Research Article

Research on the Coordination Model of Passenger Transportation Mode in the Intercity Comprehensive Transportation Corridor

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At present, the study of comprehensive transportation corridors primarily focuses on the planning and construction of transportation corridors. There are few studies on the coordinated operation of all modes of transportation after the construction of the transportation corridor is completed. Comprehensive transportation corridor takes on the characteristics that the volume of transport demand and supply is large, the number of transportation modes is not only one, and competition among different transportation modes is fierce. In order to prevent unhealthy competition among different transportation modes from disrupting the transportation market, this paper takes the passenger transportation modes within the intercity comprehensive transportation corridor as the studied object and establishes a coordination model for them. The model introduces the disaggregate model as the research theory, takes the quantizable attributes of transportation modes as the decision variables, takes the reasonable distribution of passenger flow among different transportation modes as the objective function, and takes the supply capacity of different transportation modes and the reasonable value range of decision variables as the constraints. This model is a multiobjective nonlinear programming problem. The multiobjective genetic algorithm is designed to solve the model. The real number encoding method is adopted to encode the decision variables; the penalty function method is used to eliminate the solutions that do not meet the nonlinear constraints after crossover and mutation; the repairment algorithm is used to convert the solutions that do not satisfy the linear constraints and bound constraints after crossover and mutation into the feasible region. Pareto optimal solution set is obtained through continuous selection, crossover, and mutation. Finally, a numeric example is made to demonstrate that the method proposed in this paper is effective and feasible.

1. Introduction

The transportation system is essential to the country's economic construction, and the comprehensive transportation corridor is the backbone of the comprehensive transportation system. There are multiple transportation modes in the comprehensive transportation corridor; these transportation modes work together to complete the transportation tasks within or among city clusters. In a sense, the success or failure of the construction and operation of comprehensive transportation corridors directly affects the country's economic development. There are both competition and cooperation among different modes of transportation in the comprehensive transportation corridor. When various modes of transportation strive for more

passengers for their own benefit, this shows their competition. When all modes of transportation share the passenger flow in the transportation corridor to complete the transportation task together, it shows cooperation among them. For the construction of transportation corridors, it is necessary to configure reasonable transportation modes within the transportation corridors by analyzing the transport demand and the supply attributes of different transportation modes. For the operation of the transportation corridor, it is the goal to prevent unhealthy competition among different transportation modes and promote them to complete the transportation task in a coordinated manner.

At present, a great deal of research has been done on the planning and construction of comprehensive transportation corridors; outstanding achievements have been

made. For example, Zhang et al. [1] used the Nanchang-Ji'an-Ganzhou passenger corridor as an example to establish a sharing rate prediction model based on the classical multinomial logit (MNL) model, combining SP/RP survey data of passenger travel and different combinations of attribute variables and utility functions. To make the decisions of transportation mode choice reflect the subjective preference of the travelers, Guo et al. [2] study a method of transportation mode choice in a transportation corridor, combining prospect theory and gray correlation method to consider the different attitudes of travelers facing losses and gains in comparison of transportation mode. Jiang et al. [3] establish a bilevel programming model that maximizes the social benefits and minimizes the individual generalized costs; this first level is for the decision-making department of construction management; the second level is for the individuals who use the corridor to travel. Lan et al. [4] investigate the impact of the opening and operation of high-speed rail on the regional transportation modes by introducing a corridor utility amplification factor and constructing a multimodal transport sharing rate model on the basis of the logit model for high-speed rail transportation corridors. To solve the problem of calculating the passenger flow sharing rate in the Guangzhou-Shenzhen transportation corridor, Zhu et al. [5] use behavioral survey methods to investigate the influence of the attributes of four transportation modes on the choice of transportation mode. The four transportation modes are long-distance bus, conventional railroad, high-speed railroad, and intercity railroad separately. A two-level nested logit (NL) model is applied to predict each mode of transportation's passenger flow sharing rate.

After reading and analyzing the literature, we find that most of the current research on comprehensive transportation corridors focuses on the planning and construction of transportation modes; there is less research on the coordinated operation among various transportation modes after the completion of transportation corridors construction. There is not only one transportation mode in the comprehensive transportation corridor; there is a certain degree of substitutability and competition among different modes of transportation. Healthy competition can promote the development of different transportation modes, but unhealthy competition can disrupt the transportation market and destroy fairness. Therefore, to ensure the healthy development of comprehensive transportation corridors, it is necessary to coordinate the operation of different transportation modes in the comprehensive transportation corridor. The paper studies the coordination of different transportation modes in the comprehensive transportation corridor from the perspective of the operation of transportation modes. There are several transportation modes in the comprehensive transportation corridor, some of which serve passenger transportation, and some serve freight transportation. The research object in this paper is the transportation modes serving passengers. Therefore, all subsequent modes of transportation in this paper refer to passenger transport.

2. Building the Mathematical Model

2.1. Identifying the Studied Object. Transportation corridors first appeared in Western countries; it is the inevitable result of comprehensive transportation development to a certain stage. In the 19th century, the transport industry in developed countries had entered the modern stage. However, due to the lack of overall planning of the transport system, the development of various modes of transportation is uneven, and it is difficult for the transport system to play its role fully. Based on the experience of transport development, some transport experts in developed countries have proposed studying rationally constructing transportation systems from the viewpoint of letting the transportation system give a full play to the advantages of various modes of transportation. Their research believes that the key to solving a country's transportation problem is developing and building transportation corridors [6, 7]. In short, a transportation corridor is a generally linear area where one or more modes of transportation like highways, railroads, or public transit share the same course. From the classification of the transportation corridor, the connotation of the transportation corridor can be understood more deeply.

2.1.1. Classification of the Transportation Corridor. According to different classification criteria, transportation corridors can be divided into different types. According to the needs of the research problem in this paper, after analyzing the literature of different scholars and experts, including but not limited to the literature [8–12], three types of classification criteria are used to classify the transportation corridors. One is from the perspective of the service scope of the transportation corridor, the second is from the perspective of the service object of transportation corridors, and the third is from the perspective of the number of modes of transportation in the transportation corridors:

- (1) Classification from the perspective of service scope
 - (i) Interregional transportation corridor
Based on the analysis of literature [13–15], interregional transportation corridors connect important national transport hubs with long distances and are composed of multiple transportation modes. They are generally the backbone of national or interregional transportation networks and undertake important national transportation tasks, mainly taking on transportation tasks among different urban agglomerations.
 - (ii) Regional transportation corridor
Based on the analysis of literature [9, 10, 16, 17], the regional transportation corridors connect different areas in the same economic region and are the transportation links within the area. It serves the flow of passengers and goods in the economic zone. Regional transportation corridors can be divided into regional transportation corridors serving urban clusters and regional transportation corridors serving metropolitan areas.

