to this issue not only concerns the economic benefits and service quality of intercity railway operating units, but also has profound significance for improving the operational efficiency and passenger satisfaction of the entire transportation system.

At present, academic and industry research on intercity railways mostly focuses on optimizing station stop plans, analyzing passenger travel behavior, and exploring public transportation operation modes, while there is relatively insufficient attention to optimizing crew configuration plans. This to some extent reflects the limitations of the current research perspective and highlights the importance and urgency of crew configuration issues in intercity railway operations. In view of this, this article chooses Guangzhou-Qingyuan intercity railway as the research object, and through in-depth analysis of the current situation of its high-speed train crew configuration, uses scientific methods such as task analysis to comprehensively examine and evaluate the current configuration plan. We aim to reveal the shortcomings and problems in the existing configuration schemes, such as unreasonable personnel allocation, low work efficiency, and ineffective cost control, and based on this, propose a series of targeted improvement suggestions and optimization plans (Breugem, 2020).

Through the research in this article, we hope to provide a practical and feasible crew configuration plan for the operating units of Guangzhou-Qingyuan intercity railway (The train operation route of Guangzhou-Qingyuan intercity railway is shown in Figure 1), helping them improve operational efficiency, reduce operating costs, and enhance market competitiveness. At the same time, we also hope that the research results of this article can provide useful reference and inspiration for the formulation of crew configuration plans for other intercity lines, and jointly promote the healthy development of intercity railway industry worldwide.

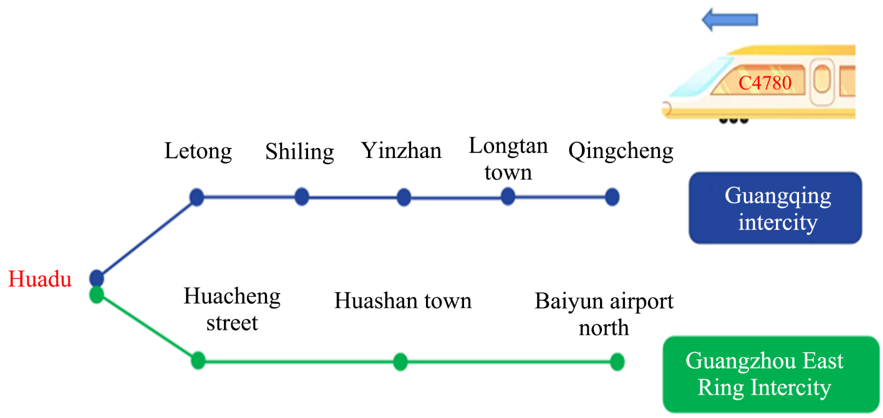

Figure 1. C4780 train operation route map.

2. Analysis of Intercity Railway EMU Crew Position Setting

According to the crew position layout mode of existing railway systems such as ordinary railway, high-speed railway and subway, intercity railway EMU has carefully constructed a diversified job system including conductor, trainman, safety officer, mechanician, cleaner, dining car attendant, etc. Through on-the-spot interviews and data analysis, including a detailed review of station management manuals and operation process documents, this study accurately defined the core responsibilities and task allocation of each post. The specific contents are shown in Table 1.

Table 1. Core responsibilities and task allocation for each position of high-speed train crew.

Position	Key Responsibilities
conductor	1) Responsible for controlling the train service process of this train, managing and supervising passenger service personnel such as train attendants, safety officers, cleaners, and dining car attendants; 2) Responsible for train broadcasting, passenger affairs processing, and passenger ticket inspection. Organize personnel from various positions to handle emergency situations; 3) Responsible for inspecting the status of train service interface equipment and facilities, checking the placement of passenger luggage, and maintaining order inside the train; 4) Responsible for organizing passenger boarding and disembarking, coordinating with drivers, platform door closing, and handover of affairs.

