Research on Multimodal Transport Path Optimization Based on KSP Algorithm

Tengfei Li [a], Rongqin Lin [b]

School of Shanghai Maritime University, College of Transport & Communications, Shanghai 201306, China;

[a]18437955608@163.com, [b]rqlin@shmtu.edu.com

Abstract

The path optimization of multimodal transport network is an important research direction in multimodal transport, and its optimal path can effectively reduce the transportation cost in multimodal transport. Starting from the path optimization direction, this paper first constructs a multimodal transport network model with the goal of minimizing transportation costs. Based on this, the KSP algorithm is used to solve the optimal path, and the principle of the algorithm is analyzed. The algorithm design for the network model is proposed. Finally, the minimum path of transportation cost that satisfies the constraint conditions such as time constraint is selected from the first 16 shortest paths obtained by the algorithm, that is, the optimal path under the multimodal transport network model is obtained.

Keywords

Multimodal transport; path optimization; KSP algorithm; optimal path.

1. Introduction

Multimodal transport generally refers to the continuous transport process that includes two or more modes of transport in the whole transport process. The main transport goods are container goods, which have the characteristics of container transport. Multimodal transport is the main mode of international freight transport, which has the characteristics of fast, efficient and standardized. Route optimization of multimodal transport is an important part of solving international economic and trade exchanges. Through the study of path optimization of multimodal transport, the economic and time costs in multimodal transport can be greatly reduced, and it is of great significance to realize resource saving and improve transport efficiency.

With the wide application of multimodal transport, the study of multimodal transport by scholars at home and abroad is also gradually deepening. TSUNG-SHENG CHANG discussed the optimal route selection in international multimodal transport; Xu Tao and others summarized the KSP algorithm in his article; Tang Jimeng, a domestic scholar, used KSP algorithm to study the urban rail transit network in order to achieve KSP search without expanding the network; CHO.J.H. and others used dynamic programming method to study the multimodal transport freight route from Busan to Rotterdam Port. Line analysis; Qiao Xinyu established a transport cost model including internal and external transport costs, and then solved the model by simulation method; Liu Jie and others used the dynamic path planning model to consider the impact of fixed departure time of various transport modes on the choice of the optimal route in multimodal transport, and proposed an alternative set of node transport modes; Liang Xiaozhong considered vaguely. With the objective of minimizing the cost and maximizing customer satisfaction, a linear programming model for multimodal transport route optimization is constructed. Hamdi et al. take time and cost as the objective of the model, establish an optimization model to solve the design problem of multimodal transport network. Yang

Hualong et al. consider transportation cost and transportation time as the main research objectives. In this paper, an optimization model of multi-modal container intermodal service purchasing is established, Mouncif et al. have improved the traditional shortest path optimization problem, and studied the multi-path shortest path transportation network system with multiple constraints.

These studies comprehensively explain the various methods of route optimization in multimodal transport. Considering the transportation cost and transportation time, they put forward their respective solutions. Compared with Dijkstra algorithm, A* algorithm and genetic algorithm, the KSP algorithm adopted in this paper has the advantage of effectively calculating the shortest path, the second short circuit and the second short circuit in a transportation network. Combining with the constraints of transportation time and carbon emissions, we can find an optimal path that meets the constraints. 。 Because the calculation focus of KSP algorithm is not only the optimal path, but also the sub-optimal path and sub-optimal path, so scholars at home and abroad seldom use KSP algorithm when only the optimal path is required, but it is undeniably an excellent and comprehensive path optimization method.

In the multimodal transport system commonly used in the world nowadays, it is hoped that the minimum transportation cost can be obtained, and the transportation time can not exceed the requirements of the demander. Therefore, based on this, this paper calculates the minimum cost path, second min cost path, third short min cost path and so on in multimodal transport network by using KSP algorithm, and then combines the transit time and cost of each node to find the minimum cost path under the time constraints of demand side, that is, the optimal path.

2. Description and Modeling of Problems

2.1 Description of the problem

Assuming that there is a lot of goods in place 'A' to be transported to place 'B', the transportation process involves water, railway and highway transportation routes, and the conversion of goods in the node takes a certain cost and time. Now we know the distance between each node, the total weight of the goods, the unit replacement cost and time of each node, the unit transportation cost and speed of the three modes of transportation. At the same time, in order to facilitate the modeling, the following assumptions are made:

There is no congestion on transportation routes, and all kinds of vehicles can operate at known speeds.