(iii) Urban transportation corridor

Based on the analysis of the literature [11, 18–20], the urban traffic corridor is composed of one or a series of relatively parallel urban traffic arteries. Its basic forms mainly include urban traffic arterial roads, or urban rail transit, or a combination of the two. The shape of the urban transportation corridor is not the same, which can be straight or curved. There are a variety of modes of transportation in the corridor due to the large traffic flow in it.

(2) Classification from the perspective of the service object

According to the different service objects of the transportation corridor, the transportation corridor can be divided into passenger transportation corridors that mainly serve the transportation of passengers [21, 22], freight corridors that mainly serve the transportation of goods [23, 24], and passenger-and-freight mixed transportation corridors, in which the difference between passenger volume and freight volume is not very big [25].

(3) Classification from the perspective of the number of modes of transportation

The significance of the existence of the transportation corridors is to complete the tasks of transporting passengers and goods near the transportation corridors. As for which mode of transportation to use, it should be determined according to the traffic demand and the actual economic situation in the transportation corridor. There may be one mode of transportation in some transportation corridors, while others may have multiple modes of transportation. Therefore, according to the number of transportation modes in the transportation corridor, the transportation corridors can be divided into single-mode transportation corridors and comprehensive transportation corridors. The single-mode transportation corridors often appear in the early stages of the transportation corridors' development and are usually dominated by roads or railways. Because the economy around the corridor is not very developed, the transport demand is not great, and the government does not have enough funds to build multiple modes of transportation. With the development of the economy, the transport demand in the transportation corridor increases, and the government has sufficient funds to build multiple transportation modes, so the comprehensive transportation corridor, including different modes of transportation, is gradually built.

The classification of transportation corridors is shown in Figure 1.

2.1.2. The Characteristics and Problems of the Comprehensive Transportation Corridor

(1) *The Characteristics of the Comprehensive Transportation Corridor.* For the definition of a comprehensive transportation corridor, scholars and experts in different countries have not reached a unified view. However, that is not important; what is essential is that these experts and scholars think that the essence of the transportation corridor is the same. After analyzing the literature of different scholars and experts, including but not limited to the literature [26–31], the authors summarize these common characteristics of the comprehensive transportation corridor as follows:

- (i) There is more than one mode of transportation in the comprehensive transportation corridor
- (ii) Comprehensive transportation corridors play a vital role in the comprehensive transportation network
- (iii) The comprehensive transportation corridor is like a line (straight or curved) that connects different towns and cities to provide transport services for its passengers or goods
- (iv) The comprehensive transportation corridor mainly serves a narrow area in terms of geographic scope
- (v) The demand for passengers and/or cargo in the comprehensive transportation corridor is great
- (vi) The comprehensive transportation corridor can provide large passenger and/or cargo supplies

Figure 2 shows the structure of the comprehensive transportation corridor for passenger transportation abstracted from the real world in China. Different transportation modes connect the cities near the transportation corridor, and different cities establish close ties through the transportation corridor.

(2) *The Relationships among Different Modes of Transportation.* All transportation companies will attract as many passengers as possible in order to obtain the maximum profit. There are three relationships among different modes of transportation: cooperation, healthy competition, and unhealthy competition:

- (i) Cooperation: the various modes of transportation in the transportation corridor jointly complete the transportation through division of labor and cooperation to meet people's needs for travel. Particularly in the peak season of passenger flow, the demand of passengers in the corridor is very great, and it is impossible to complete the transportation task by one mode of transportation alone. At this time, multiple modes of transportation are required to play their respective advantages and jointly complete the task of passenger transportation.
- (ii) Healthy competition: healthy competition can promote different transportation enterprises to invest a lot of human resources and material

FIGURE 1: The classification of transport corridors.

FIGURE 2: The structure of the comprehensive transportation corridor.

resources to develop new technologies, use new materials and equipment, provide better transportation services, reduce transportation costs so that transportation enterprises can occupy more market shares, and gain more profits. Healthy competition is beneficial to promote the improvement of the productivity of the whole society and bring about the rational allocation of the whole society's resources. Healthy competition leads to more options, lower prices, and better quality of transportation service. It is good in the marketplace not only for businesses but also for consumers.

- (iii) **Unhealthy competitions:** when transport demand is insufficient, some powerful transportation enterprises try to obtain more passenger flow sharing rate through improper means to achieve the purpose of obtaining more profits. It may reduce the sharing rate of other modes of transportation, leading to transportation enterprises being unable to obtain reasonable profits to maintain their normal operation. These transportation companies will suffer losses or even go bankrupt as a result. Then, when the peak season comes again, there is insufficient transport supply because of the bankruptcy of

transportation enterprises. It allows those remaining transportation companies to monopolize the transportation market.

(3) *The Problem of the Comprehensive Transportation Corridor.* Unhealthy competition is the problem of the comprehensive transportation corridor. In short, passenger flow fluctuates over time. When the passenger flow is insufficient, some transportation companies may obtain more passenger flow through unfair competition for their own benefit, but it will damage the development of other transportation enterprises. It is a practical problem in the comprehensive transportation corridor, which must be faced positively. Transport authorities should try to avoid this unhealthy competition through some administrative means.

2.1.3. Studied Object and Problem to Be Solved in This Paper

(1) *The Studied Object in This Paper.* Before establishing the mathematical model, the first thing that needs to be clarified is the studied object in this paper. The following will clarify the studied object from the perspective of transportation corridor classification:

- (i) From the perspective of the number of modes of transportation, in the transportation corridor, the studied object in this paper is comprehensive transportation corridors. The reason is that coordination is only necessary when there is unhealthy competition among multiple modes of transportation.
- (ii) From the perspective of service scope, the studied object in this paper is interregional comprehensive transportation corridors and regional comprehensive transportation corridors. For ease of presentation, in this paper, interregional comprehensive

transportation corridors and regional comprehensive transportation corridors are collectively referred to as intercity comprehensive transportation corridors. Because both interregional comprehensive transportation corridor and regional comprehensive transportation corridor provide service for the cities, it is just that regional comprehensive transportation corridor provides service for cities within the city cluster, and interregional comprehensive transportation corridor provides service for cities among different city clusters.

