Research on Generalized Multimodal Transport Cost Assignment Model Based on Super Transportation Network

Yonghong Zhang

CCCCC Infrastructure Maintenance Group CO., LTD, Beijing, China

Corresponding author’s e-mail: 43968490@qq.com

Abstract. In view of the problem of independent demand prediction and lack of overall integration in the current comprehensive transportation spatial planning, this research establishes a unified research framework by setting up a super transportation network, based on GIS platform in consideration of multi-modal transport demands in sectors such as railway, highway, waterway, civil aviation, postal service and pipeline. The county-level comprehensive traffic zones are established, incorporating various demands of each transport mode. This paper innovates the method of modal split prediction, via the use of passenger and cargo transportation functions to perform multimodal generalized cost model prediction distribution on the super transportation network, thus providing technical support for the integration of comprehensive transportation planning.

Keywords. integrated transportation, spatial planning, super transportation network, multimodal generalized cost model

1. Introduction

According to China’s Program of Building National Strength in Transportation, issued by the CPC Central Committee and the State Council of China, the development of transportation shall be promoted in making a shift from the pursuit of speed and scale to more emphasis on quality and efficiency, from the relatively independent development of various modes of transportation to more emphasis on integrated development, and from reliance on driving forces generated by traditional factors to more emphasis on innovation-driven transformation (hereinafter abbreviated to “three transformations”).

It is the fundamental requirement to build a safe, convenient, efficient, green and economical modern comprehensive transportation system under the strategic guidance of building national strength in transportation, by focusing on the “three transformations”. Following the above-mentioned principles, this paper analyzes the spatial distribution of population and industry in China, summarizes the characteristics and trends of the spatial flow of people and logistics, and explores to establish a multimodal generalized transportation cost flow distribution model based on a super transport network (including accurate geographic and other basic information in transport modes of railway, highway, waterway, civil aviation, post service, and pipeline), therefore offering support for building a three-dimensional national integrated transport network and developing China’s comprehensive transport service.

1.1. Connotation of comprehensive traffic flow distribution
The comprehensive traffic flow distribution highlights the concept of “three transformations”. The establishment of an accurate multimodal analysis network (with quantitative research on the relationship with inventory and incremental transport) reflects the transformation of building transport network from relying on traditional factors to paying more attention to innovation. In line with the requirements of economic and social development, this paper conducts research on the distribution trend and characteristics of comprehensive traffic flow and flow direction, identifies efficient ways and important routes, guides the intensive development of multimodal routes, so as to shift the development of transportation from pursuing speed and scale to paying more attention to quality and efficiency.

1.2. Requirements and assumptions for national integrated traffic flow assignment

The basic requirements for integrated traffic flow distribution are listed as follows: 1. establishment of an abstract and simplified multimodal integrated traffic network; 2. information concerning traffic and carrying capacity of multimodal transport routes and hubs; 3. a multimodal transport OD chart for traffic flow distribution; 4. creation of a path resistance function reflecting the relationship between multimodal traffic flow and travel time; 5. creation of a flow distribution model based on technical and economic characteristics of multimodal transport [1–3].

Achieving truly fusion of multimodal transport on this basis requires a unified analytical framework. The basic requirements are transformed into the following: 1. establishment of a multimodal traffic network with basic information and interchangeable traffic; 2. building comprehensive traffic zones which integrate the needs of multimodal transport; 3. The comprehensive requirements of various modes of unified integration are allocated to the super transportation network through a generalized cost model that coordinates multimodal transportation characteristics according to passenger and cargo transportation functions.

In consideration of supporting relevant research concerning National Comprehensive Three-dimensional Transportation Network Planning Outline of China (hereinafter referred to as Planning Research), the main premise assumptions are made for national comprehensive traffic flow distribution according to the scope, precision conditions and research requirements at the national level.

National comprehensive traffic flow distribution is based on national planning and management, with static data to predict medium and long term traffic flow trend characteristics.

The national comprehensive traffic flow distribution focuses on the county administrative unit as the object of demand research, stresses on the traffic communication relations among counties, cities, provinces and regions, with no attention to the traffic flow within counties. Limited by the data, the demand forecast of international traffic is not taken into account.