Each node has sufficient capacity for intermediate conversion.

Each node will have a mid-transformation installation at most once.

The cargo flow is uninterrupted.

2.2 Establishment of model

Objective function:

$$\mathrm{C}_{\min} = \min\left(\sum_{i\in V}\sum_{j\in V}\sum_{k\in N} c_{ij}^{k} d_{ij}^{k} W x_{ij}^{k} + \sum_{i\in V}\sum_{j\in V}\sum_{k\in N}\sum_{g\in N} h_{ij}^{kg} W y_{ij}^{kg}\right)(¥) \tag{1}$$

Constraints:

$$T_s = \left(\sum_{k\in N}\sum_{i\in M}\sum_{j\in M} \frac{d_{ij}^{k}}{v^{k}} x_{ij}^{k} + \sum_{k\in N}\sum_{g\in N}\sum_{i\in M}\sum_{j\in M} z_{ij}^{kg} y_{ij}^{kg}\right)(h) \le T_g \tag{2}$$

$$\sum_{k\in M} x_{ij}^{k} \le 1; \forall i, j \tag{3}$$

$$\sum_{g\in M} y_{ij}^{kg} \le 1; \forall k, i, j \tag{4}$$

$$\sum_{k\in M}\sum_{i\in N} x_{ij}^{k} = \sum_{k\in M}\sum_{l\in N} x_{jl}^{k}; \forall i, j, l \tag{5}$$

2.3 Model and parameter description

2.3.1 Model description

The objective function (1) denotes the minimum total cost including route transportation cost and transit loading cost; the constraint condition (2) denotes that the actual transportation time including route transportation time and transit loading time should not exceed the time specified by the cargo demander, and the constraint condition (3) denotes that only one mode of transportation can be selected between two transport nodes. Conditions (4) denote that each node can carry out intermediate loading at most once; and constraints (5) ensure that the cargo flow is continuous and uninterrupted.

2.3.2 Parametric Description

The multimodal transport network is defined as G= (N, R, M), 'N' represents the set of nodes, 'R' represents the set of lines, 'M' represents the set of modes of transport. $C_{\min}$ is the objective value of this model, representing the minimum cost; c_{ij}^{k} represents the unit transportation cost of transportation from node i to node 'j', ¥/(t*km); d_{ij}^{k} represents the distance from node 'i' to node 'j', km; 'W' represents the weight of goods, tons; x_{ij}^{k} is a 0-1 variable, used to judge whether the 'k' transportation mode is used between nodes 'i' and 'j', and if the 'k' transportation mode is used, x_{ij}^{k} = 1 otherwise x_{ij}^{k}=0; h_{ij}^{kg} represents the cost of changing the mode of transport from 'k' to 'g' after the goods are transported from 'i' node to 'j' node,¥; y_{ij}^{kg} is a 0-1 variable, which is used to judge whether the mode of transport changes from 'k' node to 'g' node, and if the mode of transport changes, y_{ij}^{kg}=1 , otherwise y_{ij}^{kg}=0; T_s represents the actual transportation of a route time; T_g represents the maximum transport time allowed by the demander, and the actual transport time is considered invalid when it exceeds that time; v^k represents the transport speed of the kth mode of transport, km/h; z_{ij}^{kg} represents the time taken by the 'j' node to change the 'k' mode of transport to the 'g' mode of transport after the goods are transported from node 'i' to node 'j', h.

2.4 Algorithmic Principle and Design

The algorithm adopted in this paper is an improved KSP algorithm (K-shortest path algorithm) based on Dijkstra algorithm. The implementation of this algorithm can be divided into two parts. First, Dijkstra algorithm is used to find the shortest path of network graph, and then the K-1 shortest path is calculated.