- (iii) From the perspective of the service object, the studied object in this paper is passenger-and-freight mixed transportation corridors and passenger transportation corridors. Most of the transportation corridors are for both passenger and freight transport. Passenger and freight transport have different characteristics, so research methods are naturally different. This paper does not intend to study them together.

To summarize in one sentence, the studied object in this paper is only passenger transportation modes in the intercity comprehensive transportation corridor.

(2) *The Problem to Be Solved in This Paper.* In order to clarify the specific problem of this study, let us analyze the travel process in the comprehensive transportation corridor. The travel process between two cities within the intercity comprehensive transportation corridor can be divided into two stages, the intercity trip and the urban trip, as shown in Figure 3. The intercity trip refers to how passengers travel from one city to another by taking some intercity transportation modes, such as civil aviation, high-speed rail, conventional rail, highway, expressway, and so on. The urban trip refers to how passengers travel between the origin (destination) and the station (airport) of transportation mode by taking urban traffic, such as urban rail transit, buses, taxis, cars, and so on.

As analyzed in Section 2.1.2, when there are multiple modes of transportation within a transportation corridor, there may be unhealthy competition among them. The problem that needs to be studied in this paper is how the transportation authorities avoid the unhealthy competition among various modes of transportation, making make them coordinately work together to complete the transportation work.

2.2. Building the Coordination Model

2.2.1. *The Ideas of Modeling.* Through the above analysis, it is not difficult to see that the essence of the coordinated operation of various modes of transportation in the comprehensive transportation corridor is to allocate passenger flow among different modes of transportation reasonably. It can avoid unhealthy competition among different transportation modes and promote healthy development. Therefore, the idea of establishing a coordination model is to allow passenger flows to be reasonably distributed among

different transportation modes in the transportation corridor so that each transportation mode can obtain reasonable profits. In this case, transportation companies can provide continuous transportation services and maintain higher service quality for passengers.

2.2.2. *Defining Objective Function.* Suppose there are two cities with multiple passenger transportation modes between them in the comprehensive transportation corridor as shown in Figure 3, and these transportation modes serve the same passengers, so there may be unhealthy competition among them. Competition is like a double-edged sword; if it is not guided, chaotic competition may cause harm to society, although healthy competition can help transportation enterprises to improve the service quality. Assuming that total passenger transport demand between two cities is R , the probability of choosing the n th intercity transportation mode is P_n . So, the number of passengers choosing the n th intercity transportation mode Nu_n is

$$Nu_n = P_n \cdot R (n = 1 \dots N), \quad (1)$$

where P_n is the probability that the n th transportation mode is chosen for travel and N is the number of transportation modes that are available for passengers.

Assuming that the supply capacity of the n th intercity transportation mode is S_n , define the actual capacity utilization coefficient of n th intercity transportation mode Cu_n as

$$Cu_n = \frac{Nu_n}{S_n} = \frac{P_n \cdot R}{S_n} (n = 1 \dots N). \quad (2)$$

Assuming that the ideal capacity utilization coefficient of n th intercity transportation mode is A_n , then the difference D_n between the actual capacity utilization coefficient and the ideal capacity utilization coefficient is

$$D_n = Cu_n - A_n (n = 1 \dots N). \quad (3)$$

The ideal capacity utilization coefficient A_n is usually a number between 0 and 1. If it is greater than 1, it means that the transport demand for the n th transportation mode is greater than its supply. If this is the case, the supply will exceed demand, so some of the demand will be difficult to meet, and overloading may occur. If it is equal to 0, it means that there is no passenger taking the transportation mode for travel. The ideal utilization capacity coefficient can be set by the decision-maker according to the actual situation. For example, it can be chosen in the interval $[0.7, 0.9]$, which does not cause waste of transport supply but also has a certain transportation reserve for the fluctuations of passenger flow. Therefore, the ideal state for all transportation modes within a comprehensive transportation corridor is that all transportation modes' actual capacity utilization coefficient is equal to the ideal capacity utilization coefficient. In this state, the passenger flow in the comprehensive transportation corridor is reasonably distributed among different modes of transportation, and the transportation enterprises of each mode of transportation can make profits.

Characteristic: there are multiple modes of transportation in the transportation corridor.

Problem: there may be unhealthy competition among different modes of transportation.

Problems to be solved: avoid the unhealthy competition by building the mathematical model.

FIGURE 3: Travel process in the intercity comprehensive transportation corridor.

Therefore, it is reasonable to use (3) as the objective function of the coordination model. However, experience tells us that the nonnegativity of the objective function facilitates the solving of the model, so (3) can be converted to

$$\min f_n = (Cu_n - A_n)^2 \quad (n = 1 \dots N). \quad (4)$$

2.2.3. Defining Decision Variables. For identifying decision variables, bring (2) into equation (4), and the following equation can be obtained:

$$\min f_n = \left(\frac{P_n \cdot R}{S_n} - A_n \right)^2 \quad (n = 1 \dots N). \quad (5)$$

From (5) and contents in Section 2.2.1, it is clear that all symbols except P_n are constants. Therefore, we can only find decision variables in P_n .

(1) Calculating the Sharing Rate. In calculating the sharing rate of different transportation modes P_n , the most mature method recognized by academia is the multinomial logit model, which is introduced in this paper. Multinomial logit models have been widely used in various industries and have achieved remarkable success [32–35]. As a mode choice model, the application of the multinomial logit model in the field of transportation is numerous [36–38]. Therefore, this paper selects the multinomial logit model to calculate the sharing rate of different transportation modes. The mathematical expression of the multinomial logit model is not complex; it can be expressed as follows, which can be found in the literature [39].

$$P_n = \frac{e^{V_n}}{\sum_{j=1}^N e^{V_j}}, \quad (6)$$

where V_n is the utility of the n th transportation mode and V_j is the utility of the j th transportation mode.

In the multinomial logit model, a linear combination of explanatory variables is used as the utility function, which is expressed as

$$V_n = \sum_{i=1}^I \theta_{ni} \cdot x_{ni} + \theta_{n0}, \quad (7)$$

where x_{ni} is the i th observable explanatory variable, which affects whether the n th mode of transportation can be chosen, θ_{ni} is the coefficient of the explanatory variable x_{ni} , θ_{n0} is the coefficient of the unobservable influence factor, and I is the number of explanatory variables.

