ISSN 2959-6130

Optimization Model of Emergency Evacuation Network Based on Genetic Algorithm

Haoning Yin

No. 2 High School of East China Normal University
555 Chenhui Road, Pudong New District, Shanghai, China
yinhaoning@hsefz.cn

Abstract

Aggregation and dispersion are the normal states. In economic production and social life, the evacuation of people and materials deserves extensive attention. From the perspective of mathematics and economics, arranging a thoughtful evacuation is essential for the best balance between personal satisfaction and cost. In this paper, evacuation is deeply studied by a genetic algorithm; the balance, cost, and willingness (satisfaction) priority models, which consider both satisfaction and cost, are established.

In this paper, based on the field investigation and questionnaire survey conducted by Oriental Sports Center, overall satisfaction is inferred by the satisfaction of each person in the tested sample, and the time cost from the evacuation point to different reception points is inferred through actual investigation. Based on these data, a balance model is established, and the calculation is performed. The ratio of the total willingness value of the evacuated individuals to the total cost is taken as the function of the optimization objective. When the optimization objective function is complex, the genetic algorithm is used to search for the optimal solution by simulating the process of natural evolution. At the same time, the cost priority and willingness priority models are established to compare the advantages and disadvantages of different evacuation schemes and their applicable situations.

The evacuation of Oriental Sports Center is studied using a genetic algorithm. The objective function value of equilibrium model optimization is 0.2155 (optimal solution), significantly different from willingness priority model optimization (0.0300). After calculating the optimization objective function value and cost value under the conditions of cost priority and willingness priority, a "People-oriented and cost-balanced" suggestion is put forward for a large crowd evacuation scheme.

Keywords: emergency evacuation, genetic algorithm, optimization model

1. Introduction

Nowadays, all kinds of emergencies often occur in social life at home and abroad, including natural disasters, such as earthquakes, volcanic eruptions, mountain fires, geological disasters, sandstorms, floods, accidents, including serial car accidents, explosions, fires, harmful gas leaks, and social security incidents, including concerts, sports meetings, and evacuation of large gatherings. From the people-oriented point of view, when these incidents occur, it is very necessary to carry out an efficient evacuation, tries to reduce the evacuation cost and transfer as many people and materials as possible to several destinations, which is an important way to protect people's lives, health, and safety. This study focuses on the optimization of the above emergency evacuation network.

Natural and man-made disasters will greatly harm people's lives and property. According to the data of the National Emergency Management Department of China, natural disasters in the first half of 2023 caused direct economic losses of CNY 38.23 billion[1]. The most obvious reasons for this economic loss lie in two aspects: the incident's severity and the secondary disaster's severity. For the former, the existing technology is often difficult to control. For the latter, if there is no reasonable evacuation strategy, proper evacuation management, scientific evacuation path planning, and correct evacuation point selection, it will cause certain economic losses, such as improper evacuation point selection, which will lead to its inability to accept evacuated people, resulting in higher evacuation costs and lower efficiency; Unscientific evacuation route planning reduces evacuation efficiency, causes congestion and increases transportation cost. The latter part can be analyzed and optimized to reduce the loss.

From the perspective of economics, emergency evacuation is essentially a resource allocation, including road resources, transportation resources, human resources, capital resources, and so on. This paper focuses on the optimization of emergency evacuation networks in order to improve emergency handling capacity, reduce evacuation costs, improve evacuation reliability, and enhance people's satisfaction.

2. Literature Review

The optimization of an emergency evacuation network is highly similar to the planning of a transportation network. The core of transportation network planning is to achieve the optimal index of some system performance of this road network under constraints (such as investment constraints, natural environment constraints, etc.). Many scholars at home and abroad have made profound explorations and studies on this issue.

Liu Guangcai [2] et al., from the perspective of a comprehensive transportation system and passenger combined transport, studied the transportation network characterized by road-general aviation short-distance combined transport. Build a two-tier planning model so that the inter-regional road and shipping intermodal network scheme can be effectively planned to solve the problem of tourists traveling in areas with tight transportation resources. This model gives passengers a better travel experience and provides a basis for the future development of public transportation between regions. At the same time, the combined transport network from highway to short-distance transport planned in other areas can also refer to this model. Xu Weiwei [3] Among the various influences of various subway stations on evacuation, we choose to study the evacuation without fire, exclude the influencing factors of fire on evacuation, and count the time it takes for people to be completely evacuated. This study analyzes the influence of the platform layout of subway stations on the evacuation effect and compares the locations where different types of platforms are prone to congestion. In addition, Xu Weiwei also compared the influence of the number of fire spots on evacuation time and casualties and confirmed the location of the fire spots with the least influence and the greatest effect. According to the reasons for congestion during the evacuation, it is found that the wrong exit is easy to select when the fire source is located, but the flame diffusion speed is estimated incorrectly, which leads to casualties. Zhang Anfeng et al. analyzed the characteristics of traffic information in their papers and expounded on the influence of different levels of traffic information on the behavior of evacuees. By considering the psychological behavior of evacuees, this paper puts forward the concept of risk perception behavior and points out the inapplicability of the traditional Logit model. The Logit model is improved in this paper, and its application scope is expanded. A fuzzy reasoning system is also established to simulate the risk perception behavior of evacuees to simulate the process of route cost evaluation by evacuees under the influence of traffic information. Zhang Chuncui [5] Based on the analysis of the composition and functional characteristics of BRT: Bus Rapid Transit) network, this paper summarizes some advantages of the BRT system compared with the conventional bus system, discusses the network planning process and route setting principle of the BRT system, establishes an optimization model to minimize passenger travel time and maximize the direct passenger flow, and determines the feasible solution set. By analyzing the basic model of particle swarm optimization, this paper combines particle swarm optimization with a genetic algorithm to form Hybrid Particle Swarm Optimization (HPSO), which optimizes the direction of the BRT line and the stops along it.