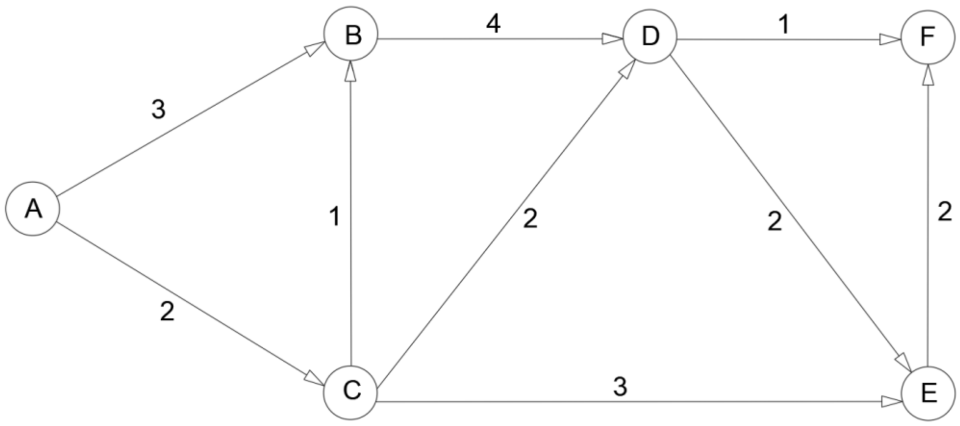

Fig 1. Transport network diagram

As shown in Fig.1, this diagram is a simple transport network schematic diagram, starting with A and ending with F. It is used here to illustrate the principle of KSP algorithm.

Step1: First, the shortest path, 'A-C-D-F', is calculated by Dijkstra algorithm. The length is 7, which is L_1.

Step2: Take L_1 as the iteration path, carry out the first iteration; take 'A' as the starting point, set the weight between 'A-C' as infinite, carry out a Dijkstra algorithm, get the path 'A-B-D-F', length is 8; then take 'C' as the starting point, set the weight between 'C-D' as infinite, carry out the Dijkstra algorithm, get the path 'A-C-E-F', length is 7; and then take 'D' as the starting point, set the weight between 'D-F'. For infinity, the Dijkstra algorithm is used to obtain a path 'A-C-D-E-F' with a length of 8. So far, the first iteration is completed, and the shortest path 'A-C-E-F' is selected from the three paths, which is the second short path, recorded as L_2.

Step3: Take L_2 as the iteration path for the second iteration. The iteration method is the same as step 2. The second short-circuit 'A-B-D-F' is obtained, which is recorded as L_3. After 'K' iterations, 'K' shortest paths are obtained as the shortest path L_1:'A-C-D-F', the second short path L_2:'A-C-E-F', the third short path L_3:'A-B-D-F'...... L_k.

Because there are reloading nodes in the actual multimodal transport network model, the cost and time of reloading at the reloading nodes are also part of the overall transport process, but the cost and time of reloading at the reloading nodes in the actual transport process are very small compared with the cost and time of transportation process, so this paper gives priority to KSP algorithm when calculating. Considering the cost and time, we can get the minimum transportation cost of the first K routes, together with the replacement cost and time at the nodes. Finally, we re-rank and screen the routes to get the optimal route.

The specific solutions are as follows:

According to the original multimodal transport network diagram, a new multimodal transport network diagram is constructed, which is convenient for KSP algorithm to calculate.

KSP arithmetic program is constructed by MATLAB programming software. The cost and time on the transport route (edge in the multimodal transport network graph) are calculated by this program, and the lowest transport cost of the front 'K' routes is obtained.

Determine whether the front 'K' paths have been changed, and if the change happens, add the cost and time of the change, and then reorder the 'K' paths to get the optimal transport line that meets the time requirements of the demander.

3. Case Analysis

A batch of goods weighing 300 tons needs to be transported from '1' place to '6' places. It is now required that the transport cost of the demander of the goods be as low as possible and that the transport time of the goods should meet the demand side's requirements. It is assumed that the demander of the goods requires that the goods be received within 56 hours, and that the demander of the goods will not accept the goods if the goods exceed 56 hours. Its transport network diagram is shown in Fig. 2. The figures between the sections in the diagram represent the mileage of the corresponding transport modes between the two places,km.