To simplify (7), assuming an assumptive explanatory variable x_{n0} for the unobservable influence factor of the n th mode of transportation, and letting $x_{n0} = 1$, (7) can be simplified as

$$V_n = \sum_{i=0}^I \theta_{ni} \cdot x_{ni}. \quad (8)$$

(2) Determine Decision Variables. From (6) and (8), it is easy to see that choosing explanatory variables as decision variables is feasible. After analyzing and summarizing the relevant literature, including but not limited to the literature [40–42], the authors divide the explanatory variables into three categories. The first category is related to attributes of the individuals, such as age, gender, salary, and so on. The second category is related to attributes of transportation modes, such as travel time, travel cost, and so on. The third category is related to travel itself, such as travel distance, origin or destination, and so on. When using the logit model, the choice of explanatory variables is flexible and needs to be adjusted to the actual context of the research problem. When coordinating various modes of passenger transportation modes within a transportation corridor, the chosen decision variables must be controlled by the authorities of the transport enterprise. That is to say, they can adjust the value of decision variables. So, the explanatory variables related to

the attributes of the individuals are meaningless because authorities cannot adjust them. At the same time, the coordination model is modeled with a given origin and destination in the transportation corridor. The explanatory variables related to attributes of travel, such as travel distance, origin, or destination, are also not necessary because they are the same for all modes of transportation. The remaining explanatory variables are only related to the attributes of transportation mode, which can be used as decision variables.

With the popularity of high-speed rail and civil aviation in China, the travel time during the intercity trip is much shortened, and the convenience during the urban trip to or from the station (airport) greatly influences the choice of the transportation mode taken by passengers during the intercity trip. If the station or airport of transportation mode for the intercity trip is too far from the city, and the public transportation is not well developed such that passengers do not have easy access to the station or airport, it will seriously affect passengers' choice of this mode of transportation. After comprehensively considering the characteristics of China's transportation corridors, the factors that influence the choice of intercity transportation modes, including rapidity, economy, comfort, safety, and convenience, can be selected as decision variables after the authors analyze and summarize the relevant literature:

- (i) Economy mainly relates to the fare of taking the intercity transportation mode
- (ii) Rapidity mainly relates to the travel time of taking the intercity transportation mode
- (iii) Convenience mainly relates to the travel time spent on urban transport for transferring to the intercity transportation mode
- (iv) Safety relates to the accident rate of the intercity transportation mode and the number of casualties in the accident
- (v) Comfort relates to the degree of comfort of taking the intercity transportation mode

The distribution of passenger flow among different modes of transportation can be adjusted by changing their values if using the above five explanatory variables as decision variables. It should be added that the authors believe that any explanatory variable that can be changed can be used as a decision variable, not limited to the above five. Of course, we can also choose a few of the five decision variables for modeling depending on the actual situation of the problem. For example, if the safety of all transportation modes is high, and travelers hardly consider safety when choosing transportation modes, we can consider not including safety in the decision variables.

2.2.4. Defining Constraints. Constraints can be added according to the actual situation, and the authors believe that the two most basic types of constraints are necessary. To avoid overloading of the intercity transportation mode, the

demand for it should not be greater than its supply. So, the following constraints expressed as (9) hold true:

$$P_n \cdot R \leq S_n \quad (n = 1, 2 \dots N). \quad (9)$$

For each decision variable, its value is bounded in the real world. Therefore, the decision variable x_{ni} must satisfy some bound constraints as follows:

$$x_{ni} \in [L_{ni}, U_{ni}] \quad (i = 1, 2 \dots I, n = 1, 2 \dots N), \quad (10)$$

where L_{ni} is the lower bound of the decision variable x_{ni} and U_{ni} is the upper bound of the decision variable x_{ni} ; x_{ni} is referred to in (7).

In summary, the coordination model can be established as follows:

$$\begin{aligned} \min f_n &= (Cu_n - A_n)^2 \quad (n = 1 \dots N), \\ \text{s.t.} \quad &\begin{cases} L_{ni} \leq x_{ni} \leq U_{ni} \quad (i = 1, 2 \dots I, n = 1, 2 \dots N) \\ P_n = \frac{\exp(V_n)}{\sum_{j=1}^N \exp(V_j)} \quad (j = 1, 2 \dots N) \\ V_j = \sum_{i=0}^I \theta_{ji} \cdot x_{ji} \quad (i = 1, 2 \dots I, j = 1, 2 \dots N) \cdot \\ Cu_n = \frac{P_n \cdot R}{S_n} \quad (n = 1, 2 \dots N) \\ P_n \cdot R \leq S_n \quad (n = 1, 2 \dots N) \end{cases} \end{aligned} \quad (11)$$

3. Model Solving

3.1. Handling of the Objective Function

3.1.1. Definition of the Optimal Solution for Multiobjective Optimization. The model established above is a multi-objective nonlinear programming model. The task of multiobjective programming is to seek an optimal solution X_{opt} such that the values of each objective function are optimal, which can be expressed as

$$\begin{aligned} \text{opt.} & (f_1(X_{\text{opt}}), f_2(X_{\text{opt}}) \dots f_N(X_{\text{opt}})), \\ \text{s.t.} & X_{\text{opt}} \in U, \end{aligned} \quad (12)$$

where $f_n(\cdot)$ stands for the n th objective function, $n = 1, 2 \dots N$; X_{opt} stands for the optimal solution, which is a vector consisting of decision variables; and U is the feasible region.

In most cases, such an optimal solution X_{opt} making all objective functions optimal cannot be found due to the contradiction of different objective functions. That is, there is no solution X_{opt} that can be found so that the following inequality holds true for all the objective functions:

$$f_n(X') \geq f_n(X_{\text{opt}}), \quad (13)$$

where X' stands for any feasible solution in the feasible region and X_{opt} stands for the optimal solution in the feasible region.

