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Research on Approval and Global Optimal Path Planning Strategy for Bulk Transportation Based on Greedy Algorithm

Bidong Deng[1], Hua Wang[1,✉], Jingyi Jiang[1]

[1] *Guangxi Transportation Science and Technology Group Co., Ltd., Nanning, Guangxi, 530007, China*

ABSTRACT

Under the new situation of continuous and stable development of China's economy, large products have extremely high requirements on transportation safety due to their high price, complex transportation technical requirements, which determines that large products should be delivered to customers in the safest and most economical way, which poses a difficult problem for decision makers to choose the optimal path. In this paper, we constructed an intelligent approval framework for bulky transportation, made technical and economic analysis of transportation routes, and established a multi-objective optimization mathematical model for path selection of bulky transportation vehicles. A hybrid genetic algorithm incorporating greedy strategy is proposed to solve the problem, which strengthens the ability of the algorithm to jump out of the local extremes and selects the optimal chromosome in the final population as the resulting optimal solution. The results of the approval and optimal route planning for bulky transportation are verified by the method of example experimental analysis. The volume of bulky transportation increases with the increase of years until 2023, and the GDP, value added of tertiary industry, total population, and road mileage are 1015987.54, 553948.15, 140563, and 536.48, respectively. In the instances where the number of orders is 2000 or more, the transportation distance, the maximum number of service bundles of orders on the route, and the maximum service hours of vehicles the mean values are 50, 3.56, and 14.33, respectively. According to the constructed mathematical model, the optimal line for the bulky transportation scheme is 0→2→4→7→8, and the total transportation cost is 670,500,000 yuan, of which the transportation costs are 116,500,000 yuan, 320,000 yuan, 151,000,000 yuan, and 83,000,000 yuan, respectively.

Keywords: Intelligent Approval of Bulky Transportation, Multi-objective Mathematical Optimization Model, Greedy Strategy, Hybrid Genetic Algorithm, Optimal Route Planning

✉ Corresponding author.
E-mail address: wanghua15@mails.jlu.edu.cn (H. Wang).
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1. Introduction

With the expansion and development of global trade, the demand for the transportation of bulky goods is increasing. Bulky transportation refers to the transportation activities in various modes of transportation in which the size, weight or special attributes exceed the prescribed limits of the means of transportation and are carried out under specific conditions. For example, mechanical equipment, construction materials, automobiles and other bulky and heavy items are selected after multiple assessment and consideration of highway, railroad, water transport and other suitable vehicles, modes of transportation, roads [1-4]. Large cargo in size and weight exceeds the permissible loading size and weight of ordinary cargo vehicles, large transport vehicles on the road space and structure requirements than ordinary trucks, so that its road adaptability and access safety is worse, more likely to have safety problems [5-8]. Bulky transportation is also an important part of modern transportation industry, which is more and more favored by the state and society. Due to the different policies and infrastructures of transportation destinations, a series of preparations such as transportation permit approval, cargo inspection, transportation mode and route selection, loading, insurance, etc. are needed before the transportation of bulky cargoes to ensure that the cargoes can be safely transported to the destinations, especially the international cargoes [9-12]. Among them, approval and route selection are essential. Based on safety and management considerations, it is necessary to carry out compliance approval for the transportation of bulky goods, and the transportation route needs to be planned according to the characteristics of the transported objects, transportation distance, cargo delivery time, transportation risk, loading and unloading, and other factors [13-15]. The purpose is to ensure that large transport activities are carried out in compliance with relevant regulations and provisions, and to protect public safety and transportation efficiency. Although the state has also issued some regulations on bulky transportation, it does not give technical requirements and specifications to guide the relevant departments in their operations. Due to the lack of scientific calculation and evaluation methods, the accessibility of bulky transportation is mostly based on the staff's experience, the factors affecting the transportation are not well considered or insufficient, it is inevitable that the transportation program is unreasonable, and due to the lack of relevant technical specifications, the approval department has no basis for the work, and is mostly based on the subjective experience of the permit [16-17]. To sum up, the bulky transportation industry is developing rapidly, in order to transport bulky cargoes safely and punctually to the destination, it is necessary to carry out a complete and compliant approval process and optimal path planning before transportation.

In this paper, with reference to the application of intelligent routing scenarios for bulky transportation, the data information of bulky transportation is obtained through data collection and other functions. Considering the influencing factors of transportation technology and economic technology, the problem of approval of bulky transportation is transformed into a multi-objective optimization problem. Establish a multi-objective mathematical optimization model for large transport path selection, design a greedy algorithm, and adopt linear enumeration to list all loading schemes for large transport and represent them with a three-dimensional vector model. On the basis of the greedy algorithm to solve the passenger car loading scheme, the whole vehicle coding scheme is used to form a string of chromosomes, and the optimal route planning strategy is updated by applying the strategy of adaptive adjustment of genetic probability. By means of example verification, the characteristics and effects of the approval of bulky transportation are evaluated, the optimal route decision is realized, and the total transportation cost of bulky transportation is calculated.

2. Overview

With the general application of intelligent algorithms, the optimal planning strategy for large cargo transportation routes has been studied several times. In the 2017-2020 study, literature [18] designed a generalized algorithm for evaluating routes for the transportation of heavy and oversized cargoes considering different forms of transportation, routes, cargoes, and cargo loading and unloading technologies, which contributed to both transportation safety and transportation costs. Literature [19] designed a framework of decision support system, which is used to solve the optimal selection of means and routes for road transportation of large transported goods and using intelligent algorithms to allocate in the system vehicles suitable for transportation, as well as the possibility of predicting the consequences of transportation of a particular transport scheme. Literature [20] optimizes the procedure of Russian road transportations of restricted weight and dimensions of large cargoes, which contains the optimization of the procedure of issuing transport permits, which guarantees the quality of transportations and at the same time provides guaranteed legal barriers to their availability.

In the latest research for the period 2021-2024, literature [21] combined the entropy weight method, cloud model and TOPSIS method to construct a model of optimal route selection for the transportation of bulky cargoes, specifically by using the entropy weight method for the analysis of the weights of the main factors influencing the weights, optimizing the results of the weights by taking advantage of the stochasticity and discretization of the cloud model, and by comparing and evaluating them with the TOPSIS method in the context of multi-objective planning. Literature [22] planned the optimal route planning to reduce vibration fatigue in transportation of precision equipment by Dijkstra's shortest path algorithm with the assistance of probabilistic statistical methods, dynamic response modeling, and calculated the interrelationships between highway information and environmental influences on the equipment in order to discover low-risk routes. Literature [23] calculates the weights of historical critical factors based on consistent fuzzy preference relationships for the transportation of oversized cargoes from South Korea to Kazakhstan, and the weighted results are used for alternative route evaluation to obtain the optimal shipping route. Literature [24] created a round-trip multimodal transportation network and obtained the optimal routes for international shipping of folding frames with shipping routes, interchange, and mode of transportation factors under hybrid genetic and ant colony algorithms calculations. Most of the algorithms used in the above studies are based on the optimal solution under partial or whole scenarios at the same time, which is relatively time-consuming, and there may be factors interfering with the global solution, resulting in non-optimal routes. The greedy algorithm, through hierarchical processing, grades the inputs to arrange the order given by the metrics taking into account a certain measure such as transportation time, cost, etc. [25]. The algorithm obtains the optimal solution in a simpler and quicker process, which exactly solves the above problem.