Similarly, foreign scholars have also studied this hot issue. Mike Hewitt and Fabien Lehuédé [6] put forward the Scheduled Service Network Design Problem (SSNDP) formula. This formula specifies the decision of the physical terminal network level. The formula is based on explicit enumeration merging to confirm the requirement for shipment synchronization. In this paper, effective inequalities are proposed to further strengthen the rationality of the formula. At the same time, a pruning mechanism is proposed to identify the integration that does not need modeling and reduce the symmetry in the model. Changchun Liu [7] et al. solved the Service Network Design (SND) by introducing the Almost Robust Optimization (ARO) model to control the violated constraints and obtained a solution that is not too conservative. In addition, a robust index is introduced to investigate and weigh the concept between objective value and punishment violation. An effective partition decomposition method is proposed to solve the model, proving that the proposed method can converge to a limited number of iterations. Numerical experiments are carried out to show the efficiency of the proposed decomposition method. This paper also summarizes some uncertainty-based management opinions, unit sensitivity analysis, outsourcing cost, and vehicle capacity.

Although the above research has its emphasis, it also has its places worthy of further exploration. For example, the team led by Liu Guangcai focused on the intermodal transportation network of highway-general aviation short-distance transportation. Still, it did not consider the transportation function of bicycles in various scenic spots. Xu Weiwei's research focuses on the fire factor and takes the set individual as the shortest escape path according to the geometric rules, but does not consider the factors of smoke, high temperature, visibility, individual behavior, and the number of deaths caused by the congestion. The paper by Zhang Chuncui and others optimizes the solution set of the route direction and stops along the way. However, it still needs to verify other links of network optimization. At the same time, it does not consider the complex factors, such as the delay of waiting for the bus, the delay of transfer and the delay caused by the intersection. Mike Hewitt and Fabien Lehuédé focused on the mode of combined delivery in their papers and proposed a new SSNDP formulaP. However, the formula proposed in this paper is not easy to adapt to the constraints of the specific time. Changchun Liu et al. focused on the transportation of containers in the paper, but because the vehicle usage is measured based on an aggregated physical network, the proposed formula based on integration is not easy to adapt to the constraints of the specific time.

In the research of emergency evacuation, the models are often complex, with many parameters and a large amount of data. When solving a complex combinatorial optimization problem, genetic algorithms can usually get better optimization results faster than some conventional optimization algorithms. A genetic Algorithm (GA) is designed and put forward according to the law of biological evolution in nature ("Adaptation in Natural and Artificial Systems," by John Henry Holland [8]), which is a computational model to simulate the biological evolution process of natural selection and genetic mechanism in Darwin's biological evolution theory. Genetic Algorithm is a method of searching for the optimal solution by simulating the natural evolution process. The algorithm transforms the problem-solving process into a process similar to the crossover and mutation of chromosome genes in biological evolution by mathematical means and computer simulation operation. Genetic algorithms have been widely used in combinatorial optimization [9], machine learning [10], signal processing [11], adaptive control [12], and artificial life [13].

3. Research Ideas and Schemes

The innovation of this paper is that genetic algorithm and two-dimensional simplification are used to optimize the solution of complex evacuation deployment in reality. In the practical application of the model, this study uses real data and, through the questionnaire survey method, draws random samples from the real huge sample, investigates the evacuation willingness value of the sampled individuals, and simulates the distribution of the overall willingness value.