The national transportation network is divided into line network system and hub system. The planning scope is the state-level route position and hubs, while the hub is the accuracy of port and station, so as to facilitate road network connection and flow distribution.

Considering the innovation impact brought by future science, technology and management, the capacity of road sections may be improved [4].

Input accurate attribute information for the current infrastructure, make attribute assumptions for the infrastructure within the planning range based on experience, and make appropriate traffic demand reductions based on the experience for the scale of unplanned and uncertain infrastructure.

Based on national conditions and combined with the strategic goal of building national strength in transportation, the national comprehensive transportation assignment gives priority to public transportation means, that is, to improve the transportation quality of people and goods flow through the development of large-capacity and high-quality public transportation services.

Except for postal nodes, postal transportation service mainly depends on the network of other modes of transportation. Postal demand is integrated into the other five modes of transportation, so the supply of postal lines and network is not considered separately.

2. Methods
2.1. Establish a unified analysis and research framework

1) Establish a super transportation network

The establishment of a super transportation network is the basis for the comprehensive traffic flow distribution. Its method is to establish the railway, highway, waterway, civil aviation and pipeline network on a unified standard platform, and realize the organic connection of the network through integrated transportation hubs. As for the current facilities, the accurate geographic information and attribute data of the road network and the port station hub are input, based on the GIS platform. Reasonable assumptions are made for the planned facilities. For example, in the eastern part of China, motorways are planned to use 6 lanes, while for the western part of China, motorways are planned to use 4 lanes. The transportation airports are planned according to different functional levels. The national transportation airports are planned to be 4E-level airports, etc. Port hubs are planned to be connected with the transportation network. The traffic flow realizes route conversion through port hubs. The location of roads and port hubs are planned, according to the following principle. County-level administrative centers across the country are planned to access to the nearest national highways in 15 minutes and motorways in 30 minutes. Prefecture-level administrative centers are planned to access to the nearest high-speed train and airport within 45 minutes and 60 minutes, respectively.

2) Establish comprehensive traffic zones

The following three principles should be taken into account in the establishment of comprehensive traffic zones.

   a) In principle, the traffic zones shall be composed of county-level administrative regions, without crossing prefecture-level divisions.

   b) Internal traffic flow should not be too large and should be controlled at 10%.

   c) They have long-term adaptability and stability.

Based on the research and analysis of 2,861 administrative units in China, 2,540 comprehensive traffic zones are identified.

3) Integrate transportation needs of various modes in comprehensive traffic zones through passenger and cargo transportation functions

Starting from the function and essence of passenger and cargo transportation services, a unified framework is established for the integration of various transportation modes, such as railway, highway, waterway transportation, civil aviation, pipeline, and postal service.

The occurrence quantity and attraction quantity of various modes of transport are superimposed to synthesize the occurrence quantity and attraction quantity of passenger and freight transportation in comprehensive traffic zones [5].

   a) The total amount of freight generated and attracted in the comprehensive transportation zones

      (1) The occurrence quantity and attraction quantity of 580 railway zones are allocated to the corresponding comprehensive transportation zones according to factors, such as the GDP ratio of the comprehensive transport zones within their scope, the distance from the railway stations, as well as certain road transportation discounts.

      (2) Add the occurrence quantity to attraction quantity (taking into account certain discounts), inferred from the volume of freight transported at the entrance/exit of the motorway (weight-based tolling) and on ordinary national highways, so as to get the volume of traffic generated and attracted in the corresponding comprehensive traffic zones.

      (3) The local freight volume of the port is included in the comprehensive transportation zones where the port is located (As for the occurrence and attraction volume that is not generated locally, it has been reflected in other collection and distribution methods).

      (4) Considering that the pipeline transportation flow and flow direction are relatively fixed, the transportation of crude oil and natural gas of its main cargo is relatively independent and mainly involves the connection with ports, so its demand is not included in the comprehensive traffic zones and its flow distribution is not within the unified analysis framework.
(5) Air freight belongs to high added value and small volume freight, and its absolute weight is small, which is not included in the unified analysis framework. Considering the value of its cargo, the aviation hubs involved should be considered in the planning layout.