Continued

trainman	1) Organize passengers to board and disembark, maintain order inside the train, and be responsible for inspecting trains and checking the placement of passengers' luggage on a daily basis; 2) Obey the management of the conductor, assist the conductor in handling various passenger affairs, supervise the cleaning staff, and assist the conductor in ticket inspection.
safety officer	Organize safe boarding and disembarking, inspect the safety operation of gate posts, and maintain gate order. Promptly identify safety issues, summarize the safety work situation of this train, report any safety problems to the conductor in a timely manner, and propose rectification suggestions.
mechanician	Responsible for monitoring the status of train facilities and equipment, as well as responding and handling emergency events.
cleaner	Responsible for the collection of bathroom, seats, coffee table, ground garbage, and sanitation patrols on the train.
dining car attendant	Responsible for providing catering services such as brewing beverages, heating snacks, and selling food at the bar of the dining car.

Given the differences in infrastructure and passenger characteristics among intercity lines, the configuration mode of cabin crew also presents a diversified feature. For example, Guangzhou-Qingyuan intercity railway has adopted a streamlined and efficient basic configuration combination of "conductor, mechanician, and cleaner"; On the other hand, the Guangzhou-Shenzhen Railway comprehensively covers the full job configuration of "conductor, trainman, safety officer, mechanician, cleaner, and dining car attendant" to meet diverse service needs. However, no matter how the crew team is streamlined and optimized, the basic prerequisite for ensuring the safe and smooth operation of high-speed trains—the core configuration combination of "conductor, mechanician, and cleaner"—is always indispensable.

3. Analysis of Crew Workload and Personnel Allocation Plan for Intercity Railway EMUs

As mentioned earlier, the current crew structure of Guangzhou-Qingyuan intercity railway includes one conductor, one mechanic, and one cleaner. For intercity operating companies, optimizing the efficiency of crew team configuration is a key element for their sustainable development. Specifically, if the staffing of cabin crew is insufficient, it will inevitably intensify individual workload, which may lead to chain reactions such as a decline in service quality; On the contrary, if there is an excess of configuration, it will lead to unnecessary human resource redundancy and cost increase. Through comprehensive research and data analysis, the most direct and efficient way to explore the rationality of the allocation of high-speed train crew members is to deeply analyze the actual workload of each position's crew members, and use this as a basis for scientific allocation.

3.1. The Concept and Analysis Method of Workload

The concept of workload essentially reveals the degree of adaptation between individuals and positions (or tasks). When the workload brought by a position is too high, it can lead to the inability to complete work tasks or cause huge physical and mental pressure on workers in a short period of time, resulting in decreased work performance and increased error rates. When the workload is too low, it can also cause adverse consequences such as mental neglect, decreased alertness, and waste of homework resources among the workers. Workload is the concept of interaction between individuals and positions, which affects the configuration plan of personnel on positions through interactive mechanisms. There is no unified consensus in the academic community regarding the connotation of workload, and its definition and evaluation methods are often diverse. In most situations, the definition of workload is mainly qualitative, usually referring to the amount of work that is applied or prepared to be applied to an objective carrier within a certain period of time. There are three main methods for evaluating workload. One is the subjective evaluation method, which studies workload by examining the operator's subjective perception and feelings; The second method is task analysis, which studies workload by examining the amount of work tasks; The third is physiological measurement method, which studies workload by examining the physiological changes of operators (Chu et al., 2025).

This work will use the DO-RATASK task analysis method to analyze the configuration of cabin crew. DO-RATASK is a workload assessment method proposed by the Operations Research and Analysis Council for air traffic controllers in the United States. Due to the similar nature and methods of work between high-speed train crew members and air traffic controllers, using the DO-RATASK method to quantitatively analyze the workload of crew members has high reliability (Stoilova, 2020).

3.2. Analysis of the Workload of the Crew of Guangzhou-Qingyuan Intercity Railway

Through on-site tracking and investigation, this section will collect statistics on the working time of Guangzhou-Qingyuan intercity train conductors and cleaners under different passenger load conditions, and analyze their workload. It should be noted that as the work of mechanics mainly revolves around trains and is less affected by passenger flow, we only analyze the workload of train conductors and cleaners. In addition, considering that the current intercity trains in Guangzhou-Qingyuan include two types: eight formation and four formation, we also analyzed the workload of train conductors and cleaners under different formation conditions (Van Rossum et al., 2024).