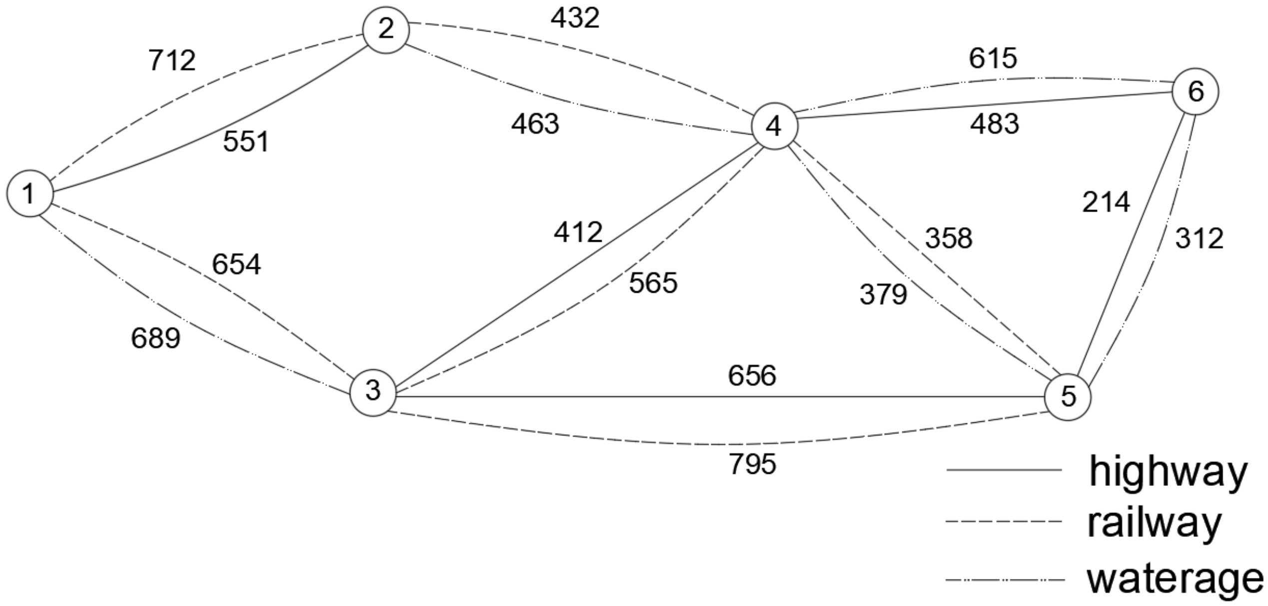

Fig.2 Multimodal transport network diagram

Table 1 Unit freight rates and average speeds in the three modes of transport

Mode of transportation	Unit freight （ $yuan \bullet (t \bullet km)^{-1}$ ）	Average speed on the way （ $km \bullet h^{-1}$ ）
highway	0.46	60
railway	0.32	45
waterage	0.23	28

From the data in Table 1 and the transportation distance between the nodes in Fig.2, we can calculate the transportation cost of various modes of transportation among the nodes (excluding the cost of node replacement). We can get Fig.3. The unit of data in Fig.3 is yuan.