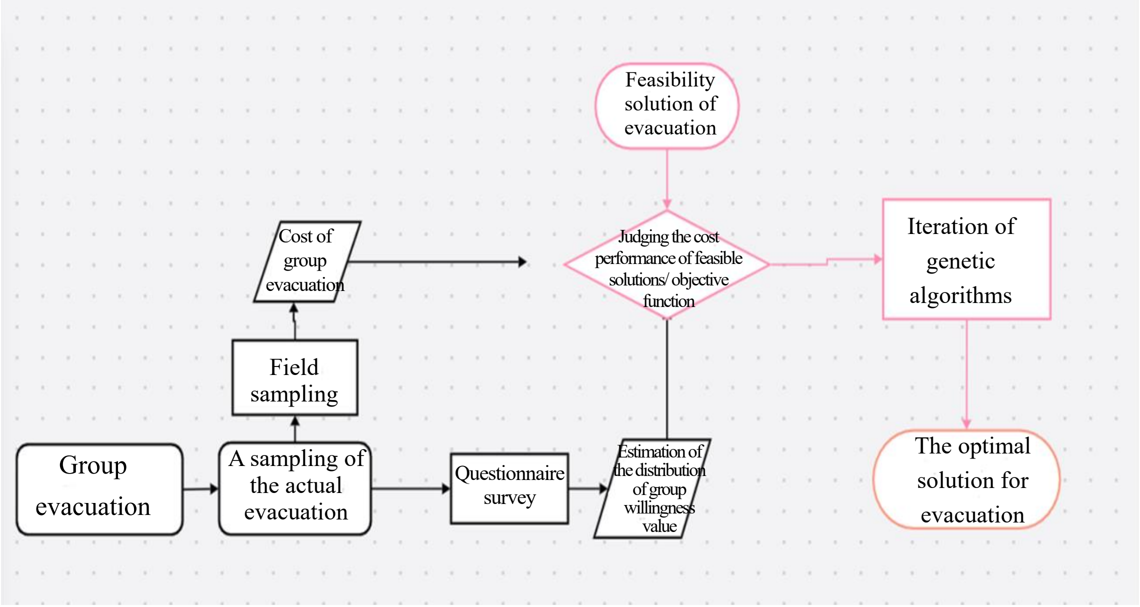

Figure 1: Solution Framework of Evacuation Problem Based on Genetic Algorithm

Based on the above data, this paper uses R language to calculate the genetic algorithm and randomly generates 100 simplified solutions in a simplified way within the model. Then, after selection, crossover, and mutation, a new and better solution set is generated and enters the next iteration. After 10,000 iterations, a relatively stable optimal solution and the optimal value of the solution are obtained, as shown in Figure 1.

4 Establishment of Model

4.1 Hypothesis of the Model

To establish the evacuation model, the following six hypotheses are specially given:

Hypothesis 1: There are evacuation points K (A_1, A_2, ... ……A_k) and reception points t (B_1, B_2 ... B_t); the people or materials at evacuation point K must be transferred to reception points t. (This model focuses on multi-point to multi-point evacuation, and in the subsequent case analysis of this paper, single-point to multi-point evacuation is adopted);

Hypothesis 2: There is a route between any two points, and the unit transportation cost is C_{AiBj} (one unit for each person or one kilogram of materials). Cost can be capital, time, and other elements, or it can also be a combination of these elements.);

Hypothesis 3: The collection of personnel and materials that need to be transported out of the evacuation point A_i is {ai_1, ai_2, ……, ai_{mi}};

Hypothesis 4: The maximum carrying capacity of the reception point B_j is b_j, and the bearing capacity of the reception point for continuously transporting people or materials to the outside can be divided into two categories: one is that b_j is a fixed value, and the other is that b_j is a function b(t) about time t, for example, b(t)=b0+ct, b0 is the inherent bearing capacity, and C is the increment per unit time (for example, subway station b0 refers to the maximum number of people that a subway station can carry. C refers to the number of people transported by each subway. And T refers to the time interval of each subway.);

Hypothesis 5: In reality, everyone has different preferences for being evacuated to different locations, and this preference is characterized by the value of Transfer Intention Value (referred to as Transfer Intention Value). In this paper, customer satisfaction represents evacuation benefits, while customer satisfaction is characterized by Transfer Intention Value, as shown in Table 1.

Table 1: Customer Satisfaction Based on Transfer Intention Value

	B_1	B_2	B_3	B_4	...	B_{t-2}	B_{t-1}	B_t
$a1_1$	X_{a11B1}	X_{a11B2}	X_{a11B3}	X_{a11B4}		$X_{a11Bt-2}$	$X_{a11Bt-1}$	X_{a11Bt}
$a1_2$	X_{a12B1}							
...								
$a1_{m1}$	X_{a1m1B1}							
$a2_1$	X_{a21B1}							
$a2_2$	X_{a22B1}							
...								
$a2_{m2}$	X_{a2m2B1}							
...								
ak_1	X_{ak1B1}							
ak_2	X_{ak2B1}							
...								
ak_{mk}	X_{akmkB1}							

For example, X_{akmkBt} is ak_{mk}'s willingness to go to point B_t. Since the sum of the willingness of the same person to go to each reception point is 1, the sum of each line is 1, so there are:

$X_{a11B1}+X_{a11B2}+\ldots\ldots+X_{a11Bt}=1$

$X_{a12B1}+X_{a12B2}+\ldots\ldots+X_{a12Bt}=1$

……

$X_{akmkB1}+X_{akmkB2}+\ldots\ldots+X_{akmkBt}=1$

Table 2 shows the sum of customers' total willingness.

