Research on Optimization Method of Space Performance of Intercity Railway Underground Station Based on BP Neural Network

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Abstract. With the development of economy, China is facing the contradiction between urban development and the shortage of urban space resources.This article takes the small and medium-sized underground stations on the Guanhui Intercity Railway and the Changzhutan Intercity Railway as the main research objects of this thesis; Analyze the influencing factors of the space performance of the underground station, and design the BP neural network structure based on this; According to the preparation of relevant technical data, Anylogic is used to simulate the setting of simulation parameters and current station operation, to extract ideal samples, and to build and train the underground station Spatial performance characteristic analysis model.Finally, the spatial performance optimization method of Intercity Railway Underground Station Based on neural network is summarized, the optimization process is sorted out, the numerical optimization results are obtained, and the optimization scheme is proposed to verify the effectiveness of the method.

Keywords: Intercity railway underground station, Neural networks, Space performance, optimization strategy, Optimization method

1 Introduction

With the development of the economy, China has already had the phenomenon of population and industries congregating in cities. Due to the rapid expansion of urban construction and the increasing demand for motorized travel, the problems of traffic jams and parking difficulties have become more and more serious. The efficiency of urban operations and residents' lives have become more and more serious. The quality gradually deteriorated. As a country with a large population, China has limited land resources in urban core areas. In response to this contradiction, the intercity railway underground station, which began to develop urban underground space resources as a railway station, also emerged.Author or institution information should be omitted in the blind review process. This information should be only included once the article has been accepted for publication.

On March 4, 2020, the Politburo meeting of China's Central Committee proposed that "the progress of new infrastructure construction such as 5G networks and data centers should be accelerated", and the term "new infrastructure" has entered the eyes of all parties, including intercity railways. The provinces have gradually shifted their construction targets to the fields of intercity railway and intercity rail transit.

Since the underground intercity railway station is a relatively new type of railway transportation station building in China, the current station building design mainly draws on the experience of the subway and lacks targeted specifications. Most of the intercity railway underground stations have not been in operation for a long time, and the current passenger flow is far from reaching the designed maximum passenger flow. However, in the preliminary investigation, it was found that some stations have begun to have unreasonable space allocation, and the "bottleneck" space of obvious congestion in passenger flow(Figure 1); In the long-term considerations, how to optimize the design of long-term full-load operation and the future new intercity railway underground station design Space performance is also worthy of in-depth discussion.

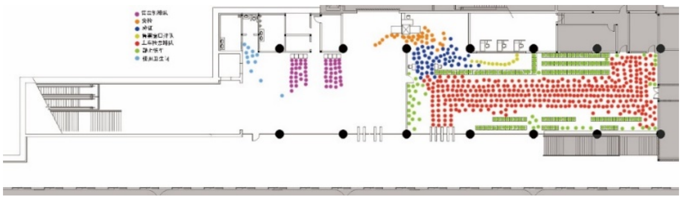


Figure 1. Observation record of behavior map of Lidui Park Station on Chengguan line. Source: self drawn by the author.

This thesis aims to study the optimization method of the space performance of the intercity railway underground station, accurately grasp the optimization direction, and quantify the optimization scale. Combining the experience summaries of various types of underground transportation buildings in the past, analyze the current situation of the use of intercity railway underground stations, quantify the space layout of the station building and the use of the station building, build a mathematical characteristic model through the neural network, and analyze the intercity railway underground station. Optimize the space performance of the existing station buildings, and put forward constructive and referable suggestions for the design of the future intercity railway underground station buildings.

According to the definition of the intercity railway in China's "Code for Design of Intercity Railways", intercity railways refer to passenger-dedicated railways that serve adjacent cities or urban groups with pedestrian trains designed at speeds of 200km/h and below.According to incomplete statistics from the research team, as of the end of 2019, China has opened a total of 30 intercity railway underground stations, and 19 underground stations are expected to be opened to traffic in the next two years.