3.2.1. The Workload of the Conductor

According to the train conductor's work process and the required time attributes of the work tasks, we can divide the train conductor's task units into fixed work tasks and variable work tasks. Among them, fixed work tasks (such as receiving trains at the platform, inspecting trains, organizing train capacity, etc.) refer to the work that the train conductor must complete according to the operation process, and the required time is generally fixed; And variable work tasks (such as carrying elderly and child care, serving key passengers, business acceptance, etc.) refer to the work tasks that the train conductor needs to adjust according to the needs of passengers, and the required time is variable, generally increasing with the increase of passenger flow. By using task analysis method and analyzing survey data and statistics, we can obtain the average passenger load factor and conductor workload rate of each train, as shown in **Table 2** (Wang et al., 2024; Wang et al., 2025).

Table 2. Passenger load factor of trains and workload of train conductors in April 2025.

Date	Passenger load (%)	Workload (%)	Date	Passenger load (%)	Workload (%)
April 1	17.62	75.71	April 16	9.41	52.54
April 2	19.3	78.89	April 17	9.24	50.79
April 3	10.63	56.83	April 18	15.47	71.11
April 4	10.83	57.31	April 19	17.00	74.92
April 5	17.01	74.65	April 20	19	77.46
April 6	9.41	52.54	April 21	14.17	67.3
April 7	9.24	50.79	April 22	15.96	72.22
April 8	15.47	71.11	April 23	10.62	56.51
April 9	17.00	74.92	April 24	9.7	52.7
April 10	19	77.46	April 25	15.86	71.03
April 11	10.61	56.03	April 26	17.62	75.71
April 12	9.32	51.43	April 27	19.3	78.89
April 13	9.33	51.9	April 28	10.63	56.83
April 14	9.8	53.01	April 29	10.83	57.31
April 15	16.61	73.33	April 30	17.01	74.65

According to existing research, there is a certain proportional relationship between the workload rate of train conductors and the passenger load factor of trains. Therefore, based on the data in **Table 2**, we used a power function to fit the workload rate of the train conductor and the passenger load factor of the train, in order to obtain the functional relationship between the workload rate of the train conductor and the passenger load factor of the train. The fitting process is as follows:

According to Figure 2, we can obtain the regression equation as $W = 14.379K^{0.4501}$, where $R^2 = 0.9906$, indicating that the reliability of the regression equation is high and can also be used to predict the future workload of train conductors.

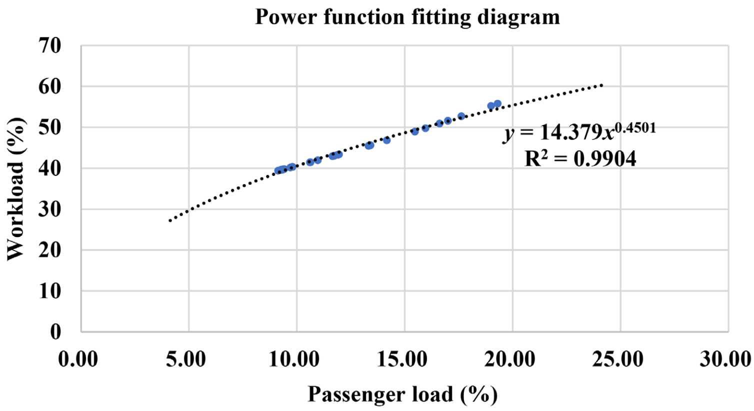

Figure 2. Power function fitting diagram between the workload of the train conductor and the passenger load factor.

Based on the functional relationship between W and K, we can predict the workload results of the train conductor under different passenger load factors, as shown in Table 3.

Table 3. Expected workload rates of train conductors under different passenger load factors.

Passenger load	Workload
$0 \leq K < 17\%$	$0 \leq W < 50\%$
$17 \leq K < 31\%$	$50\% \leq W < 80\%$
$31\% \leq K < 37\%$	$80\% \leq W < 100\%$
$37\% \leq K < 53\%$	$100\% \leq W < 160\%$
$53\% \leq K < 64\%$	$160\% \leq W < 200\%$
$64\% \leq K < 75\%$	$200\% \leq W < 240\%$
$75\% \leq K < 86\%$	$240\% \leq W < 300\%$

Similarly, by using task analysis method to analyze survey data and statistical data, we can obtain the average passenger load rate and cleaner workload rate of each train, as shown in Table 4.