3. Intelligent authorization and optimal route planning for large shipments

3.1. Intelligent Approval Application Design

3.1.1. Intelligent line selection, effective filtering of invalid line declarations. In the traditional network mode, the transportation enterprises to declare routes rely on manual experience, paper maps and familiarity with road conditions, resulting in a large number of declared routes can not pass the normal review, the need for multiple rounds of negotiations between the transport management department and transport enterprises to complete the “re-routing” operation, which not only increases the workload of the review and prolongs the examination and approval time. Time. Intelligent route selection system based on GIS map can effectively improve the success rate of transportation enterprises to declare routes. Figure 1 shows the application of intelligent route selection scenario for bulky transportation. Through the functions of geographic data acquisition, storage, management, analysis and visualization, the system obtains real-time key information such as road capacity, traffic flow, road bridge and tunnel conditions, carries out accurate measurement, optimization analysis and visual display of transportation routes, and accurately and efficiently provides route recommendation schemes by combining the situation of transport vehicles and goods as well as route preferences of the enterprises.

In addition, the intelligent routing system also predicts and evaluates various risks in the process of bulky transportation, analyzes the road construction blocking conditions and bridge carrying capacity, predicts the existence of safety hazards in the passage section, and formulates precautionary measures in advance.

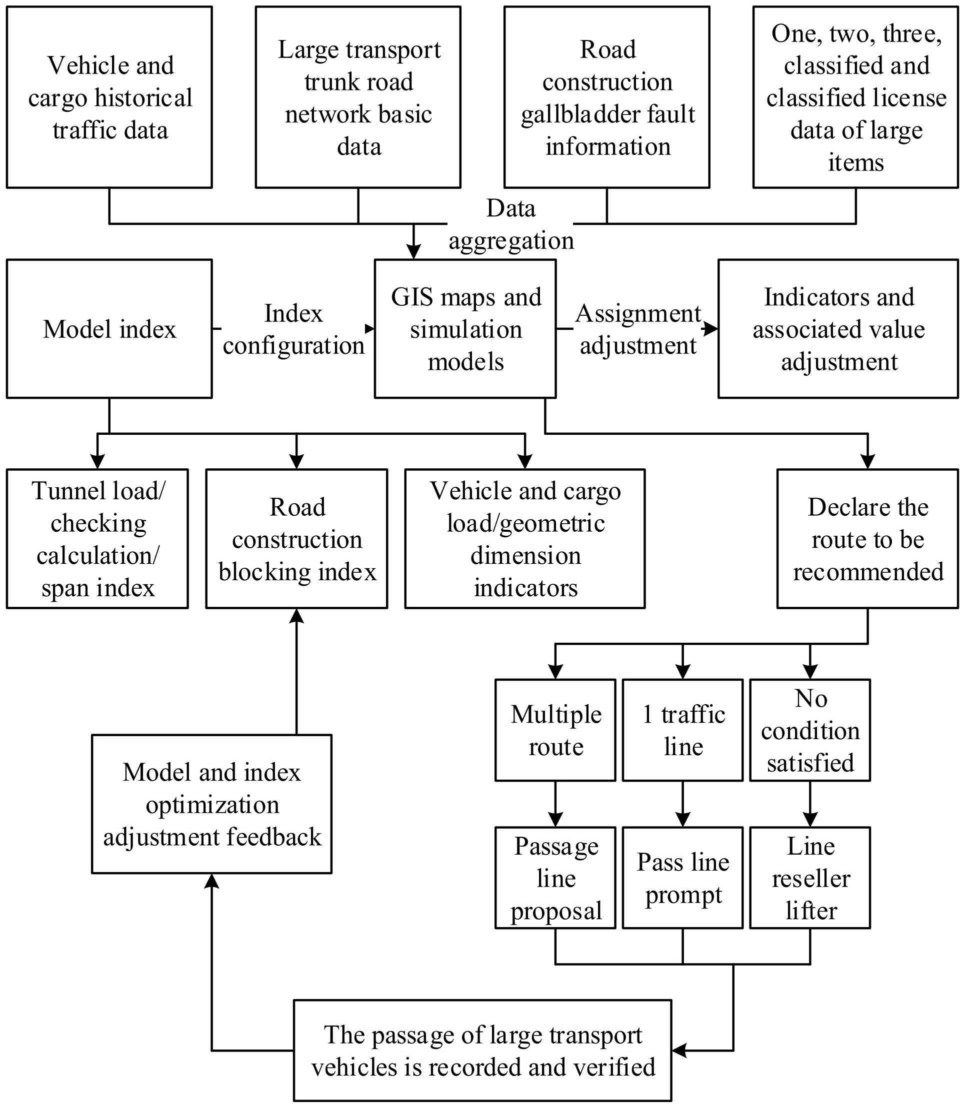


Fig. 1. Application diagram of intelligent route selection scenario for large cargo transportation

3.1.2. Automated distribution, "zero-wait" intake triage management. With the explosive growth of large transport cross-provincial average daily declaration, manual acceptance to carry out the formal review of the declaration materials and along the line of communication of the disadvantages of the access conditions are increasingly prominent, especially the human factor caused by delays will significantly increase the waiting time for enterprises to declare the permit, affecting the overall progress of the case.

Compared with the traditional receiving mode, the automatic distribution system realizes "zero-waiting" receiving and streaming. The introduction of automatic distribution mode in the receiving process effectively reduces the workload of manual distribution and accelerates the processing speed of receiving. Using big data intelligent analysis technology, the system identifies the keywords of the starting and ending points of the routes to be passed by enterprises, and automatically distributes the permits that meet the requirements for declaration to the transportation authorities corresponding to the starting and ending points for manual review. Based on the "keyword collection matching algorithm of the responsible unit", the declaration materials are automatically verified to see if they meet the requirements and conditions of the permit, and the corresponding review department is scientifically identified.

3.2. *Analysis of Factors Affecting Approval of Bulky Transportation*

Transportation units in the carriage of large cargo, need to consider the technical impact of transportation and economic impact factors, which technical impact factors are not subject to economic impact factors, is the necessary conditions to follow the passage of large items, the origin to the destination to meet the technical conditions of the line screening, the remaining lines need to do the technical and economic analysis to ensure that the selected line has the highest security, the strongest economy, so the optimal route decision-making problem is a typical multi-objective optimization problem, so the decision-making problem is a typical multi-objective optimization problem. Therefore, the decision-making problem of the optimal route for bulky transportation is a typical multi-objective optimization problem.

3.2.1. Analysis of technical factors. Large transport vehicles in highway transportation may need to pass through the toll booths, ramps, tunnels, flyovers, gantries and other types of geometric constraints exist in the route, which requires that the body geometry parameters of the large transport vehicles need to meet the geometric constraints of the type of facilities [26]. So that the body width of the large transport vehicle is B, the body length is L, the body height is H, for the ordinary straight section of the highway there are:

$$\begin{cases} W < W_1 \\ H < H_b \end{cases} \tag{1}$$

where: W_1 is the width of the highway on an ordinary straight section, and H_b is the height of obstacles on the highway, such as flyovers, tunnels, gantries, and so on.