In the meantime, there exists at least one n such that the following inequality holds true:

$$f_n(X') \neq f_n(X_{\text{opt}}). \quad (14)$$

Unlike a single-objective optimization problem, the optimal solution for a multiobjective optimization problem may not exist. Therefore, Pareto solutions are used to replace the optimal solution in multiobjective programming. That is to say, the purpose of multiobjective programming is to find the Pareto solutions. When finding the Pareto solutions, the concept of the inferior solution needs to be used [43]. The inferior solution X'' of the problem means that there exists an X , $X \in U$, such that inequality (15) holds true for all $n \in N$.

$$f_n(X) \leq f_n(X''). \quad (15)$$

And there exists at least one n such that inequality (16) holds true.

$$f_n(X'') \neq f_n(X). \quad (16)$$

The Pareto solution is also called nondominated solution, which means that an improvement in one objective function requires degradation of another. If a solution X' is a non-dominated solution, then there does not exist an X , $X \in U$, such that the following inequality holds true for all $i \in N$:

$$f_n(X) \geq f_n(X'). \quad (17)$$

And there exists at least one n such that the following inequality holds true:

$$f_n(X') \neq f_n(X). \quad (18)$$

From the definition of the Pareto solution, for a multiobjective optimization problem, there is usually more than one Pareto solution, which forms a set of solutions, namely, Pareto front. The decision-maker selects one or more from the set as the basis for the decision-making, according to his or her preference.

3.1.2. Methods for Solving Multiobjective Optimization.

There are many methods to solve multiobjective optimization problems; the single-objective method is the most common and easiest method to implement. The single-objective method, also called scalarization by some scholars, scalarizes a set of objectives into a single objective by adding each objective premultiplied by a user-supplied weight. The weight of an objective is chosen in proportion to the relative importance of the objective. The biggest advantage of this method is simple. It transforms multiobjective optimization into single-objective optimization, and then it can be solved by the single objective optimization method. However, its disadvantages are also obvious, including the following:

- (1) It is difficult to determine the weight of each objective function. The optimal solution obtained by different weights is different. Therefore, how to determine the weight will cause some confusion to the users.
- (2) Many methods for solving single-objective optimization require the objective function to be convex. When the objective function is nonconvex, it cannot be guaranteed that the solution is Pareto optimal.
- (3) The most methods for solving single-objective optimization stop iterating when the value of the objective function is not getting better. The optimal solution obtained by these methods is usually only one. However, there are multiple optimal solutions to multiobjective optimization problems. Therefore, the single-objective method is not efficient in solving multiobjective optimization.

The coordinated operation of various transportation modes in the comprehensive corridor requires each transportation company to adjust the attributes of their transportation modes as much as possible according to the optimal solution. If the optimal solution obtained is a specific real number, it is difficult or even impossible for each transportation company to adjust the attributes of their transportation modes according to the optimal solution in real life. If the optimal solution obtained is an interval instead of a single real number, each transportation company only needs to restrict its transportation mode attributes within the corresponding interval, which is easier to achieve. In this way, although there is no guarantee that the result will be Pareto optimal, it must be near the Pareto optimal solution. It can be seen from the above analysis that the single-objective method can only get a single solution under normal circumstances; one specific solution has limited practical value in real life. So, the single-objective method used for solving the multiobjective optimization problems established in this paper is inappropriate.

The problem would be simpler if multiple Pareto optimal solutions could be obtained by solving the problem once and then using these Pareto optimal solutions to seek the value intervals of different attributes of various transportation modes. Fortunately, the multiobjective genetic algorithm can achieve this. Using the multiobjective genetic algorithm to solve the model established in this paper has the following advantages:

- (1) Multiple Pareto optimal solutions can be obtained in a single run. Then, it is possible to use these Pareto optimal solutions to explore the value interval of each decision variable.
- (2) The mutation operator makes the genetic algorithm have certain global searchability, which increases the possibility that the obtained Pareto optimal solution is the global optimal.
- (3) The ability of the genetic algorithm to simultaneously search different regions of a solution space makes it possible to find a diverse set of solutions for complex

problems with nonconvex, discontinuous, and multimodal solutions spaces.

- (4) Using scalarization to solve multiobjective optimization problems, whether to use weights to convert multiple objectives into single objectives or to reduce the number of objective functions by transforming relatively unimportant objectives into constraints, it is necessary to ask decision-makers to provide their preferences before solving the problem. The multi-objective genetic algorithm does not require users to participate in the model solving process, which makes the solving process simple.
- (5) Many algorithms need to calculate the derivative of the objective function in solving the mathematical model. The objective function established in this paper is complex, so it is difficult to derive. The genetic algorithm does not need to use the objective function derivative for solving mathematical models. Hence, using the genetic algorithm to solve the model is more suitable.

3.2. Algorithm Design. For an introduction to multiobjective genetic algorithms, one can refer to the relevant literature, such as the literature [44–46]. In general, genetic algorithms are search heuristic that is inspired by Charles Darwin's theory of natural evolution; the algorithm is an idea for solving the problem. Before using it to solve a specific optimization problem, it needs to be designed according to the actual situation of the problem. The following is the solving process of using the multiobjective genetic algorithm to solve the multiobjective optimization model established in this paper.

3.2.1. Encoding. The first step is encoding when using the algorithm to solve the optimization problem. Genetic algorithms' most common encoding methods are binary encoding, gray encoding, real-value encoding, symbolic encoding, and so on. This model is solved by real-value encoding; that is, the individual is expressed as

$$X = x_{11} \cdots x_{1I} \cdots x_{n1} \cdots x_{ni} \cdots x_{N1} \cdots x_{NI}, \quad (19)$$

where X is a vector composed of decision variables, N is the number of all transportation modes, x_{ni} is the i th decision variable of transportation mode n , and I is the number of decision variables of each transportation mode.

After finishing encoding, each individual is a vector with all decision variables as its element. So, each element in the vector is equivalent to a decision variable, also called gen. An individual represents a solution of the model. In this paper, vector, individual, and coded string all mean the same thing. Decision variable, gene, and element also mean the same thing.

3.2.2. Selection. The commonly used selection operators are roulette wheel selection, random traversal selection, and so on. In this paper, we use the tournament selection operator. The process is as follows.

- (1) Randomly select k individuals from the population to compare their fitness, and then select a non-inferior solution to be inherited to the next generation
- (2) Repeat the above process m times to get m individuals into the next generation

3.2.3. Crossover. Crossover is the exchange of some of the genes between two paired chromosomes in some way to form two new chromosomes. The model in this paper is solved by using the arithmetic crossover operator. The arithmetic crossover operator randomly selects two chromosomes for crossover; two offsprings are produced by a linear combination of the two chromosomes. Suppose the two individuals are x_1, x_2 , and the new individuals after arithmetic crossover are X'_1 and X'_2 .

$$\begin{aligned} X'_1 &= rand \cdot X_1 + (1 - rand) \cdot X_2, \\ X'_2 &= rand \cdot X_2 + (1 - rand) \cdot X_1. \end{aligned} \quad (20)$$

Here, $rand$ is a random number that follows a uniform distribution within $[0,1]$.