The research in this thesis is mainly aimed at the optimization of the space performance of the underground station of the intercity railway. According to previous research and analysis, the main public space of the underground station of the intercity railway includes the hall floor and the platform floor. The functional requirements are more complicated. In addition, most of the time passengers stay in the station are on the hall floor, so this paper will focus on the optimization of the space performance of the underground station hall floor of the intercity railway.

2 Selection of key technologies

2.1 Simulation technology

Anylogic is a simulation software with a wide range of applications at the forefront of the field. Anylogic's main applications include pedestrian traffic simulation, logistics transportation, manufacturing, and resource management layout. Compared with traditional simulation software, Anylogic has unique technical advantages. Its operation is simple, optimized for multiple disciplines, built-in multiple evaluation and analysis tools, can be visually expressed, and design data interfaces with multiple software.The biggest feature of Anylogic is the use of discrete events, proxy models, and system dynamics to develop simulation models with a variety of advanced methods, which can respond to the needs of various environments, different scales, and different objects.

Due to objective reasons such as research time constraints, equipment deviations, and personnel measurement errors, the passenger flow data obtained by researchers have a lot of interference, has certain limitations, and cannot guarantee absolute accuracy and objectivity. If the data is directly used to build a neural network, it may affect the results of this paper on the performance of intercity railway underground stations. Therefore, this paper decided to analyze the data obtained from the survey and use it as the relevant parameter setting of Anylogic simulation, directly simulate the current situation of the space use of the intercity railway underground station, and retrieve the required sample data from the Anylogic software.

2.2 BP neural network technology

BP neural network was first proposed by Rumelhart, McCelland and other scientists in 1986. It is a multi-layer feed forward neural network based on error back propagation. It is similar in structure to multi-layer perceptrons and is currently widely used in various scientific fields.

BP neural network has great advantages for dealing with the space performance of intercity railway underground station, which has a complicated internal mechanism. It has the following characteristics：

1.The neuron structure of the BP neural network enables it to have distributed parallel processing capabilities, replacing the traditional serial processing of information in the past, thereby greatly improving the speed and efficiency of data analysis.

2.The BP neural network adds an excitation function to its construction, so that it can handle non-linear relationships, has excellent expression capabilities, and can approximate any functional relationship.

3.The parallel distributed processing model of the BP neural network makes the results are independently operated by multiple neurons and determined by overall planning. The damage of the local structure has a limited impact on the global training results and has good fault tolerance.

4.During the training process, the BP neural network uses error back propagation to adjust the weight coefficients of each layer of nodes, so that the output error is gradually reduced, and it has excellent learning and memory capabilities.

This paper uses BP neural network, takes the influencing factors of underground station space performance and space performance indicator variables as input and output variables, respectively, builds a neural network model to find the relationship between the variables. Then with the aid of the trained neural network model, according to the expected value of the expected result of the space performance, the optimization interval of the influencing variable is used as the basis for the optimization of the space station.

3 Analyze the influencing factors

Combining the previous research on the public space characteristics of the intercity railway underground station and the actual survey of the stations of the two lines, this paper analyzes the various factors that can affect the space performance of the intercity railway underground station, from passenger flow, station location and space, and facilities. Analyze and summarize the factors that affect the performance of the public space of the intercity railway underground station.

This paper analyzes the internal connection between each optimization variable and spatial performance through the neural network model. The performance indicators of spatial performance mainly start from three aspects of time, space, and time. The specific data are shown in Table 1.

Table 1. The optimization direction and the spatial performance index of the influencing factors of the space performance of the intercity railway underground station.