Curved road section is a common section of highway interchange or hub, which usually appears in the form of ramps in the highway network, large transport vehicles in the curved road section, such as can not ensure that the sweeping area of the super-long body is included in the curved area, it is very easy to cause the large vehicles or goods and curved boundary obstacles to direct contact or collision, with a great safety risk. In addition, due to the presence of centrifugal force when the vehicle bends, when the centrifugal force of the vehicle bends is greater than the vehicle ground friction, it will cause the vehicle rollover, so the large transport vehicle bend passability is the key technical factors in the transportation path selection of large vehicles. In order to calculate the curve passability data, usually according to the curve latitude and longitude data to obtain a continuous curve boundary, and then use the Lagrange difference method to interpolate the coordinates to get the curve function, and the sweeping area of the bulky transport vehicle needs to be calculated by the vehicle profile model, as shown in Fig. 2, gives a typical profile point of the bulky transport vehicle A, I points of the driving coordinates of the trajectory, and the calculation formula were as in equation (2), Equation (3) shown.

A points:

$$\begin{cases} X_A = X_{A0} + V \times \Delta t \times \sin(\alpha_{A0} + \alpha_{Z0}) \\ Y_A = Y_{A0} + V \times \Delta t \times \cos(\alpha_{A0} + \alpha_{Z0}) \\ \alpha_A = \alpha_{A0} + \arcsin \dfrac{V \times t \times \sin(\alpha_{Z0})}{L} \end{cases} \tag{2}$$

I point:

$$\begin{cases} X_I = X_A - L_{AI} \times \sin(\alpha_A) \\ Y_I = Y_A - L_{AI} \times \cos(\alpha_A) \end{cases} \tag{3}$$

where: (X_A, Y_A) is the coordinates of the traveling trajectory of the A point, V is the traveling speed of the bulky transport vehicle, Δt is the instantaneous sampling time of the vehicle when cornering, α_{A0} is the angle between the front end of the vehicle and the positive direction of the Y axle, and α_{z0} is the angle of the front end turned in the Δt interior of the vehicle.

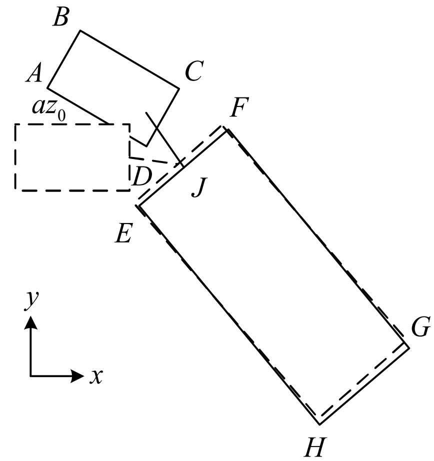


Fig. 2. Schematic diagram of turning of large transport vehicles

Bridge passability is one of the basic technical conditions for large transport vehicles to travel safely on the highway, for all bridges on the highway, the use of finite element models to calculate the structural internal force of the vehicle load div, and compared with the bridge carrying capacity, when the structural internal force under the load of large vehicles is less than the bridge's maximum carrying capacity, allowing vehicles to pass through the bridge where the line. When the structural internal force under the load of bulky vehicles is greater than the maximum carrying capacity of the bridge, vehicles are prohibited to pass through the route where the bridge is located. In summary, the bridge carrying capacity limitations are as follows:

$$M_d < \gamma M_c \tag{4}$$

where: M_d is the internal force of bridge under the load of bulky transportation vehicles, M_c is the bridge carrying capacity on the access route, and γ is the safety reserve coefficient of bridge carrying capacity.

Take the bridge and hub as the node of the highway route for segmentation, and select the space passability of bulky transportation vehicles and bridge carrying capacity surplus degree as the objective function of technical conditions, as shown in equation (5):

$$\min\{O_1, O_2, O_3\} = \min\left\{-\mu_1\sum_{i=1}^{n}(W_{li} - W_i), -\mu_2\sum_{i=1}^{n}(H_{bi} - H_b) - \mu_3\sum_{i=1}^{n}\frac{M_{ci} - M_{di}}{M_{ci}}\right\} \tag{5}$$

where: μ_1, μ_2, μ_3 is the weight of the technical indicator and n is the number of segments on the highway with bridges as nodes.

3.2.2. Analysis of economic factors. The transportation cost of large transport vehicles is more complex, not only contains fuel costs, modification of vehicles and other basic transportation costs, but also includes transportation time, transit costs and other indirect transportation costs, so for the optimal choice of transportation economics of large transport vehicles need to be considered at the same time in the process of transportation of large parts of the economic cost of the hundreds of economic costs and time costs, select the two factors to establish the economic conditions of the objective function, as shown in Equation (6) As shown in equation (6):

$$\min\{C_1, C_2\} = \min\left\{\varphi_1 \sum_{i\in N}\sum_{j\in N} x_{ij}^a t_{ij}^a, \varphi_2 \sum_{i\in N} c_{ij}\right\}$$
$$x_{ij}^a = \begin{cases} 1 & \text{Take route } a \text{ from City } i \text{ to City } j \\ 0 & \text{Or else} \end{cases} \tag{6}$$

where: φ_1, φ_2 is the weight of economic indicators, t_{ij} is the transportation time between i, j cities, and c_{ij} is the transportation cost between i, j cities.

3.3. Mathematical modeling

Large transport vehicles through the path optimization problem is different from the general path optimization problem, is not a simple solution to the origin and destination of the shortest passage path, but according to the nature of the large transport vehicles of the over-limit, in the consideration of the route planning should be the first to ensure that the passage of the path of the technical factors to meet the conditions, at the same time, based on the modification of the large transport vehicles, the hydraulic flatbed trucks can be added or reduced by adding or reducing the wheel axle way to Control the loaded axle weight of the flatbed truck. Reducing the number of axles of flatbed trucks will lead to an increase in axle weight, at this time $P_1 > P_2$, due to the control of the carrying capacity of bridges, some of the bridges on the route can not pass the requirements, but the reduction of the number of axles makes the length of the body lower, and the spatial passability of the route is enhanced. On the contrary, when the flatbed truck increases the number of axles so that the axle weight is reduced, $P_1 < P_2$, part of the route on the bridge carrying capacity can meet the technical indicators, but due to the increase in the area of curved sweeping, part of the route on the space passability may not meet the requirements.

Therefore, this paper transforms the optimization problem of the access path of bulky transport vehicles into the optimization problem of bulky transport vehicle parameters, the change of vehicle application parameters can change the accessibility of each path, and through the optimized vehicle parameter information to re-match the access paths in the highway bridge database, to determine the optimal path of the optimized vehicle application parameters. At this point, the optimization problem is a nonlinear optimization model of vehicle parameters. The axle weight of the hydraulic flatbed truck of the bulky transport vehicle is selected as the parameter to be optimized, and based on the technical and economic indicators, the multi-objective mathematical optimization model of the path selection of the bulky transport vehicle is constructed as shown in Eq. (7), and the optimal path is determined under the premise of guaranteeing the accessibility of space and bridges [27]:

$$\begin{cases} Find P \\ \min\{0, C\} \\ s.t.\ P_{\min} \le P \le P_{\max}, S > 0 \\ \gamma M_{ci} > M_{di} \\ T \le T_{\max} \\ C \le C_{\max} \end{cases} \tag{7}$$

where: P is the axle weight to be optimized for the moving vehicle, P_{min} and P_{max} are the upper and lower limits of the variable range of axle weights for flatbed trucks, S is the spatial accessibility on the route, T is the transit time, T_{max} is the maximum acceptable transit time applied for by the transport unit, C is the cost of the transport, and C_{max} is the maximum affordable cost of access applied for by the transport unit.