Table 2: Sum of total customer Willingness

	B_1	B_2	B_3	B_4	...	B_{t-2}	B_{t-1}	B_t
$a1_1$	Y_{a11B1}	Y_{a11B2}	Y_{a11B3}	Y_{a11B4}		$Y_{a11Bt-2}$	$Y_{a11Bt-1}$	Y_{a11Bt}
$a1_2$	Y_{a12B1}							
...								
$a1_{m1}$	Y_{a1m1B1}							
$a2_1$	Y_{a21B1}							

$a2_2$	Y_{a22B1}							
...								
$a2_{m2}$	Y_{a2m2B1}							
...								
ak_1	Y_{ak1B1}							
ak_2	Y_{ak2B1}							
...								
ak_{mk}	Y_{akmkB1}							

In which Y is a variable of 0-1, i.e.

$$Y=\begin{cases}0, \textit{When a is not transported to the corresponding point B}\\ 1\ \textit{When a is transported to the corresponding point B}\end{cases}$$

The above formula shows that the sum of the numbers in each row equals 1 (there is only one 1 in each row, and all others are 0).

Total willingness =Σ

Hypothesis 6: Use transportation cost to describe the evacuation cost, as shown in Table 3.

Table 3: Customer Transportation Costs

	B_1	B_2	B_3	B_4	...	B_{t-2}	B_{t-1}	B_t
$a1_1$	C_{a11B1}	C_{a11B2}	C_{a11B3}	C_{a11B4}		$C_{a11Bt-2}$	$C_{a11Bt-1}$	C_{a11Bt}
$a1_2$	C_{a12B1}							
...								
$a1_{m1}$	C_{a1m1B1}							
$a2_1$	C_{a21B1}							
$a2_2$	C_{a22B1}							
...								
$a2_{m2}$	C_{a2m2B1}							
...								
ak_1	C_{ak1B1}							
ak_2	C_{ak2B1}							
...								
ak_{mk}	C_{akmkB1}							

In this paper, the case study takes time as the cost, regardless of freight, and assumes that the cost is 1.1 times for every five minutes of waiting time.

Total cost= =ΣY* C

Hypothesis 7: The satisfaction of unit cost is an index to measure the advantages and disadvantages of evacuation schemes. We construct the optimization objective function

$$W=\frac{\text{Total willingness}}{\text{Total cost}}=\frac{\Sigma X*Y}{\Sigma Y*C}$$

. The higher the value of W, the higher the degree of satisfaction, and the scheme with the highest value of W is the optimal solution.

4.2 Description of Parameter

The parameters involved in this model are shown in Table 4.

Table 4: Symbols, definitions, and units of parameters involved

Parameter	Definition	Unit
k	Evacuation points	One point

t	Reception points	One point
C	Transportation costs	/five minutes
a	Transport personnel and materials	/
b	Bearing capacity	/ten people
X	Willingness	/

4.3 A Case Study (Equilibrium Model)

According to the field investigation of the venue, the Oriental Sports Center has an evacuation point and five reception points, including a parking lot for private cars (with 1,200 parking spaces), a bus stop, and three subway lines. The original carrying capacity of the subway station can be as high as 6,000 passengers, and three subway lines pass by. Each subway shift can carry about 1,920 people, of which two lines run every 5 minutes and the other runs every 10 minutes. The total number of evacuees in the venue is 13,000 (10,000 in the stands + 3,000 in the infield). Shown in Figure 2.

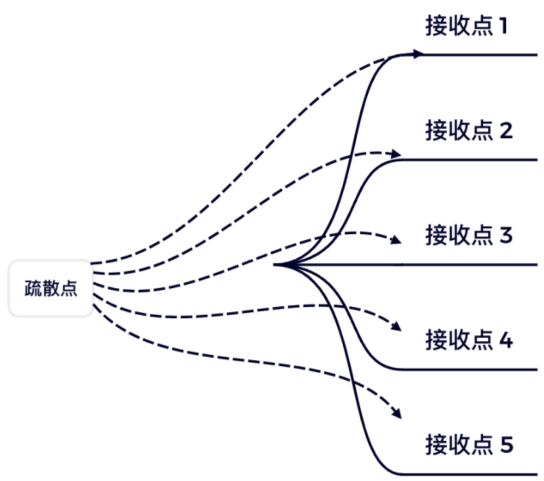

Figure 2: Evacuation map of Oriental Sports Center

This study found that among the people who participated in the questionnaire survey, about 29.23% agreed that private cars are the best way to be used for evacuation, 67.69% agreed that subways are the best way, and 3.08% agreed that buses are the best way.

Suppose individuals have three psychological scores of 0.1, 0.3, and 0.8 for different evacuation modes, corresponding to dislike, acceptable, and like, respectively.

According to the sample data to simulate the whole population, for private cars, it can be assumed that 29.23% of people choose the highest psychological score of 0.8 for private cars, while the rest divide their scores for subways and buses according to the proportion of willingness to choose the remaining two modes of transportation.