3.2.4. Mutation. The mutation operator improves the global search ability of the genetic algorithm and maintains the diversity of the population. It prevents premature convergence of the genetic algorithm. The uniform mutation is used as the mutation operator in this model, and its mutation process is divided into three steps.

Step 1. Randomly specify a mutant gene for each individual; that is, each decision vector is specified with one decision variable for mutation.

Step 2. Generate a new random number within the value range of the decision variable.

Step 3. Use the generated random number to replace the specified decision variable for mutation with a certain probability p .

For example, if the individual is $X = x_{11}x_{12} \cdots x_{NI}$, the mutation point is x_{ki} , and the value range of x_{ki} is $[B_{\min}^{ki}, B_{\max}^{ki}]$, then the new gene x'_{ki} after mutation is

$$x'_{ki} = B_{\min}^{ki} + rand \cdot (B_{\max}^{ki} - B_{\min}^{ki}), \quad (21)$$

where $rand$ is a random number that follows a uniform distribution within $[0,1]$.

3.2.5. Handling Constraints. Different handling methods can be applied for different types of constraints.

(1) *Feasible Region Strategy.* This method works for some simple constraints. The value of the decision variable is still within the feasible region after crossover and mutation by using appropriate encoding and decoding methods. For some complex constraints, it is difficult to find a way to make the individual still in the feasible region after crossover and

mutation, so the feasible region strategy is limited in use and is usually applied to bound constraints.

(2) *Repairment Strategy*. The method examines the crossed and mutated individuals one by one and repairs those not in the feasible region by converting them to the feasible region. Finding a good and effective repair algorithm is the key to this strategy.

(3) *Rejection Strategy*. This strategy only accepts those individuals that are in the feasible region and uses these individuals as the parent population for crossover and mutation to generate the child population. If the child is not in the feasible region after crossover and mutation, it will be rejected. The parents are crossed and mutated until all the children are in the feasible region.

(4) *Penalty Function Strategy*. This method's idea is adding a penalty value to the fitness of the individuals that are not in the feasible region [47]. It can increase the fitness value of the individuals so that the probability of inheriting into the next generation population is greatly reduced.

The model established in this paper has both linear and nonlinear constraints; different strategies are used for different constraints. The penalty function method is used for the nonlinear constraints as

$$f_n(X_j) = \begin{cases} f_n(X_j) & X_j \in U \\ f_n(X_j) + P(X) & X_j \notin U \end{cases}, \quad (22)$$

where $f_n(\cdot)$ stands for the n th objective function, $n = 1 \dots N$; X_j stands for the j th vector consisting of decision variables; and U is the feasible region.

$$P(X) = \max(0, C), \quad (23)$$

where C is a sufficiently large number.

A repairment strategy is used for linear constraints and boundary constraints. The individuals that do not satisfy the linear and bound constraints are transformed into the feasible region by solving the following model [48]:

$$\min f(x) = 0.5\|X - \tilde{X}\|^2, \quad (24)$$

$$AX \leq B, \quad (25)$$

$$L \leq X \leq U, \quad (26)$$

where (25) is the linear constraint, (26) is the bound constraint, X is the decision vector, $\tilde{X}$ is the solution vector that does not satisfy the constraints after mutation and crossover, and A , B , L , and U are the corresponding constant matrices or constant vectors.

3.3. Determining the Value Interval of Each Decision Variable.

Using the genetic algorithm designed in Section 3.2, the coordination model established in this paper can be solved, and the Pareto front is obtained, which is a set of solutions. For the authorities, some specific Pareto solution is not their

focus because it is difficult to ask each transportation enterprise to determine the attributes of transportation mode exactly according to a certain solution. Besides, the attributes of transportation modes are somewhat random, especially for road traffic, and it is difficult to set them at a specific value. Therefore, it is not very appropriate to choose a specific Pareto solution as the basis for the coordination of various transportation modes in the comprehensive corridor. If we can let transportation enterprises set the attributes of transportation modes in a certain interval instead of a real number, then various attributes of each transportation mode take values in its interval. So, we can ensure that the values of all objective functions fall near the Pareto front, which ensures the relative optimum of coordination results and has strong operability.

Assuming that the genetic algorithm obtains m individuals after the calculation is complete, the solution set X composed of n decision variables is

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1N} \\ x_{21} & x_{22} & \cdots & x_{2N} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m1} & \cdots & x_{mN} \end{bmatrix}. \quad (27)$$

The value interval of the i th decision variable x_i is

$$[x_i^l, x_i^u] = [\min(X_i), \max(X_i)], \quad (28)$$

where x_i^l is the lower bound of value interval of the i th decision variable x_i and x_i^u is the upper bound of value interval of the i th decision variable x_i .

$$X_i = [x_{1i}, x_{2i}, \dots, x_{mi}]. \quad (29)$$

4. Examples

4.1. Data. There are three transportation modes between two central cities A and B in a comprehensive transportation corridor, including expressway, highway, and intercity railway. Similar transportation corridors serving different cities within urban clusters are common in China. Taking this type of transportation corridors as an example has practical significance. All the three travel modes will provide passenger transportation services between cities A and B in the comprehensive transportation corridor. Obviously, the service objects of the three modes of transportation are the same, and there will inevitably be competition among them. In order to prevent the unhealthy competition from destroying the fairness of the transport market, the transport authorities need to supervise them and guide them to carry out legal transport business. Different modes of transportation have different service attributes; for example, fares and travel time are different. Passengers choose the travel mode according to the attributes of different modes of transportation. The transport authorities can control the service attributes of different transportation modes within a certain range so that each mode of transportation can obtain reasonable profits and maintain the continuity of transportation services.