3.4. Greedy Algorithm Design

The problem of vehicle path optimization in logistics centers belongs to NP-hard problem, with the increase in the number of nodes of distribution stations and coupes, it will generate a diversity of solutions, which makes the difficulty of obtaining the global optimal solution increase geometrically. In this paper, a hybrid genetic algorithm incorporating greedy strategy is proposed to solve this problem, which strengthens the ability of the algorithm to jump out of the local extremes, and through genetic operations such as encoding, decoding, selection, crossover, and mutation, the adaptability of the whole population is continuously improved based on the natural rules of the selection of the fittest and survival of the fittest, and the optimal chromosome in the final population is taken as the optimal solution obtained [28-29].

Linear enumeration is used to enumerate all the loading solutions for the lower and upper levels of the kth coupe. A 3D vector model representation is used [30].

The permutation vector expression for the loading scheme of the upper layer with 1 column is:

$$\overrightarrow{\alpha_k} = (u_{k1}, u_{k2}, u_{k3}) \tag{8}$$

The permutation vector expression for the lower loading scheme is:

$$\overrightarrow{\beta_k} = (d_{k1}, d_{k2}, d_{k3}) \tag{9}$$

All permutations of $\overrightarrow{\alpha_k}, \overrightarrow{\beta_k}$ for both coupes can be searched using a memorized search. A feasible overall loading scheme for a particular coupe of type k is to choose one arrangement in each of $\overrightarrow{\alpha_k}$ and $\overrightarrow{\beta_k}$ and determine whether the reproduction scheme is fully loaded or not. If it is full, the loading scheme is regarded as a qualified arrangement. It is recorded in $\overrightarrow{\alpha_k}$ (upper) or $\overrightarrow{\beta_k}$ (lower). On the contrary, the scheme is not qualified and is discarded, and the case is recorded in the failure queue to form a "memory factor" to avoid searching for the failure case next time.

Therefore, each permutation, the sedan car there is a "space utilization" problem, here to the sedan car the remaining length of the sum of each column to measure. If the sum of the remaining lengths is larger, the lower the space utilization rate is, and the more sedan cars are needed. Conversely, the higher the space utilization, the lower the number of cars required.

Total length occupied by passenger cars loaded on the lower deck of the Type k sedan: When a set of combination $\overrightarrow{\beta_k} = (d_{k1}, d_{k2}, d_{k3})$ is selected, there is:

$$S'_k = \sum_{j=1}^{3} (d_{kj} \times (l_j + 0.1)) - 0.1 \tag{10}$$

When $k = 1$, it is type 1-1:

$$S''_k = S''_1 = \sum_{j=1}^{3} (u_{1j} \times (l_j + 0.1)) - 0.1 \tag{11}$$

When $k = 2$, it is type 1-2:

$$S_k'' = S_2'' = (\sum_{j=1}^{3}(u_{2j} \times (l_j + 0.1)) - 0.1) + (\sum_{i=1}^{3}(u_{2j}' \times (l_j + 0.1)) - 0.1) \tag{12}$$

Then the remaining effective length of the litter when a certain permutation of $\overrightarrow{\alpha_k} \times \overrightarrow{\beta_k}$ is selected for loading by the litter of type k:

At $S_k' \le L_k$ and $S_k' \le L_k \times k$, there is:

$$Q_k = (L_k - S_k') + (L_k \times k - S_k'') \tag{13}$$

where k in $L\_k \times k$ can be considered as a loading factor:

When $k=1$, it is type 1-1, multiplied by the loading factor 1, and when $k=2$, it is type 1-2, multiplied by the loading factor 2.

Obviously, the smaller Q_k is, the lower the residual space is, indicating the higher the effective utilization of the sedan, and the higher the selection priority, and the larger Q_k is, indicating the lower the effective utilization of the sedan, and the lower the selection priority.

Let's say that for a given $N_j (j = 1,2,3)$, m_1 1-1 sedans and m_2 1-2 sedans are finally selected. The objective function for the entire complete loading scheme:

$$\min T = \min \sum_{k=1}^{2} m_k \times Q_k \tag{14}$$

$$\begin{cases} m_1 \ge 5 \times m_2 \\ \sum_{i=1}^{m'} (D_{ij} + UL_{ij} + UR_{ij}) = N_j, \forall j \\ S_k' \le L_k \\ S_k'' \le L_k \times k \end{cases} \tag{15}$$

3.5. Genetic Algorithm Design

3.5.1. Coding. Simple and intuitive natural number coding method can be realized, but the data given in the question passenger cars, coupes, a large number of natural coding will lead to slow computing speed, the number of iterations. In this paper, the greedy algorithm solves the passenger car loading program on the basis of the whole vehicle coding program. The specific approach is to use the greedy algorithm to load passenger cars into the coupe, each coupe is treated as a gene, when all the passenger cars are loaded, so these coupes form a string of chromosomes. The coding model expression is shown below:

$$m_i = \sum_j n_j, \theta = \sum_i m_i, N_j = \sum_i \sum_j n_{ij} \tag{16}$$

3.5.2. Population initialization. The steps for generating the initial population are as follows: in the first step, based on the numbering of the distribution centers and customers, generate a natural number string $(0,1,2,3,\cdots\cdots,n)$ 0 for the distribution center and $1,2,\ldots,n$ for the m customer points. In the second step, $m-1$ zeros are randomly inserted into the above natural number string to form a chromosome of length $m+n$. In order to prevent producing an invalid chromosome, the inserted 0s satisfy that any two 0s are not adjacent to each other. The third step, in the chromosome randomly select the gene value is not all 0 of the two points, exchange, when the number of exchanges reached k times, to produce another chromosome, k for a random number. Step 4, repeat step 3 until the population size, popsize, is satisfied.

3.5.3. Strategies for population variation:

1) Constraint handling and fitness function. The application of the betting method requires that the fitness value is not negative, so the objective function is transformed into the fitness function through changes:

$$f_k = \frac{b_z}{z_k} \tag{17}$$

where: f_k is the fitness of the k nd chromosome, b is a constant, z is an estimate of the total transportation cost of the optimal chromosome in the initial population, and z_k is the transportation cost corresponding to the current chromosome.

For the VRP problem, the objective function is constrained using the following equation:

$$sumdd = \begin{cases} pathlen, carrycase = 0 \\ pathlen + C, carrycase = 1 \end{cases} \tag{18}$$

Where sumdd denotes the total path length of transportation, carrycase of 0 indicates that the objective function value is the actual total path length when the traveling scheme meets the requirement of carload, carrycase of 1 indicates that the objective function value is the actual total path length plus the penalized path length when the traveling scheme is overloaded, and C is the penalized path length.

2) Selection operator. The selection operator adopts an improved gambler's method, which uses an elite strategy to directly copy the best chromosome so far into the next generation population. It makes the selection probability of each chromosome proportional to its fitness value, for the i nd chromosome with fitness f, the probability of being selected is:

$$p(i) = \frac{f_i}{\sum_{j=1}^{popsize} f_i} \tag{19}$$

That is, $p(i)$ is equal to the proportion of the fitness of the i nd chromosome in the sum of the fitnesses of the whole population, and the greater the fitness of a chromosome, the higher the probability that it will be selected.