Make an analogy, in turn, where the psychological scores of each individual for different means of transportation are standardized to a total of 1, and the simulation of the overall willingness value is obtained. Shown in Figure 3.

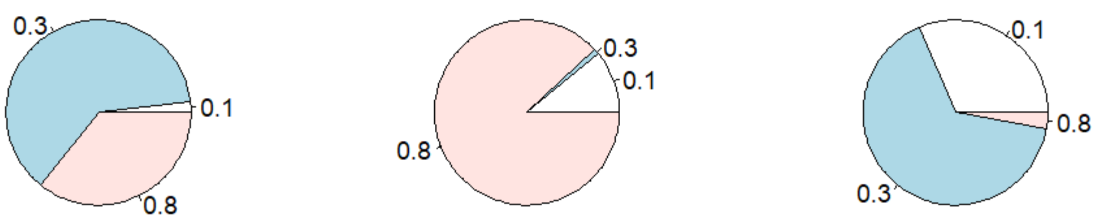

Figure 3: Scores of Different Evacuation Points

4.4 Solution Based on Genetic Algorithm

For the evacuation of people, this paper pays more attention to the ideal situation so that everyone can reach their destination while completing the evacuation at a lower cost, so everyone's whereabouts and wishes are considered.

This is a complex optimization to find the best solution to this issue and maximize the objective function W. This paper uses the genetic analysis method to iteratively score this, and Figure 4 shows the breakdown.

Evacuation point

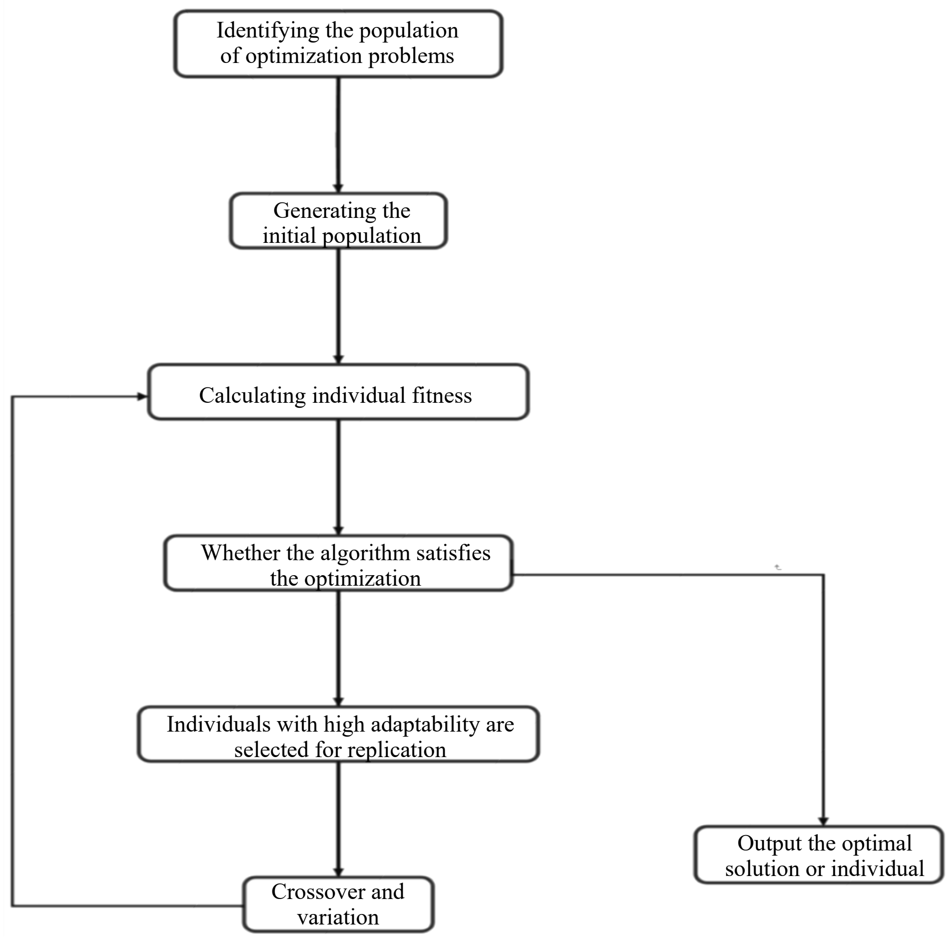

Figure 4: Calculation Flow of Genetic Algorithm

Step1:

In this paper, the destination of each individual is simplified as a factor variable, so the solution of a group evacuation can be calculated as an optimal solution in the form of a matrix, as shown in Table 5.

Table 5: Orientation Matrix

	V1	V2	V3	V4	V5	V6
1	0	0	1	0	0	0
2	3	0	0	0	0	0
3	0	0	0	0	0	1
4	0	0	0	0	2	0
5	0	0	0	0	2	0
6	0	3	0	0	0	0
7	3	0	0	0	0	0
8	0	0	0	0	1	0
9	3	0	0	0	0	0
10	0	0	0	0	0	2

The above table is a randomly generated solution in which the whereabouts of the top ten people are: 1 for private cars, 2 for subways, and 3 for buses. When the destination number appears in the first line, it represents the 0^{th}-minute trip, the second line represents the 5^{th}-minute trip, and so on.