In Section 2.2.3, five explanatory variables can be chosen as decision variables. But, considering the actual situation of comprehensive transportation development in China, safety is not included in the choice of transportation mode. Because the Chinese government attaches great importance to transportation safety and the overall safety of all transportation modes is very high, the public basically ignores safety when choosing transportation mode to travel. At the same time, the comfort of each mode of transportation is difficult to change, so transportation enterprises temporarily do not consider changing the comfort to adjust the attraction to passengers. Based on the above analysis, economy, rapidity, and convenience can be incorporated into the decision variables. At the same time, considering that there are three modes of transportation, there are a total of 9 decision variables. For ease of understanding, Table 1 explains the mathematical symbols used in the model.

The supply capacity, ideal capacity utilization coefficients of the three transportation modes, and the bounds of the decision variables for each transportation mode are shown in Table 2.

The coefficients of the multinomial logit model are shown in Table 3, after using SP and RP survey data to calibrate the parameters of the three modes of transportation (this example intend to show how to use the model established in this paper to make the transportation modes more coordinated, assuming that all parameters of the logit model have been calibrated and passed the test), and the total passenger demand between two cities in the transportation corridor is $R = 40,000/\text{day}$.

4.2. Model Solving. The multiobjective genetic algorithm is used to solve the model, and the solving process is shown in Section 3.2. The model is solved by computer programming. The population size is set to 200, crossover probability is set to 0.8, mutation probability is set to 0.05, and the maximum number of iterations is set to 200. The calculation results are shown in Table 4 (because there are many Pareto optimal solutions, the first ten are selected out for display).

As shown in Figure 4, the algorithm stops iterating when the population reaches about 100 generations. The average distance of Pareto optimal solutions is 12 when the algorithm stops. It reflects the diversity of the genetic algorithm; that is, not all solutions converge to one point. Because if all solutions converge to one point, the average distance of all Pareto solutions is 0. It reflects the fact that the multi-objective optimization problem has multiple different Pareto optimal solutions.

Figures 5 and 6 show the distribution of the objective function. These figures can visually show the values of the objective functions on the Pareto front. Figure 7 shows the distribution of all solutions on the Pareto front after grouping them according to their objective values. Figure 8 shows the contradictory relationship between different objective functions.

4.3. Analysis of the Results. Based on the above results, the following conclusions can be obtained.

Figure 4 shows that decision variables do not converge to a single point after the algorithm stops iterating, which indicates that the decision variables take different values. The designed multiobjective genetic algorithm can obtain multiple Pareto optimal solutions at one time. It is not available by the scalarization method, which converts the multi-objective optimization into a single-objective optimization and then solves it.

From Figures 5–7, it can be seen that the values of objective function 1 (intercity railways) are overwhelmingly concentrated around 0; its value range of the objective function is in the interval $[0, 0.0045]$. The value range of objective function 2 (expressway) is in the interval $[0, 0.0405]$. The value range of objective function 3 (highway) is in the interval $[0, 0.0225]$. It shows that the decision variables have a negligible effect on objective function 1 (intercity railways), the larger effect on objective function 3 (highway), and the largest effect on objective function 2 (expressways).

Figure 8 shows the contradictory relationship between different objective functions. Figure 8(a) to Figure 8(c) are pairwise comparison charts of the objective function values of the three modes of transportation. Figure 8(d) compares the objective function values of the three modes of transportation together; the points in the subgraph are formed by the objective function values of the three modes of transportation. Figure 8(a) shows the contradictory relationship between the intercity railway and the expressway; it is clear that when the objective function value of intercity railway is close to the optimum, the objective function value of expressways is far from the optimum, which reflects the fact that there is fierce competition between the intercity railway and the expressway. Figure 8(b) shows the contradictory relationship between the intercity railway and the highway. From the points composed of the values of the two objectives with the intercity railway as the abscissa, it can be seen that, in most cases, no matter how the value of the objective function of the highway changes, the values of the objective function of the intercity railway are mostly concentrated near 0, which indicates that highway does not pose a great threat to the intercity railway in the competition. Figure 8(c) shows the contradictory relationship between the expressway and the highway. From the points composed of the values of their two objectives with the expressway as the abscissa, it can be seen that the distribution of points is more even. It indicates that there is competition between expressway and highway but not much.

4.4. Operation Suggestions

- (1) According to (28), the value intervals of the attributes associated with different transportation modes are shown in Table 5, after the Pareto solutions are obtained using the multiobjective genetic algorithm.

The transportation enterprises adjust their attribute values of the transportation mode according to the value range specified in the above table. Although it cannot guarantee the result is Pareto optimal, it is close to the Pareto optimal. The authorities can

TABLE 1: Mathematical symbols used in the model.

Symbol	Meaning
x_{ni}	Stands for the i th decision variable for the n th mode of transportation
N	Stands for the subscript of the n th mode of transportation, $n = 1$ stands for the intercity railway, $n = 2$ stands for the expressway, $n = 3$ stands for the highway
I	Stands for the subscript of the i th decision variable, $i = 1$ stands for the fares of the intercity transportation modes, $i = 2$ stands for spent time on urban traffic for intercity transportation mode, $i = 3$ stands for the travel time of the intercity transportation modes
L_{ni}	Stands for the lower bound of the decision variable x_{ni}
U_{ni}	Stands for the upper bound of the decision variable x_{ni}
θ_{ni}	Stands for the coefficients of the decision variable x_{ni}
S_n	Stands for the supply capacity of the n th intercity transportation mode
A_n	Stands for the ideal capacity utilization coefficient of the n th transportation mode

TABLE 2: Raw data used in the model.

n	Transportation mode	L_{n1}	U_{n1}	L_{n2}	U_{n2}	L_{n3}	U_{n3}	A_n	S_n
1	Intercity railway ($n = 1$)	30	60	70	120	30	60	0.8	32000
2	Expressway ($n = 2$)	35	65	20	50	120	150	0.75	10000
3	Highway ($n = 3$)	20	40	20	50	150	200	0.85	6000

TABLE 3: Coefficients of the multinomial logit model.

n	Transportation mode	θ_{n0}	θ_{n1}	θ_{n2}	θ_{n3}
1	Intercity railway ($n = 1$)	0.18	-0.007	-0.006	-0.005
2	Expressway ($n = 2$)	0.08	-0.018	-0.017	-0.0026
3	Highway ($n = 3$)	0.13	-0.005	-0.011	-0.013

TABLE 4: Pareto optimal solutions.