Table 4. Passenger load factor of trains and workload of cleaners in April 2025.

Date	Passenger load (%)	Workload (%)	Date	Passenger load (%)	Workload (%)
April 1	9.34	20.35	April 16	9.18	19.81
April 2	9.41	20.42	April 17	9.13	20.18

Continued

April 3	9.24	20.28	April 18	13.41	24.63
April 4	15.46	27.34	April 19	14.17	25.59
April 5	17.01	29.60	April 20	15.96	28.04
April 6	19	32.84	April 21	10.62	21.55
April 7	10.61	21.54	April 22	9.7	20.68
April 8	9.32	20.35	April 23	11.65	22.61
April 9	9.33	20.35	April 24	11.74	22.70
April 10	9.81	20.77	April 25	9.8	20.77
April 11	16.62	29.00	April 26	9.38	20.40
April 12	17.63	30.56	April 27	11.95	22.93
April 13	19.31	33.36	April 28	10.97	21.90
April 14	10.62	21.56	April 29	13.32	24.52
April 15	10.84	21.71	April 30	11.89	22.87

We used a exponential function to fit the workload rate of cleaners and the passenger load factor of the train, in order to obtain the functional relationship between the workload rate of cleaners and the passenger load factor of the train. The fitting process is as follows:

According to Figure 3, we can obtain the regression equation as $W = 12.797e^{0.0493K}$, where $R^2 = 0.9993$, indicating that the reliability of the regression equation is high and can also be used to predict the future workload of cleaners.

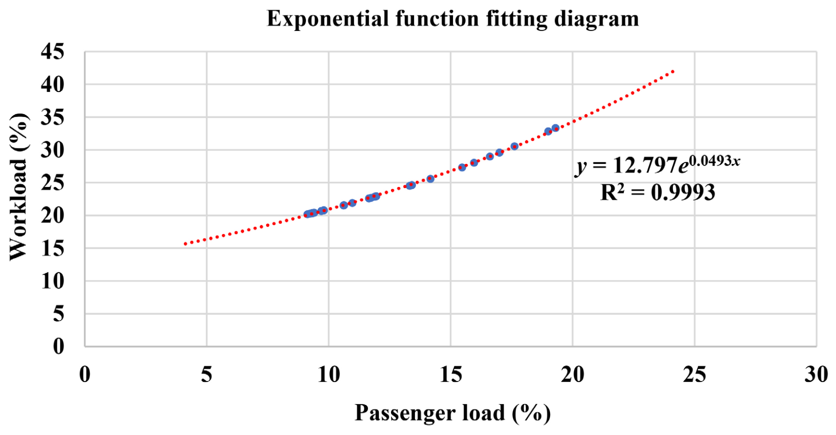

Figure 3. Exponential function fitting diagram between the workload of cleaners and the passenger load factor.

Similarly, based on the functional relationship between W and K, we can predict the workload results of cleaners under different passenger load factors, as shown in Table 5.

Table 5. Expected workload rates of cleaners under different passenger load factors.

Passenger load	Workload
$0 \le K < 28\%$	$0 \le W < 50\%$
$28\% \le K < 37\%$	$50\% \le W < 80\%$
$37\% \le K < 44\%$	$80\% \le W < 100\%$
$44\% \le K < 58\%$	$100\% \le W < 160\%$
$58\% \le K < 65\%$	$160\% \le W < 200\%$
$65\% \le K < 72\%$	$200\% \le W < 240\%$
$72\% \le K < 80\%$	$240\% \le W < 300\%$

3.2.2. Analysis of Quantitative Evaluation Results of Workload

The British Rail and Standards Agency divides workloads into three levels based on time occupancy rate (Table 6):

Table 6. Classification criteria for workload levels.