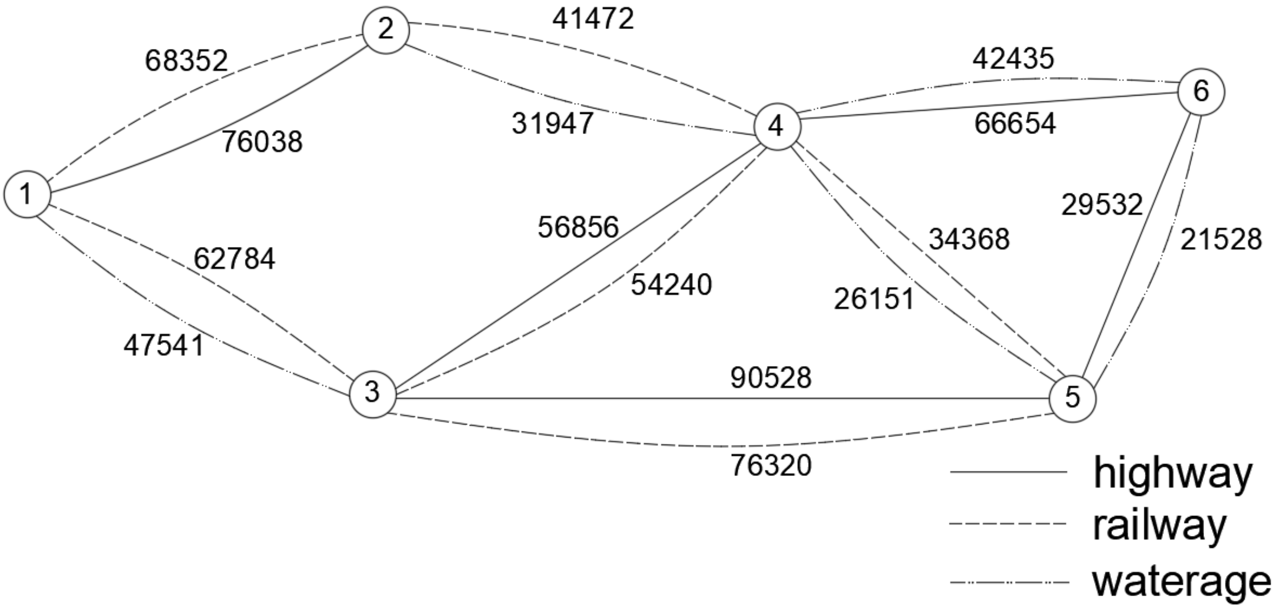

Fig.3 Multimodal transport network diagram showing transportation costs

In addition, in order to facilitate the subsequent use of KSP algorithm to analyze and solve the multi-modal transport network, and then simplify the multi-modal transport network in Fig.3, and get a new multi-modal transport network as shown in Fig.4.

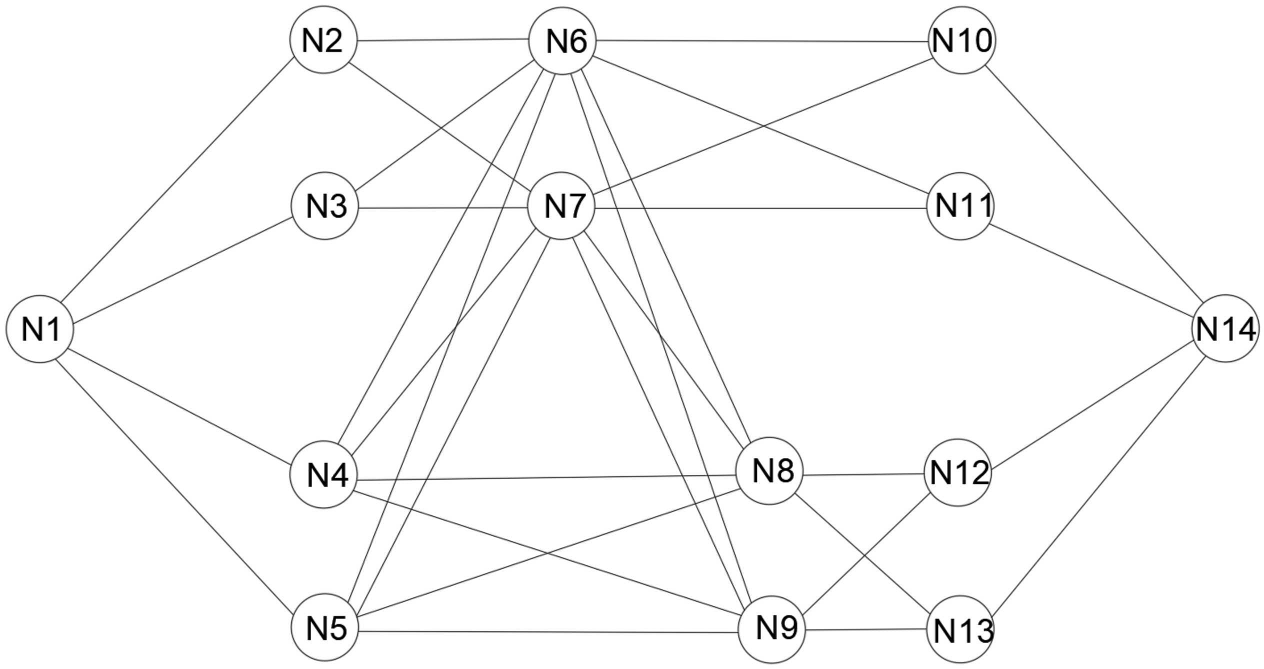

Fig.4 Simplified multimodal transport network diagram

Because the multimodal transport network requires a higher choice of transport routes and transport nodes, the scale of the model will not be particularly large. In this model, the front 16 routes with the least transport costs will be calculated by matlab. The specific routes, transport costs, transport time and replacement times are listed in Table 2.