The overall visualization of the solution is shown in Figure 5.

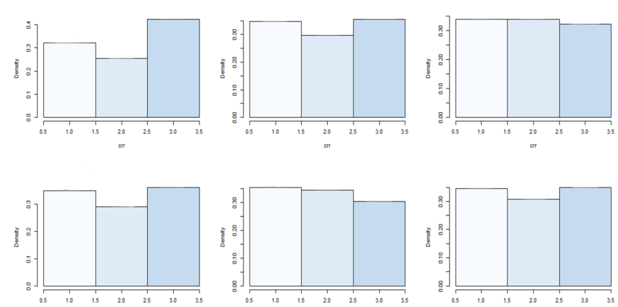

Figure 5: Evacuation in Unit Time

Suppose a person can take the next vehicle to evacuate within one hour, and the cost of waiting for ten minutes each time will be different. Otherwise, the solution may be unique. At the same time, the cost table is no longer in the previous form but in three dimensions, or it can be changed to every ten minutes, and the cost increases by

10%. At this time, the optimization objective function is W;

Step2:

According to this initialization idea, many feasible solutions are initialized. Considering the calculation's time complexity and the target value's convergence speed, the number of initialization solutions is set to 100.

Step3:

Set the fitness function as P because of the consideration of transportation cost and personal willingness. This algorithm should choose the individual with a large W value as the better solution, so we set the evaluation method of the individual, that is, the fitness function, as P = W.

To meet the requirements of the feasible region, we add a penalty P= (original P)-1 to the fitness of individuals who exceed the maximum carrying capacity of any evacuation point in a certain period to reduce the probability of occurrence and ensure that the selection of the optimal solution is not disturbed;

Step4:

Selection, crossover, and mutation operations are performed on the solutions to introduce diversified solutions and improve the quality of solutions. Crossover operation refers to generating a new solution by exchanging two factors, and mutation operation refers to changing someone's whereabouts in a selected solution with a certain probability. The mutation probability is set to 0.01 for randomness and stability of convergence. For 100 solutions in the population, according to the size of the optimization objective function, we give individuals with a large optimization objective function a greater probability of being the parent of the next-generation solution. After 50 operations were performed, 50 male parents were selected. Then, the whereabouts of someone in the solution of each father were exchanged with each other. Figure 6 shows a male parent on the left and right sides, and blue and red are two different sub-solutions produced after crossing. If we perform the same operation on 50 male parents, we will get 100 offspring.