Optimization direction		Performance indicators
Spatial attributes	**Facilities attributes**	**Space performance**
station hall floor public space total usable area	Number of ticket vending machines	Average pit stop time
Number of entrances and exits	Number of security inspection machines	Average waiting time
average length of entrance and exit passage	real-name verification quantity	Average collection time
Waiting area area	Number of inbound ticket gates	Highest density of waiting area
station hall floor area of paid space accounted for	Outbound ticket gate number	The highest density in the distribution area
station hall floor paid space area		Maximum passenger flow at the pitting section
station hall floor non-paid space area		Maximum passenger flow of outbound section
Proportion of the area of the distribution area		
distribution area area		
waiting area proportion		

Source: self made

4 Obtain and analyze data

4.1 Simulation

Intercity railway underground station simulation ideas are mainly divided into three steps: preparation of relevant technical data, the establishment of simulation models, and retrieval of ideal sample data (Figure 2).

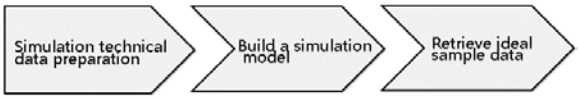


Figure 2. Anylogic simulation modeling ideas. Source: self drawn by the author.

After the establishment of the simulation model of the underground station is completed, the model will be demonstrated several times, revised and debugged, to achieve the desired effect. When the model is completely debugged, the relevant data interface can be called in the Anylogic software to export the pedestrian sample data, which can be used to build the neural network feature model of the intercity railway underground station.

According to the foregoing description, it can be seen that the simulation modeling of the intercity railway underground station mainly includes two parts: environment modeling and behavior modeling, and statistics are obtained for the parameters required for the simulation modeling of the intercity railway underground station.

The following is a simulated image of Xipingxi Station in the investigated route, and the green origin indicates pedestrians (Figure 3).

Figure 3. Anylogic simulation modeling ideas. Source: self drawn by the author.

4.2 Data analysis

Each AnyLogic model now has a built-in fully integrated database to read input data and write simulation output and store the input and output data of all completed simulation runs. The simulated data can be read by calling the relevant API, and the data can be exported to an Excel file through the corresponding operation.

The sample data of this research is divided into space attributes, equipment attributes and space performance indicators. After consulting related materials, field survey records and Anylogic simulation analysis, specific sample data can be obtained.

Before solving regression problems, machine learning, or neural network training, it is generally necessary to standardize the acquired original samples and use the processed data for output analysis. This is because the sample data used in data analysis in practical applications are generally not in the same evaluation index system. As in different dimensions, with different orders of magnitude and dimensions, it is difficult to compare. If the raw data is directly imported into the neural network, it is difficult to achieve the ideal training results. Through data standardization, the original data of different dimensions can be pulled to the same scale, which is convenient for data analysis and improves the speed and accuracy of neural network training convergence.

This article selects the most commonly used Min-Max standardization to process the sample data dimensionless. The conversion formula is as follows.

$$\frac{x_i - \min(x_i)}{\max(x_i) - \min(x_i)} \quad (1)$$

5 Establishing neural network model

5.1 Building and training models

This section first determines the number of layers of the BP neural network and the number of nodes in each layer according to the spatial performance influencing factors and sample attributes of the intercity railway underground station, and then selects the appropriate tool function, sets the corresponding model parameters, and builds the BP neural network. The parameter setting logic diagram is shown in Figure 4.

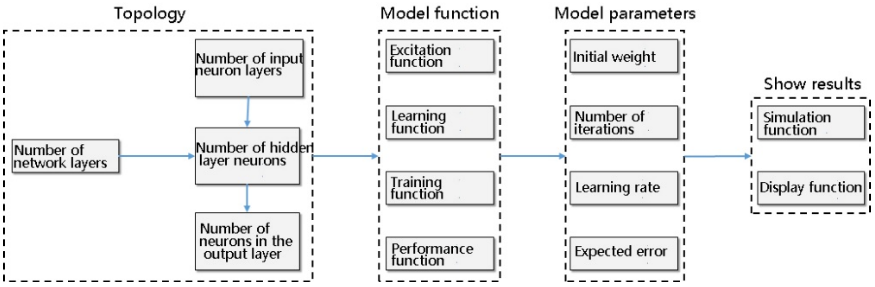
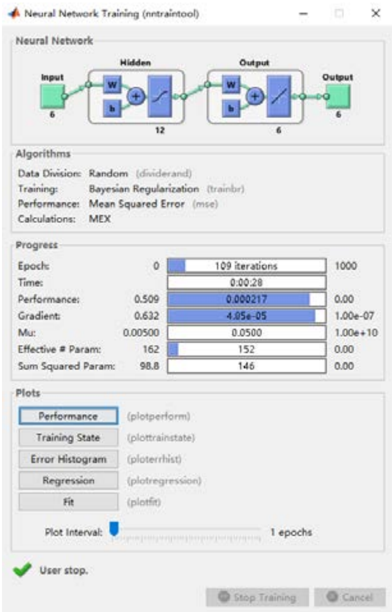