3) Crossover operator. Crossover reorganization of chromosomes is performed with a certain crossover probability in each generation of the population. The non-full VRP problem is characterized by inter-group disorder and intra-group ordering, and if the traditional crossover operator is simply used, it tends to destroy some excellent sub-paths. Moreover, when the two parent strings are the same, no new individuals can be generated to avoid “premature convergence”, so a crossover operator that improves on the sequential crossover (0X) method is used.

Given any of the following two parent strings, randomly choose two numbers as crossover points, move the crossover segment of each chromosome to the beginning of the other chromosome to get chromosomes A_1 and B_1, and trim off the same term to get two new individuals A_2 and B_2.

3.5.4. Population renewal strategies. Selecting appropriate control parameters is very important for algorithm design. Traditional genetic algorithms have control parameters that are constant during the genetic process, this paper adopts the strategy of adaptively adjusting the genetic probability. The basic idea is that a larger crossover, mutation probability should be used in the early stage of evolution so that there is enough diversity within the population, which will help to find the global optimal solution. While in the later stage of evolution, smaller crossover and mutation probabilities will allow the algorithm to have good convergence and make the search in some local neighborhoods that may have optimal solutions.

4. Bulk transport authorization and optimal route planning validation

4.1. Analysis of the characteristics and effects related to the approval of bulky transportation

4.1.1. Time. The distribution of starting time by month in the 9354 records of approval of large transportation in Yunnan Province in 2023 is shown in Figure 3.

As can be seen from Figure 3, the month distribution of the start time of large transportation in addition to January to February has a significant decline, the rest of the months are basically balanced, March to December of the provincial approval and cross-provincial approval of 517 and 328. The reason for this is that, on the one hand, the relevant transport enterprises will be affected by the Spring Festival holiday in January ~ February, the transportation project will be reduced, on the other hand, the transportation management department takes into account the sharp rise in traffic on the road section during the Spring Festival in January ~ February, the large transport vehicles may bring congestion to the road section, and at the same time, to ensure the safety of driving during the Spring Festival, the number of approval of the large transport is limited. At the same time in the second half of 2023, the proportion of projects approved across provinces is higher than that approved within the province, indicating that Yunnan is actively integrating into the construction of the "Belt and Road", the economy continues to develop, and the location advantage is gradually reflected, the scope of transportation from the province to the inter-provincial transportation gradually transferred to the proportion of the major.

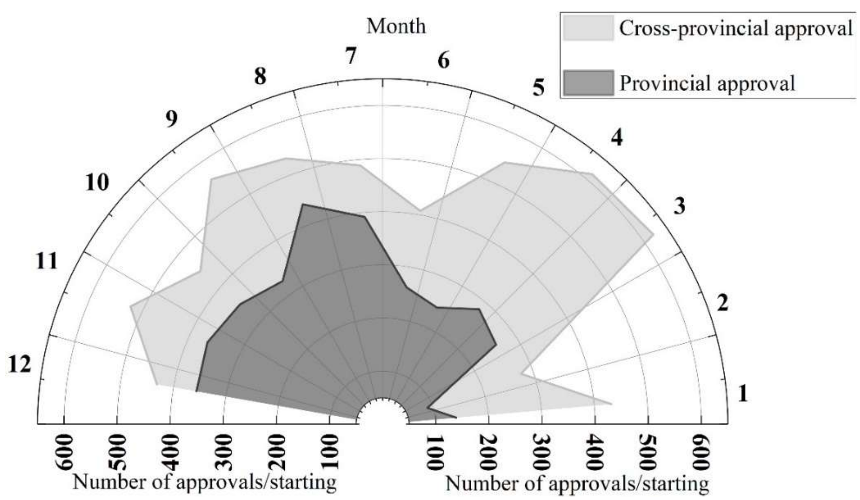


Fig. 3. Monthly distribution characteristics of starting time of bulky transportation

4.1.2. Vehicle attributes. The distribution of vehicle dimensions in the 9354 records of approval of bulky transportation in Yunnan Province in FY2023 is shown in Fig. 4, and Figs. (a)-(c) represent the length, width, and height, respectively. The length of the vehicle dimensions of large transportation is concentrated in 20m (2828) and 22m (2546), the width is concentrated in 3.4m and 3.5m, and the number of approvals is 2278 and 3217 times respectively. The height is concentrated in 4.5 m. The current highway regulations limit the height of vehicles to 4 m, and the width is limited to 2.5 m. The dimensions of large transport vehicles represent the relevant dimensions of the models exceeding the current regulations.

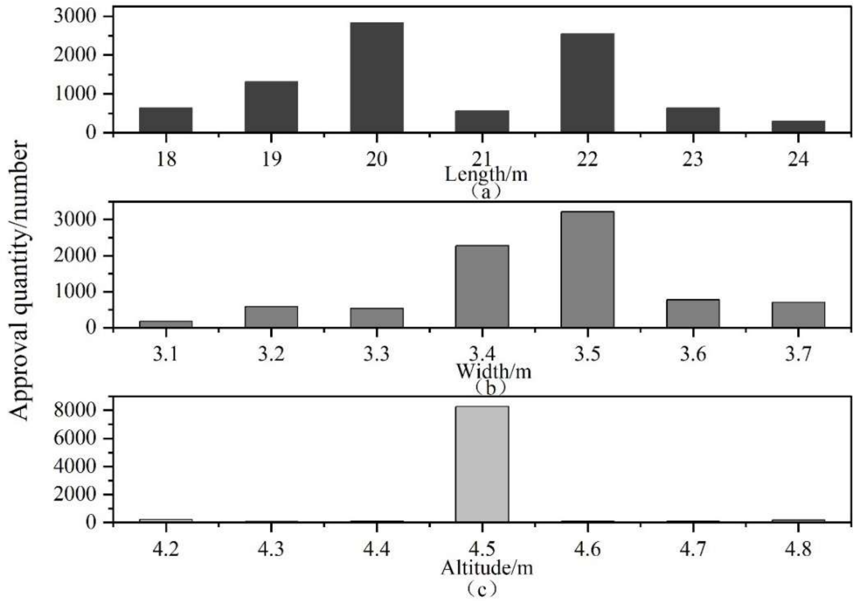


Fig. 4. Size distribution characteristics of large transport vehicles

4.1.3. Bulk transportation volume. Since the large-scale logistics and transportation industry is inextricably linked with the national economy and road construction, in the selection of the characteristics that affect the annual traffic volume of large-scale logistics and transportation, through the rigorous analysis of the relevant data over the years, the relationship between GDP x_1, the added value of the tertiary industry x_2, the total population x_3, the highway mileage x_4 and the turnover of large-scale transport goods x_5 and the annual volume of large-scale logistics and transportation y is selected, and the data of the past 20 years are shown in Table 1 below. GDP, tertiary sector value added, total population and highway mileage rise with each passing year until 2023, when they are 1015987.54, 553948.15, 140563, and 536.48, respectively.