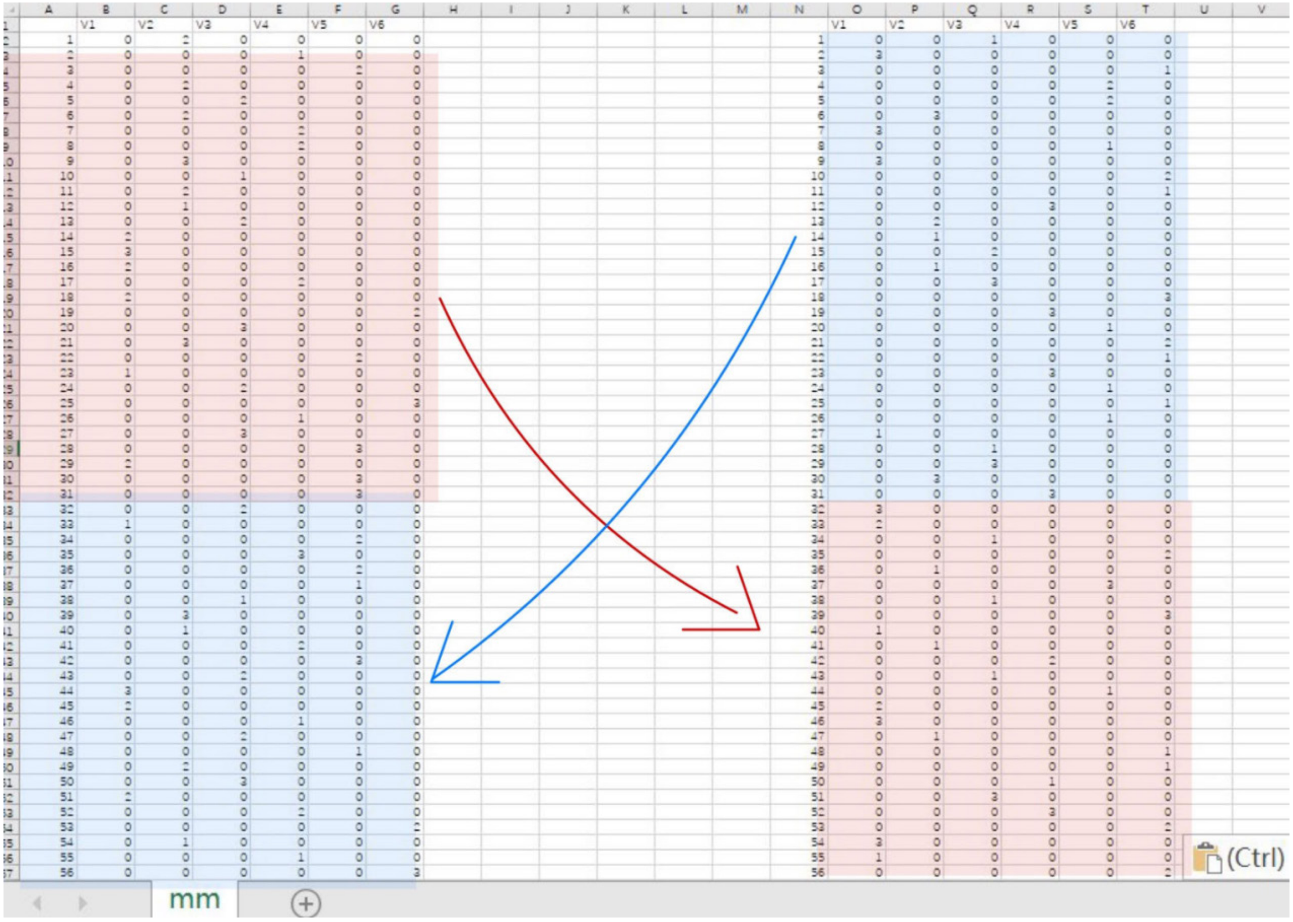

Figure 6: Crossed offspring

The mutation operation is performed on the newly generated sub-solution, and the mutation individuals in the offspring are selected according to the probability of 0.01. Then, the whereabouts and departure time of one person in the solution are completely randomly selected. That is to say, introduce a completely random new solution to the group with a very small probability.

Step5:

Select an appropriate number of iterations to iterate, pay attention to the maximum value generated by the new population generated by each iteration, that is, the optimal individual, observe whether the value converges, and stop the iteration when the value of the maximum fitness converges; If there is no convergence, iterate again.

4.5 Model Solving

Run the above algorithm 10,000 times and get the best result of the optimization objective function of each generation. You can get the convergence curve of the optimization objective function W, as shown in Figure 7.

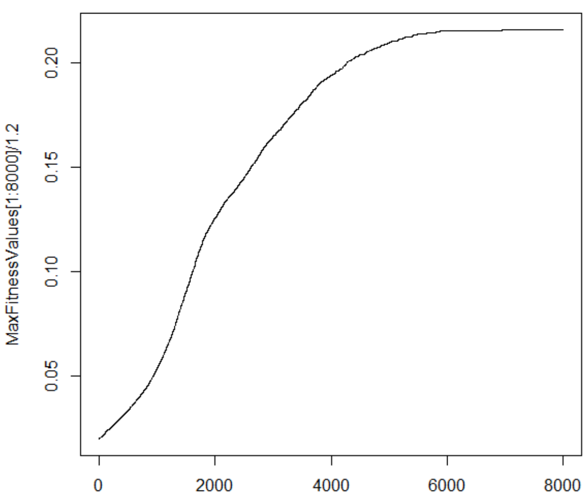

Figure 7: Convergence curve of optimization objective function W

As shown in the figure, the genetic algorithm can't produce better values when the optimal value of the optimization objective function converges after 6,000 iterations. From this, we can get the equilibrium equilibrium model's optimization objective function value W_1=0.2155.

5. Discussion on the Model

To investigate the solution ideas and optimization effects of evacuation for different models, this chapter establishes the cost and willingness priority models for discussion and comparison.

5.1 Cost Priority Model

Starting with minimizing the cost, this section establishes a mathematical model that does not consider personal will value. This model shows that each individual has no different satisfaction score for different evacuation destinations. Change the willingness value based on the equilibrium model analysis in section 4.3. At this time, the sum of total willingness is shown in Table 6.

Table 6: Sum of Total Customer Willingness

	B_1	B_2	B_3	B_4	...	B_{t-2}	B_{t-1}	B_t
a11	Y_{a11B1}	Y_{a11B2}	Y_{a11B3}	Y_{a11B4}		$Y_{a11Bt-2}$	$Y_{a11Bt-1}$	Y_{a11Bt}
a12	Y_{a12B1}							
...								
a1m1	Y_{a1m1B1}							

Y is a variable of 0-1

$$Y=\begin{cases}0, \textit{When a is not transported to the corresponding point B}\\ 1\ \textit{When a is transported to the corresponding point B}\end{cases}$$

The sum of each row equals 1; that is to say, there is only one 1 in each row, and everything else is 0.

This section considers that the optimization objective function $W=\frac{\text{Total willingness}}{\text{Total cost}}=\frac{\Sigma X*Y}{\Sigma Y*C}$

According to this idea, the solution in section 4 is used to solve the planning again, and the maximum optimization objective function value is "9.88748 * 10 - 5".