Objective function						Decision variables					
1	2	3	x_{11} (¥)	x_{12} (min)	x_{13} (min)	x_{21} (¥)	x_{22} (min)	x_{23} (min)	x_{31} (¥)	x_{32} (min)	x_{33} (min)
0.0000	0.0405	0.0012	46.82	107.73	44.64	60.97	37.25	137.18	24.20	31.34	179.80
0.0045	0.0000	0.0032	39.05	93.76	40.44	59.19	48.74	135.39	23.26	24.67	181.74
0.0000	0.0325	0.0000	46.61	102.34	45.54	60.83	38.02	130.40	24.41	30.93	174.49
0.0000	0.0399	0.0011	46.91	107.86	44.64	61.08	37.30	137.22	24.20	31.21	179.80
0.0029	0.0001	0.0000	44.26	91.95	45.20	60.99	48.18	134.23	23.72	26.72	177.60
0.0004	0.0010	0.0217	45.43	95.45	42.55	62.04	43.73	135.66	26.73	32.47	156.88
0.0000	0.0349	0.0000	46.90	107.12	45.57	61.16	37.90	137.02	24.68	31.21	176.37

require transport enterprises to use the above table to adjust their operating conditions and promote the coordinated development of all transportation modes. It can ensure the relative optimality of different transportation modes and, at the same time, has strong operability. In other words, by requiring each transportation enterprise to limit the value of the attributes of each transportation mode to the range in the above table, the transportation corridor can achieve a reasonable distribution of passenger flow among the three transportation modes, which can promote the healthy development of all transportation modes.

- (2) From the analysis in the previous section, it can be seen that the objective function values of intercity railway have the smallest variation range whose most values are near 0, as shown in Figure 7. It indicates that the changes in decision variables have a limited impact

on it. The reason is that the intercity railway has the most attraction; no matter how the decision variables change, it maintains a high sharing rate. Table 5 shows that the highway's value range of the fare is much smaller than that of the expressway, and the value range of the travel time of intercity railway is much smaller than that of the expressway. The objective function values of the expressway have the largest interval, and they are almost evenly distributed. They indicate that the expressway is sensitive to changes of the decision variables and faces strong competition with the intercity railway in terms of travel time and with the highways in terms of fares. Administrative departments of transportation enterprises should pay more attention to this in actual operation, and if the expressway share rate decreases significantly, they should investigate whether it is caused by unfair competition from other transportation modes.

FIGURE 4: The diversity of genetic algorithm.

FIGURE 5: Distribution Pareto solutions (from 1 to 100).

FIGURE 6: Distribution Pareto solutions (from 101 to 200).

FIGURE 7: Distribution of grouping of objective function value in Pareto front.

FIGURE 8: Pareto front of transportation modes.

TABLE 5: The value intervals of attributes associated with different transportation modes.

n	Transportation mode	p_i	t_i	T_i
1	Intercity railway	[34, 40]	[85, 108]	[32, 43]
2	Expressway	[46, 61]	[42, 47]	[121, 141]
3	Highway	[20, 29]	[19, 34]	[150, 162]

- (3) From Table 5, we can see that the highway's value range of decision variables is close to the lower bound in its feasible region, which means low fare, less spent time in urban traffic, and shorter spent time during the intercity trip to achieve Pareto optimal. It shows that highway has the weakest passenger competitiveness in the transportation corridor. Considering that road transport has many stations and a network of well-connected lines, it is possible to focus on developing transport markets that are not served by other transportation modes so that it can find new opportunities for more passengers, given that they are less competitive with other transportation modes.

5. Conclusions

The comprehensive transportation corridor has several passenger transportation modes in it, and there may be fierce competition among different passenger transportation modes. Healthy competition is conducive to transportation enterprises adopting advanced technology, reducing transportation costs, and improving service quality. However, unhealthy competition will lead transportation enterprises to suppress their peers through improper means and finally form a monopoly. To avoid the unhealthy competition among different passenger transportation modes, which may disturb the normal order of the transportation market, a coordination model for the passenger transportation modes in the comprehensive transportation corridor is established based on the multinomial logit model. The main contributions of this paper are as follows:

- (1) Put forward the idea of establishing the coordination model of passenger transportation modes in the comprehensive transportation corridor

The coordination model's idea is to make the passenger flow in the transportation corridor reasonably distributed among various transportation modes so that each transportation enterprise can obtain a certain profit to operate rather than go bankrupt.

- (2) Establish a mathematical coordination model for passenger transportation modes

First, the paper introduces the multinomial logit model into the paper as the basis for establishing the coordination model. Second, the paper defines the ideal capacity utilization coefficient and the actual capacity utilization coefficient. Finally, a coordination model is established. The model takes the

minimum difference between the ideal capacity utilization coefficient and the actual capacity utilization coefficient of different transportation modes as the objective function, takes the attributes of different transportation modes as the decision variables, and takes the supply capacity of different transportation modes and the reasonable value range of decision variables as the constraints.

- (3) Design the genetic algorithm to solve the model

The established model is a multiobjective, nonlinear optimization model. This paper analyzes the disadvantages of the common methods for solving multiobjective optimization and proposes the advantages of using the genetic algorithm to solve the model. Then, the genetic algorithm is designed to solve the model from four aspects: selection, crossover, mutation, and handling of the constraints.

- (4) Use interval number instead of a single actual number as the solution, which is easy to adjust the attributes of the transportation modes for the transportation enterprises. If the values of decision variables are specific real numbers rather than intervals, it is very difficult for all transportation enterprises to adjust the attributes of transportation modes in practical applications. Based on multiple Pareto optimal solutions, the values of each decision variable are aggregated, and the value range of each decision variable is obtained. As long as the attribute values of all transportation modes are in their corresponding value interval, the approximate optimization among different transportation modes can be achieved.

However, it should be noted that this research also has its limitations and should be improved in future research work. For example, in China, the transportation management department has strong power over transportation enterprises. It is easy to make each transportation enterprise adjust its attributes of transportation mode to meet a specified requirement, which provides a guarantee for the practical application of the model established in this paper. The situation may not be the same out of China, where management power over transportation enterprises is weak, so it is difficult to make transportation enterprises adjust their attributes of transportation mode by the authorities' requirement. If so, this model is not very practical.

The greatest difficulty in solving nonlinear optimization problems is that the solutions obtained may be locally optimal rather than globally optimal. Although the genetic algorithm has some global search capability, it also cannot guarantee that the solutions obtained must be globally optimal. Therefore, the next step is to study how to improve the global search ability of the algorithm based on this paper.

Data Availability

The datasets used in the present study are available from the author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of the paper.

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