Table 1. Bulk logistics volume data set from 2004-2023

Year	x_1	x_2	x_3	x_4	x_5	y
2004	110864.13	45764.26	127348	169.45	129.54	7289.26
2005	121896.96	51648.28	128863	176.53	137.03	7736.13
2006	137486	57994.53	129248	181.56	146.46	8166.36
2007	161869.63	66648.48	129846	187.45	185.46	8844.96
2008	187365.53	77648.41	130648	334.93	216.63	9681.45
2009	219184.65	91735.26	131496	347.96	234.95	10598.63
2010	270935.34	113459.55	132148	358.44	272.48	11864.36
2011	319187.13	137854.54	132249	372.64	294.41	13469.45
2012	348696.62	154985.36	132849	384.64	329.64	14697.59
2013	412648.16	182364.35	133436	400.87	380.69	16854.48
2014	487645.36	216324.34	134098	413.95	427.41	19226.36
2015	538461.16	244965.48	135469	424.79	466.36	21358.36
2016	592487.59	277983.48	136098	434.83	451.48	21348.69
2017	643484.15	310689.15	136798	446.18	483.31	21668.66
2018	688446.13	349648.84	137469	458.62	479.42	21716.95
2019	761845.63	390498.31	138758	467.25	503.45	22816.69
2020	832454.85	438648.36	139006	479.45	523.46	24986.68
2021	915654.26	489654.68	139548	485.43	548.15	26798.15

2022	984646.44	534865.63	140064	502.68	535.49	24562.69
2023	1015987.54	553948.15	140563	536.48	528.15	24098.15

4.2. *Example Verification of Global Optimal Path Based on Greedy Algorithm*

4.2.1. Introduction to examples. The sizes of large-scale instances were randomly generated uniformly in the range of 1000~2800. A total of 15 groups of large-scale instances of different sizes were set up, in which 10 groups of data were randomly generated in the range of 1000~1900 according to the step 100, and 9 groups of data were randomly generated in the range of 2000~2800 according to the step 100, and each group of data contained two instances, and a total of 38 large-scale instances of different sizes were tested to see how the greedy algorithm works on the large-scale instances.

Table 2 shows the comparison of the transportation network parameters of large-scale instances and describes the transportation network parameters of each group of scale instances in detail. A total of 19 groups of large-scale instances of different scales are generated, and each group of scale instances contains two instances. Among them, 20 JS_{case} instances under the scale of 1000~1900 and 18 ZJ_{case} instances under the scale of 2000~2800 were generated. In all the ZJ_{case} instances, the mean values of transportation distance, maximum number of service bundle orders on a route, and maximum service hours of vehicles are 50, 3.56, and 14.33, respectively. It can be seen that the data extraction is relatively uniform, in different sizes from 1000 to 2800, the order instances of bundled transportation distance, the maximum number of bundled transportation orders, the maximum running time of the vehicle, the loading and unloading rules and so on are included in each of the values, which ensures the representativeness of the data.

Table 2. Comparison of large-scale instance transport network parameters

Class		N	E(km)	B	T_{max}	Greedy algorithm
JS_{case}	JS_1000	1000	50	3.5	15	0.5
	JS_1100	1100	60	4	14	1
	JS_1200	1200	50	3.5	14	0
	JS_1300	1300	60	4	16	1
	JS_1400	1400	60	3.5	14	0.5
	JS_1500	1500	50	4	15	0.5
	JS_1600	1600	60	4	15	0
	JS_1700	1700	40	3	16	0
	JS_1800	1800	50	3	14	1
	JS_1900	1900	60	4	16	0.5
ZJ_{case}	ZJ_2000	2000	50	3.5	14	0.5
	ZJ_2100	2100	40	3.5	14	1
	ZJ_2200	2200	50	4	16	0
	ZJ_2300	2300	60	3	16	1
	ZJ_2400	2400	40	3.5	12	1
	ZJ_2500	2500	50	4	13	0.5
	ZJ_2600	2600	60	3.5	14	0.5
	ZJ_2700	2700	60	3.5	16	0
	ZJ_2800	2800	40	3.5	14	1

4.2.2. Experimental results and analysis. Since the column generation algorithm runs inefficiently on instances larger than 2000 orders, the running results of the greedy algorithm and column generation are compared on JS_{case} only.

Figure 5 shows a comparison of the algorithm runtimes and Figure 6 shows a comparison of the runtimes. The distribution of the greedy algorithm and column generation running time with respect to the saving value is depicted. When the number of order sizes is in the scale of 1000~1900, the solution time of the column generation algorithm is significantly longer, and most of the instances require 50~200 minutes of solution time. On the other hand, on instances of the same size, the greedy algorithm can get an optimized solution in 10~15 minutes, and most instances can get an optimized solution in 10 minutes. When the number of orders is larger than 2000, an optimal solution can definitely be reached in less than 24 minutes. On large-scale instances, the running time is significantly longer because the column generation process needs to iteratively search for paths that violate the current plan in a very large-scale solution space. The greedy algorithm, on the other hand, has a shorter running time.