Currently, the total transportation cost C_2 is 10113.80, and the total willingness value X_2 is 8212.84. The objective function of the ratio of total willingness to total cost is used to estimate the value of the optimal solution obtained by this method; that is, the objective function value W_2=0.0596 of the cost priority model can be obtained.

5.2 Willingness Priority Model

In most evacuations, it is difficult to prearrange everyone's destination and evacuation time simultaneously; most individuals choose the evacuation destination according to their wishes in the order of first come, then adjust according to the actual situation. Therefore, this section discusses the model solution in the most real case for the above example. For each individual, let's label it in turn to represent the order in which individuals make choices in the evacuation. Individuals will choose the evacuation point with the largest score based on their wishes and the earliest time to leave. Where the capacity of evacuation points at that time is reduced by one, the number of people who need to be evacuated is reduced by one. However, when the evacuation point has been fully loaded at this time, according to the common sense of life, the individual will generally choose to wait until the next time point. If the individual cannot be evacuated until one hour later, he will choose to change the mode of transportation. If the above selection is carried out for each individual in the evacuation, it can be obtained that the total willingness X_3 is 1067.9, and the total transportation cost C_3 is 34500.07. Objective function value of willingness priority model W_3=0.0300.

6. Analysis and Comparison of Results

(1) The genetic algorithm model has the highest response to the objective function. In the case study of Oriental Sports Center, the maximum value of the optimized objective function value W_1 of the equilibrium model is 0.2155.
(2) Regardless of the willingness value, the cost priority model is established. The total cost is the smallest among the three models, and the objective function value W_2 is 0.0596, which is relatively low. The cost priority model can't consider both the willingness and cost values, so it is suitable for the transportation and distribution of materials.
(3) Given the real situation, everyone chooses the destination according to their own wishes; if the target destination capacity is fully loaded, they can wait a little or change the evacuation point and establish a willingness priority model. The objective function value W_3 is 0.0300, the lowest among the three models. At the same time, the total cost is three times higher than that of the cost priority model, and the total willingness value cannot reach a higher value.
(4) It is very important to optimize the reference balance model of the emergency evacuation plan and consider cost and willingness.

7. Evaluation of the Model

7.1 Conclusion

In this paper, from the perspective of economics, based on quantification, the objective function values of the equilibrium model, cost priority model, and willingness priority model are 0.2155, 0.0596, and 0.0300, respectively, and the equilibrium model is the best scheme for emergency evacuation.

7.2 Innovation

(1) Moderately simplifying the complex analysis can reduce the high computational complexity caused by the dynamic change of the weight of each factor, simplify the numerical change of each factor into a fractional form, and use the unitless relative value to represent the reasonable degree.
(2) Willingness and cost are taken into account simultaneously, and willingness and cost are two important aspects in the economic decision-making process, which are often a pair of contradictory entities and need to be balanced when making decisions.
(3) Given the differences in evacuation efficiency and cost of various modes of transportation, the feasibility of this study, as a case in the real world, is ensured by combining the actual survey data.

7.3 Shortcomings

(1) Error analysis. Given the large amount of data involved in real cases, if these data are directly substituted into the model, it will inevitably lead to too much calculation and too long calculation time. In this paper, ten people are turned into a unit of measurement. Meanwhile, five minutes are turned into a time measurement unit by rounding the traffic modes with slightly different intervals per shift. This may lead to a little deviation in the calculation results. The complexity of the algorithm of the current model makes it difficult to meet the calculation requirements of massive data in the real world, and the model and algorithm need to be further optimized in the future.
(2) The variability of the optimized objective function in the decision-making process is ignored, such as the dynamic change of the customer's transfer intention value due to the long waiting time in the queue.
(3) In evacuation, relatively important small probability events are ignored, such as trampling, reception point failure, and special groups with high transfer priority, such as the old, the young, the pregnant, and the disabled.

References:

[1] Department of Emergency Management: In the year's first half, natural disasters caused a total direct economic loss of CNY 38.23 billion [EB/OL]. http://www. jwview.com/jingwei/html/07-07/547952.shtml

[2] Liu Guangcai, Xu Yujie, Qi Fuqiang, et al., Ma Yinsong, Research on the Road-air Intermodal Tourism Transportation Network Based on Bilevel Programming, Science Technology and Engineering, 2023, 23(12): 5244-5250

[3] Xu Weiwei, Simulation Study on Emergency Evacuation in Subway Station under Sudden Disaster, Xinjiang: Xinjiang University, 2014:1-104

[4] Zhang Anfeng, Huang Xiao, Zhu Chunqiu, Urban Rail Transit Network Planning and Practicing in Shanghai Under the Background of High-Quality Development, Traffic & Transportation, 2023, Vol 39, No. 3: P30-35

[5] Zhang Chuncui, Research on the Planning Method of Rapid Public Transport Network Based on Hybrid Particle Swarm Optimization Algorithm, Shaanxi: Chang'an University, 2009:1-69