Workload	Level
$W < 50\%$	Low load
$50\% \le W < 80\%$	Medium
$80 \le W$	High load

According to Table 3 and Figure 2, it can be seen that the passenger load factor (K) of the train has a significant impact on the workload of the train conductor. At that time, $0\% \le K < 17\%$, and the train conductor was in a low load working condition. At this time, it is possible to consider the situation of the train conductor and the mechanic taking on both roles, but the prerequisite for taking on both roles is that the train conductor (or mechanic) must not only ensure the smooth completion of their own work unit, but also be proficient in each other's work requirements; When $17\% \le K < 31\%$, the conductor is in a medium load state; When $31\% \le K < 37\%$, the conductor is in a high load state. It should be noted that if the conductor is in a high load state for a long time, the quality of service provided will decrease. At this time, a feasible solution is to arrange mechanics (or other positions) to assist the conductor in completing some of the work; When $37\% \le K < 53\%$, one conductor is completely unable to complete the corresponding task and needs to designate one conductor to assist the conductor. At this time, both the conductor and the conductor are in a medium load state; When $53\% \le K < 64\%$, the configured one conductor and one conductor are both in a high load state; When $64\% \le K < 75\%$, one train conductor and one train attendant are no longer able to complete the job requirements, and an additional train attendant is needed to assist the conductor. At this time, the one train conductor and two train attendants are both in a medium load state; When $75\% \le K < 86\%$, the configured train conductor and two train attendants are both in a high load state.

Similarly, by comparing Table 5 with Figure 3, we can analyze the workload of the cleaners. When 0% ≤ K < 28%, the configured one cleaner is in a low load state; When 28% ≤ K < 37%, one assigned cleaner is in a medium load state; At that time, 37% ≤ K < 44%, and one assigned cleaner was in a high load state; At that time, 44% ≤ K < 58%, one cleaner was unable to complete the work task and an additional cleaner was needed. At this time, both cleaners called for a medium load state; When 58% ≤ K < 65%, the two assigned cleaners are in a high load state; At that time, 65% ≤ K < 72%, and 2 cleaners were unable to complete the task, so an additional cleaner was needed. At this time, all three cleaners are in a medium load state; When 72% ≤ K < 80%, the three assigned cleaners are in a high load state.

3.2.3. Crew Configuration Plan

Based on the calculation and analysis of the appeal, we can obtain the configuration plan of the high-speed train crew under different passenger load factors, as shown in Table 7.

Table 7. Crew configuration plan under different passenger load.

Passenger load	Conductor	Trainman	Mechanician	Cleaner
0 ≤ K < 17%	Working part-time as a mechanician	Zero	Working part-time as conductor	1 person
17% ≤ K < 37%	1 person	Zero	1 person	1 person
37% ≤ K < 53%	1 person	1 person	1 person	1 person
53% ≤ K < 64%	1 person	1 person	1 person	2 people
64% ≤ K	1 person	2 people	1 person	2 people

The Guangqing intercity railway belongs to the commuting type of line. Due to its early opening, the current passenger occupancy rate is relatively low. Therefore, the personnel configuration plan adopted is "1 train conductor + 1 mechanic + 1 cleaner". With the completion of the intercity railway network and the increasing maturity of operation, it is necessary to dynamically evaluate the selection of the crew configuration plan. Inter city railway line managers should dynamically predict the next stage's passenger load factor and select the corresponding crew configuration plan based on the expected passenger load factor (refer to Table 2). In the early stage when passenger flow is not yet mature, it is considered to set up train conductors and mechanics simultaneously, but this requires adjustments to the organizational structure of management and employee training.

4. Conclusion

This study proposes a dynamic crew allocation model for intercity railway EMUs based on workload analysis, using the Guangzhou-Qingyuan Line as a case study. By quantitatively linking passenger load factors to the workload rates of conductors and cleaners through power and exponential regression models, we developed a graded configuration scheme that adjusts crew size in real time to match operational demand. The scheme ensures service quality while optimizing resource utilization, providing a scalable and practical solution for intercity railway operations. This approach not only enhances the economic efficiency and flexibility of crew management but also offers a transferable framework for similar rail systems, supporting sustainable development in China's intercity railway network. Future work could integrate real-time predictive analytics to further refine dynamic allocation strategies.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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