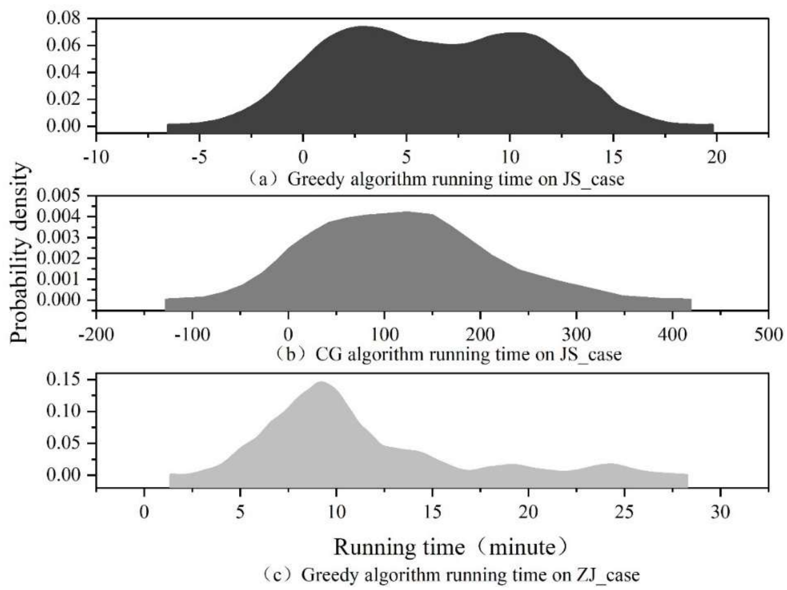


Fig. 5. Algorithm running time contrast

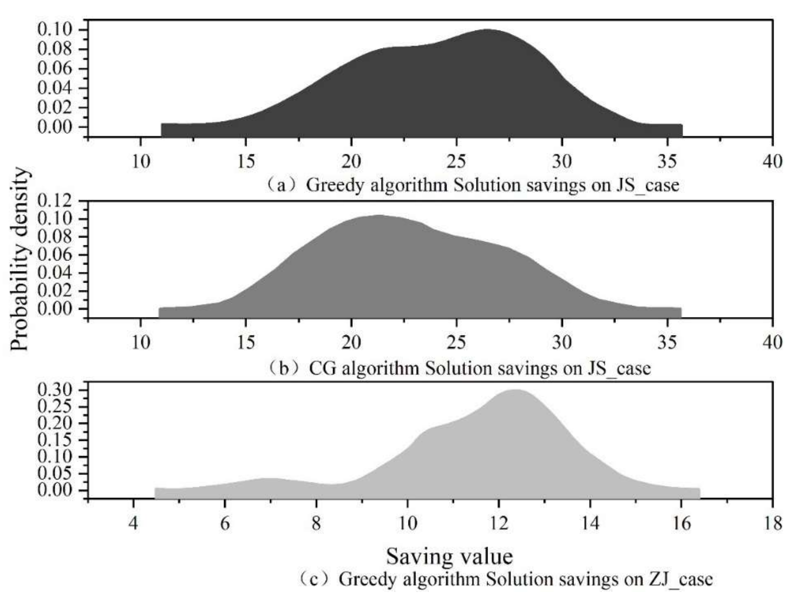
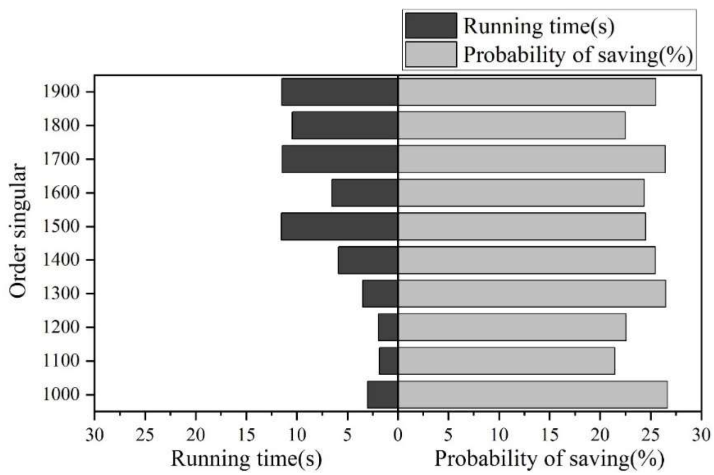
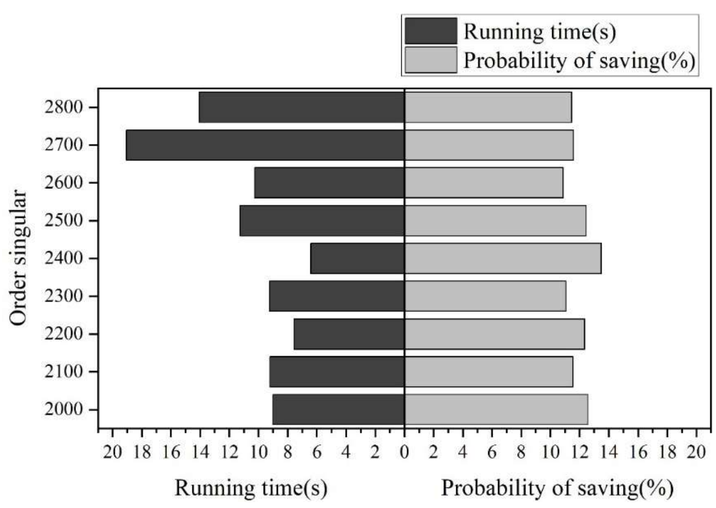


Fig. 6. Performance contrast

4.2.3. Sensitivity. Fig. 7 shows the effect of the number of orders on the running effect of the greedy algorithm, (a) and (b) are the number of JS_{case} order by the length of the algorithm and the number of ZJ_{case} orders by the length of the algorithm, respectively. It can be seen that the greedy algorithm can get the optimized solution scheme for 1100 order sizes in less than 2.344 minutes at the fastest. As the order size increases, the solution time of the greedy algorithm increases, and the running time and the number of orders are approximately linear, but the solution time with the increase in the number of orders is not very obvious, which means that the efficiency of using the greedy algorithm on large-scale instances is higher. For instances with the number of orders less than 2800, the iterative local search algorithm can give a better optimized solution in 19 minutes. Moreover, for instances under the same transportation network, the increase in the number of orders does not lead to a worse solution scheme. Therefore, for large-scale transportation and distribution scenarios, using greedy algorithm for path planning is a suitable choice.



(a) JS_{case} The number of orders is affected by the length of the algorithm



(b) ZJ_{case} The number of orders is affected by the length of the algorithm

Fig. 7. The effect of the order singular on the operation effect of the greedy algorithm

4.3. Transportation

4.3.1. Transportation mileage. Due to the special nature of large cargo transportation, different attributes of goods, different technologies used, differences in terrain between city nodes and other reasons will affect the price of large cargo transportation, so the tariffs of different transportation projects are different. Referring to the transportation cost of many large projects, the transportation rate of road transportation ranges from [0.8~1], railroad transportation is [0.6,0.8], river transportation is [0.3,0.5], and sea transportation is [0.4,0.6]. The weight of the large equipment transported in this project is 120 tons, 220 tons, and the total weight of the equipment is 340 tons, and the transportation rates of road, railroad, river transport, and sea transport are 0.9, 0.8, 0.35, and 0.45, taking into account various factors; therefore, it is estimated that the cost of highway transport in the process of this transportation of large goods is about 384 yuan per kilometer, the cost of railroad transport is about 274 yuan per kilometer, the cost of river transport is about 12 yuan per kilometer, and the cost of river transport is about 12 yuan per kilometer. , the cost of river transportation is about $122 per kilometer, and the cost of sea transportation is about $159 per kilometer.

Figure 8 shows the transportation network of the marking method, for the convenience of calculation, the name of each city node is digitized, and the marking operation is performed on it. Where 0 represents Kunming City, Yunnan Province, the place of origin, 1 represents Dali, 2 represents Lijiang, 3 represents Chongqing, 4 represents Wuhan, 5 represents Nanjing, 6 represents Hangzhou, 7 represents Shanghai, and 8 represents the destination of transportation, Qingshan Town, Jiaxing City, Zhejiang Province.

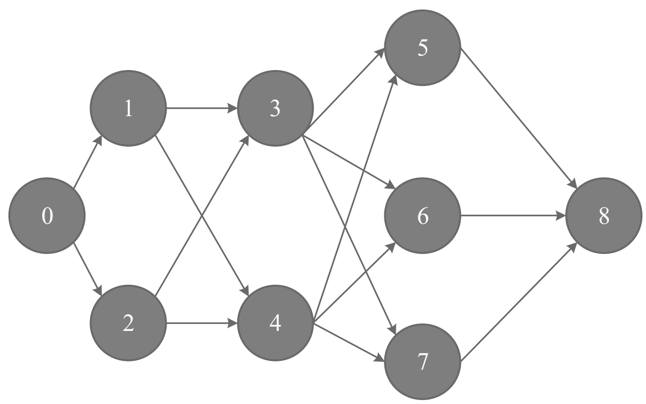


Fig. 8. The transport network of the label method

The transportation task between two city nodes can be accomplished by a variety of transportation modes, but there are obvious differences in the routes passed by each mode of transportation and the transportation mileage required, which makes the transportation cost and transportation time differ when choosing different modes of transportation between city nodes. The transportation mileage of this large cargo transportation mainly includes the road transportation distance, railroad transportation distance, river transportation distance and sea transportation distance between each city node from 0 to 8. The specific mileage is shown in Table 3, for example, in the transportation route 8→9, the road transportation distance is 103 kilometers, the railroad is 105 kilometers, and the sea transportation is 195 kilometers.