Figure 4. BP neural network parameter setting logic diagram. Source: self drawn by the author.

The variables filtered by the neural network are used as the output samples of the BP network, and the Bayesian regularization algorithm is used for sample data training. At this time, the structure of the BP network risk evaluation model after MIV dimensionality reduction is a three-layer structure, in which the number of nodes in the input layer is 6, the number of nodes in the hidden layer is 12, and the number of nodes in the output layer is 6, and the neural network structure is shown in Figure 5.



x

Figure 5. Algorithm neural network structure diagram. Source: self drawn by the author.

The training error curve after dimensionality reduction is shown in Figure 6, which is the error change graph of the training set and the test set. The error of the training set is gradually reduced after continuous iteration to correct the error to meet the requirements. The error of the test set also reached less than 0.01, and the training results were good.

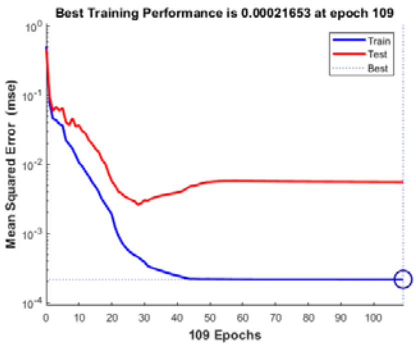


Figure 6. Algorithmic neural network training performance graph. Source: self drawn by the author.

It can be seen from the data fitting figure 7 that the correlation coefficient R of the training set, the test set, and the total data is greater than 0.95, indicating that the model prediction effect is good.

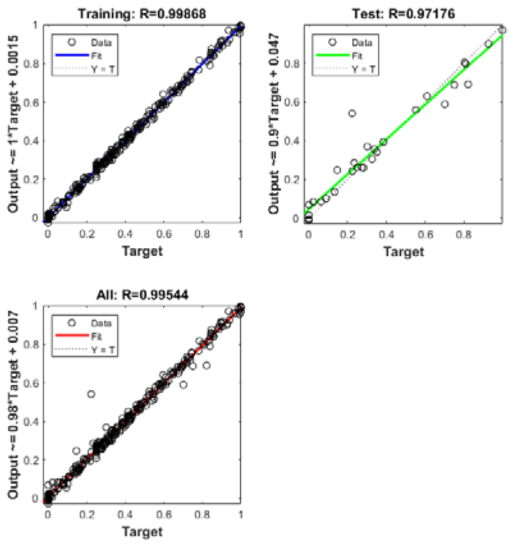


Figure 7. BR algorithm neural network data fitting graph. Source: self drawn by the author.

After analyzing the influencing factors of the intercity railway underground station, selecting variables and screening, designing and debugging the BP neural network structure, and then selecting the Bayesian regularization algorithm as the training algorithm, this research has completed the neural network model of the intercity railway underground station, which is built with good accuracy.

5.2 Analysis model

According to the K-means clustering method, the service level of the intercity railway underground station is classified, and the optimal level is selected as the expected value.Using the obtained expected value as the final input of BP neural network training, running the BP neural network model, the final prediction is:

T=[2884.0000 48.7500 0.1760 0.3940 2.0000 4.9999]

The data of the influencing factor variables under the expected value performance index are shown in Table 2.