Table 2 Top 16 routes with the least transportation costs (excluding replacement costs and time)

Transport routes	Transportation costs (yuan)	Transportation time (h)	Replacement times
1-railway-2-waterage-4waterage-6	142734	54.3	1
1-waterage-3-railway-4-waterage-6	144216	59.1	2
1-waterage-3-railway-5-waterage-6	145389	53.4	2
1-waterage-3-highway-4-waterage-6	146832	43.4	2
1-railway-2-waterage4-waterage-5-waterage-6	147978	57.0	1
1-waterage-3-railway-4-waterage-5-waterage-6	149460	61.8	2
1-highway-2-waterage-4-waterage-6	150420	47.6	1
1-waterage-3-highway-4-waterage-5-waterage-6	152076	56.2	2
1-railway-2-railway-4-waterage-6	152259	47.4	1
1-waterage-3-railway-5-highway-6	153393	45.8	2

1-highway-2-waterage-4-waterage-5-waterage-6	155664	50.4	1
1-railway-2-waterage-4-waterage-5-highway-6	155982	49.5	2
1-railway-2-waterage-4-railway-5-waterage-6	156195	51.5	3
1-waterage-3-railway-4-waterage-5-highway-6	157464	54.3	3
1-railway-2-railway-4-waterage-5-waterage-6	157503	50.1	1
1-waterage-3-railway-4-railway-5-waterage-6	157677	56.3	2

Table 2 shows that the lowest transportation cost is 1-Railway-2-waterage-4-waterage-6 and the lowest transportation cost is 142734 yuan without considering the cost and time of node replacement. However, in actual transportation, node replacement needs to consume a certain amount of cost and time, so the unit replacement cost and time of each route in Table 2 and Table 3 are calculated. The replacement cost and time of 16 routes are updated in Table 2 to get Table 4.

Table 3 Replacement costs and replacement time for the three conversion modes

Replacement mode	Unit replacement cost ($yuan \bullet t^{-1}$)	Replacement time （ h ）
highway-railway	4.57	3.8
highway-waterage	5.66	4.5
railway-waterage	6.83	5.4

Table 4 Top 16 routes with the lowest transportation costs after the update (including replacement costs and time)

Transport routes	Transportation costs (yuan)	Transportation time (h)	Replacement times
1-railway-2-waterage-4-waterage-6	144783	59.7	1
1-waterage-3-railway-4-waterage-6	148314	69.9	2
1-waterage-3-railway-5-waterage-6	149487	64.2	2
1-railway-2-waterage4-waterage-5-waterage-6	144783	62.4	1
1-waterage-3-highway-4-waterage-6	148314	52.4	2
1-highway-2-waterage-4-waterage-6	149487	52.1	1
1-waterage-3-railway-4-waterage-5-waterage-6	150027	72.6	2
1-railway-2-railway-4-waterage-6	150228	52.8	1
1-waterage-3-highway-4-waterage-5-waterage-6	152118	65.2	2

1-highway-2-waterage-4-waterage-5-waterage-6	153558	54.9	1
1-waterage-3-railway-5-highway-6	154308	55.0	2
1-railway-2-railway-4-waterage-5-waterage-6	155472	55.5	1
1-railway-2-waterage-4-waterage-5-highway-6	156762	60.3	2
1-waterage-3-railway-4-railway-5-waterage-6	156813	67.1	2
1-railway-2-waterage-4-railway-5-waterage-6	159552	67.7	3
1-waterage-3-railway-4-waterage-5-highway-6	159729	69.6	3

As can be seen from Table 4, after adding the cost and time of node replacement, the data in the table have changed to some extent compared with Table 2, but the general trend remains unchanged, that is, the cost of routes with more waterway transportation modes is obviously lower. Because the cargo demander requests to receive the cargo within 56 hours, it can be clearly seen from Table 4 that the transportation cost of using 1-waterage-3-highway-4-waterage-6 is the lowest, which is 148314 yuan, which is the optimal path in this example.

4. Conclusion

Multimodal transport, as the most commonly used mode of long-distance transport in the world, has incomparable advantages. Compared with a single mode of transport, this mode of transport has the characteristics of fast transport speed, low transport costs and more flexibility. This paper calculates the lowest cost routes of the first 16 transport routes in a multimodal transport network by using KSP algorithm, combining with time constraints and other constraints. After obtaining the lowest cost routes of the first 16 transport routes, this paper calculates the node reloading time and cost according to the reloading situation of each route, and then calculates the total cost of the 16 routes including reloading nodes. The transportation cost and time are updated, and finally the minimum transportation cost path satisfying the time constraints is obtained according to the time stipulated by the cargo demander, which realizes the path optimization.

In the constraints of this paper, it is assumed that the cargo flow from the starting point to the end point is uninterrupted, and the weight of the cargo from the starting point to the end point does not change. However, there may not be only one end point of goods in the actual multimodal transport, and some of them may use a transit node as the end point of transportation. Therefore, when this happens, the above model and algorithm need to be further improved.

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