Table 3. Statistical table of transport distance between cities of each node

Mode of transportation	Highroad	Railway	River Movement	Sea Transportation
1→2	75	60	/	/
1→3	263	135	/	/
2→4	390	500	/	/
2→5	1462	1269	/	/
3→4	435	1769	716	/
3→5	1286	2000	1869	/

4→6	1436	1836	2069	/
4→7	1736	2496	/	/
4→8	1700	2369	2348	/
5→6	549	521	648	/
5→7	896	1169	/	/
5→8	816	948	1069	/
6→9	323	399	/	/
7→9	118	90	/	/
8→9	103	105	/	195

4.3.2. Transportation time. The attributes of the transported bulky goods are different, and there are also differences in the requirements for their transportation speed. Taking road transportation as an example, the running speed of the vehicles for this transportation is as follows: the normal transportation speed must be controlled at 30km/h, the speed of uneven road sections must be controlled at 5km/h or less, and the speed of passing through bridges and various obstacles is controlled at 5km/h or less. The transportation speed of different modes of transportation is different, and its transportation time also has a big difference, the transportation time required by different modes of transportation between the nodes of this large cargo transportation is shown in Table 4. For example, in the transportation line 8→9, the transportation time is 3.46h for road, 1.46h for railroad and 12h for sea transportation.

Table 4. Statistics of transportation time between cities of each node

Mode of transportation	Highroad	Railway	River Movement	Sea Transportation
1→2	2.65	0.81	/	/
1→3	8.76	1.79	/	/
2→4	13.66	6.34	/	/
2→5	48.15	15.46	/	/
3→4	14.36	22.56	83.84	/
3→5	42.76	25.13	220.96	/
4→6	47.53	22.95	238.18	/
4→7	57.59	31.26	/	/
4→8	56.75	28.93	278.96	/
5→6	18.34	6.51	81.56	/
5→7	29.56	14.79	/	/
5→8	27.23	11.63	123.46	/
6→9	10.88	4.94	/	/
7→9	3.85	1.26	/	/
8→9	3.46	1.46	/	12

4.3.3. Transportation costs. According to the transportation rate and transportation mileage can be obtained in the transportation of large cargo in the transportation between the nodes of each city by road, railroad, river transport, sea transport and other modes of transportation costs. And the actual transportation cost in addition to consider the obstacle removal fees, road compensation fees, etc., but also need to consider the lease of transportation equipment. After actual research, the actual transportation cost of each node city is shown in Table 5. For example, in transportation route 8→9, the cost of road transportation is 43,300 yuan, railroad is 279,800 yuan, and sea transportation is 70,000 yuan.

Table 5. Statistics of transportation costs between cities of each node

Mode of transportation	Highroad	Railway	River Movement	Sea Transportation
1→2	3.46	26.79	/	/
1→3	10.26	28.73	/	/
2→4	15.64	38.74	/	/
2→5	56.68	58.44	/	/
3→4	16.89	72.89	10.23	/
3→5	49.87	104.66	27.29	/
4→6	55.23	74.96	29.23	/
4→7	66.97	92.63	/	/
4→8	66.64	113.39	34.16	/
5→6	21.43	39.15	10.26	/
5→7	34.59	56.98	/	/
5→8	31.98	50.83	14.96	/
6→9	13.18	35.74	/	/
7→9	4.89	27.69	/	/
8→9	4.33	27.98	/	7

4.4. Path Decision Realization

According to the theoretical basis of the model in Chapter 2, the optimization model for the selection of large transport solutions in Yunnan Province is established:

$$Z_1 = \min \sum_{p=1}^{N} \sum_{i=1}^{J} a_{i,i+1}^{p} t_{i,i+1}^{p} + \sum_{p=1}^{N} \sum_{q=1}^{N} \sum_{i=1}^{J} b_i^{pq} t_i^{pq} \tag{20}$$

$$Z_2 = \min \sum_{p=1}^{N} \sum_{i=1}^{J} a_{i,i+1}^{p} c_{i,j+1}^{p} + \sum_{p=1}^{N} \sum_{q=1}^{N} \sum_{i=1}^{J} b_i^{pq} c_i^{pq} \tag{21}$$

$$\sum_{i=1}^{J} a_{i,i+1}^{p} = 1 \tag{22}$$

$$\sum_{p=1}^{N} \sum_{q=1}^{N} b_i^{pq} = 1 \tag{23}$$

$$a_i^p + a_{i+1}^q \geq 2 b_i^{pq} \tag{24}$$

$$a_{i,i+1}^{p} = \begin{cases} 1 & \text{Select p mode of transport from City } i \text{ to City } i+1 \\ 0 & \text{From City } i \text{ to City } i+1 \text{ choose a mode of transport other than p} \end{cases} \tag{25}$$

$$b_i^{pq} = \begin{cases} 1 & \text{The transportation mode of goods in city } i \text{ is changed from } p \text{ to } q \\ 0 & \text{The mode of transport of goods in } i \text{ does not change} \end{cases} \tag{26}$$

$$i \in J = [1,30] \tag{27}$$

$$p, q \in N = \{\text{Road transport, rail transport, water transport}\} \tag{28}$$

Among them:

When optimizing a bi-objective function with a genetic algorithm solution, the function is generally converted to a single objective function by some transformation. Here the weight δ of the overdue penalty cost is introduced to change the objective function to:

$$Z = Z_1 + Z_2 \tag{29}$$

Among them:

$$Z_1 = \begin{cases} 0 & t \le T \\ \delta(t-T) & t > T \end{cases} \tag{30}$$

$$t = \sum_{p=1}^{N}\sum_{i=1}^{J} a_{i,i+1}^{p} t_{i,i+1}^{p} + \sum_{p=1}^{N}\sum_{q=1}^{N}\sum_{i=1}^{J} b_i^{pq} t_i^{pq} \tag{31}$$

t is the specified transportation period, formula (30) represents the penalty cost, and formula (31) represents the time spent in transportation.

At the same time, it should be pointed out that through the path selection support system can be obtained through a variety of path selection results, each of which takes less time to obtain, through the combination of the various modules of the entire system and screening, the decision maker can be given to meet the requirements of a variety of transportation options. The optimal route for the project is 0→2→4→7→8, and the transportation mode used is road transportation→river transportation→river transportation→road transportation, and the total transportation cost is 670,500 yuan, of which the transportation cost is 116,500 yuan, 320,000 yuan, 151,000 yuan, and 83,000 yuan, respectively.

It can be seen that the time of the transportation path derived by using the path selection support system is very short, and the whole calculation process is scientific, the time used is much smaller than the result of manual experience, and can give multiple alternative paths to give decision-makers decision support. At the same time, it can also be seen that the realization and feasibility of the establishment of the path selection support system for large transportation.

5. Conclusion

In this paper, the intelligent approval framework of bulky transportation is designed, the factors affecting the approval of bulky transportation are sorted out, and the optimal route mathematical model of bulky transportation is constructed. Lian Li greedy and genetic algorithms are used to propose the global optimal route planning strategy for bulky transportation, and the optimal route planning effect is verified through examples. The characterization of 9354 records of approval of bulky transportation in Yunnan Province in 2023 shows that the lengths of bulky transportation vehicles are concentrated in 20m and 22m, the widths are concentrated in 3.4m and 3.5m, and the numbers of approvals are 2278 and 3217, respectively. Using the model to generate transportation network parameters uniformly and randomly in the range of size 1000~2800, in all ZJ_{case} instances, the mean values of transportation distance, maximum number of service bundle orders on the line, and maximum service hours of the vehicle are 50, 3.56, and 14.33, respectively. It can be seen that the data extraction is relatively uniform. After the optimization operation of genetic algorithm for the selection of bulky transportation scheme, the optimal route for the project is obtained as 0→2→4→7→8, and the total transportation cost is 670,500 yuan, of which the transportation cost is 116,500 yuan, 320,000 yuan, 151,000 yuan, and 83,000 yuan, which is seen as the optimal path planning for bulky transportation, which gives the decision maker decision-making support.

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