Table 2. Influencing factor variables under spatial performance optimization target data.

Total usable area of station hall floor (m^2)	2884.0000
Average length of entrance and exit passage (m)	48.7500
Proportion of distribution area	0.1760
Proportion of waiting area	0.3940
Number of facilities-security inspection machine	2.0000
Number of facilities—outbound gates	4.9999

Source: self made

6 Make optimization based on optimization results

Taking the Xipingxi station as an example, the functional area division and facility layout of the research station were optimized and adjusted.

The functional area division and facility layout of the public space of Xipingxi Station Hall is optimized, and the optimization plan is shown in Figure 8.

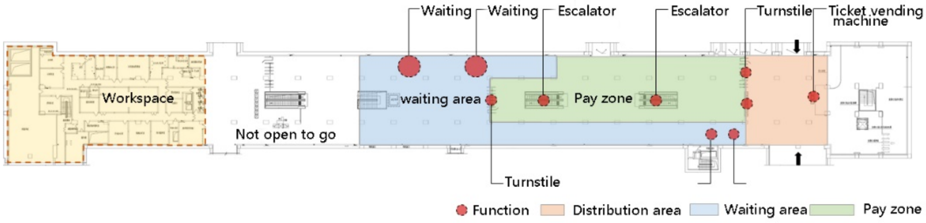


Figure 8. Optimized layout plan for the space of the hall floor of Xiping West Station. Source: self drawn by the author.

In the optimization plan of Xiping West Station, the area of the distribution area is reduced, the area of the waiting area and seats are increased, the real-name verification and security inspection facilities are added, and the exit ticket checking facilities are added to make the space flow line more concise. The specific data is shown in Table 3.

Table 3. Optimal use of space in Xiping West Station.

Project	Before optimization	Optimized
Average pit stop time (s)	184.3	113.2
Average waiting time (s)	89.4	25.8

Average collection time (s)	371.3	284.8
The highest density of waiting area space (per/m^2)	0.286	0.248
The highest density of the distribution area (per/m^2)	0.061	0.099
Maximum passenger flow of outbound section (per/h)	2412	3240

Source: self made

The optimization schemes of Xipingxi Station, Songshan Hubei Station, and Longfeng Station were tested by Anylogic simulation.

The optimized Xipingxi station space station is simulated, and the simulation image is shown in Figure 9. The queuing situation of security screening facilities and outbound ticket checking facilities in the station hall level has been significantly improved, and the flow line interference between the oncoming pedestrians, the queued pedestrians, and the outgoing pedestrians is also weakening.

Figure 9. Simulation image of the optimization plan for the hall floor of Xiping West Railway Station. Source: self drawn by the author.

After extracting simulation data from the optimization schemes of Xipingxi Station, Songshan Hubei Station, and Longfeng Station, the optimization results were compared and analyzed.

After optimization and simulation verification of Xipingxi Station, Songshan Hubei Station, and Longfeng Station, the spatial performance of each station has been significantly improved and is close to the expected value, which proves that the spatial performance optimization analysis of the intercity railway underground station based on the neural network model is effective.

7 Conclusion

Based on related data investigation and research, field investigation and observation, using mathematical software MATLAB, simulation modeling software Anylogic, and artificial neural network mathematical modeling, this paper has compiled a set of feasible and effective intercity railway underground station space performance Optimization. The flow chart of the optimization method is shown in the figure 10.

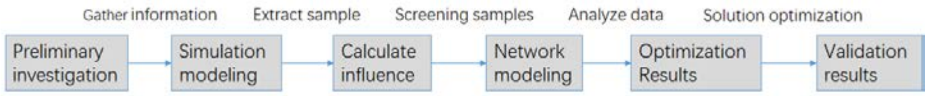


Figure 10. Optimization method flow chart. Source: self drawn by the author.

Through the previous modeling analysis of the research site and the verification of the space optimization plan based on the optimization results by Anylogic simulation, this proves the validity and feasibility of the neural-network-model-based analysis method of space performance optimization.

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