\textit{b) Total occurrence and attraction of passenger transport in comprehensive traffic zones:}

1) The occurrence and attraction of the 580 railway zones shall be distributed to the corresponding comprehensive traffic zones according to the population proportion of the comprehensive traffic zones within its scope, in consideration of some reduction of road transport.

2) Add the occurrence and attraction quantity of passenger transport (considering a certain reduction) for the motorway and ordinary national highway, obtained from the passenger traffic volume of the motorway and ordinary national highway (converted according to the average number of vehicles in the traffic survey), as the road occurrence and attraction volume for the corresponding integrated traffic zones, using mobile internet location data and mobile phone signaling data to check the number of people.

3) The occurrence and attraction quantity of civil aviation airports shall be allocated to the corresponding comprehensive transportation zones, according to the population proportion in the comprehensive transportation zones within the airports’ radiation range. A certain highway transit reduction is considered (determine the proportion, population and distance, according to the radiation range).

4) The volume of passenger transport by waterway is small, which is not included in the comprehensive traffic zones.

\textit{4) Traffic generation volume and distribution prediction under the unified analysis framework}

Based on the aforementioned basis and the needs of supporting the Planning Research, the study adopts the bottom-up administrative unit at the county level for the nodes, calculates the traffic growth coefficient in prefecture-level cities according to the influencing factors, such as population and industrial layout, and then conducts comprehensive traffic generation volume forecast for county-level zones (2540 comprehensive traffic zones), and controls from top to bottom at national and regional level to determine the occurrence and attraction of traffic forecast in 2050 (Figures 1 and 2). This study forecasts the national passenger and freight transportation demand distribution in 2050, based on the Fratar Method and the gravity model method, in accordance with the data and characteristics of the flow direction of each transport mode, combined with the development and utilization of land space, regional development strategy, urbanization system, urban agglomeration development pattern and other influence change trends.

\textbf{Figure 1.} 2050 National Freight Traffic Flow Expectation Line
2.2. Analysis of multimodal generalized cost model

According to the technical and economic characteristics of multimodal transport, this paper estimates travel time, travel cost and generalized cost with related attributes, and then establishes the generalized cost model with the actual road network distribution, thus exploring innovative ways to the modal split forecast, by highlighting the concept of developing transport modes according to real conditions.

1) Analysis of technical and economic characteristics and comparative advantages

In modeling a multimodal transport generalized cost, it is necessary to first analyze the technical and economic characteristics of each mode of transportation. Through research and comparison, the advantages of railway transportation are large capacity, fast speed, and low cost, while its disadvantages are narrow coverage, poor accessibility, and high cargo damage. Moreover, due to the huge fixed capital and the inflexibility of operation, operating costs often increase. Railway transportation is generally considered to be suitable for long-distance, large-volume passenger and cargo transportation. The advantages of road transportation are wide coverage, strong adaptability, direct accessibility, and flexibility. However, its disadvantages are large land occupation, high energy consumption, large environmental pollution, and many traffic accidents. Road transportation is generally considered to be suitable for short and medium distance, small-batch passenger and cargo transportation. The advantages of waterway transportation are small land occupation, large transportation capacity, low energy consumption, and low cost, while its disadvantages are the restriction by natural conditions, narrow coverage, poor accessibility, slow transportation speed, and poor punctuality. Waterway transportation is generally considered to be suitable for large-volume, low-value, long-distance bulk cargo transportation, sightseeing passenger transportation with loose travel schedules, and small-batch passenger transportation across rivers and land islands. The advantages of air transportation are high speed, safety, comfort, and less cargo damage, but its disadvantages include large investment, high cost, together with limited volume and weight of cargo, so it is generally considered to be suitable for domestic and international long-distance passenger transportation, as well as long-distance transportation of emergent, high value-added, and fresh goods. The main advantages of pipeline transportation are large transportation capacity, low cost, less land occupation, low energy consumption, less pollution and high safety. It is easy to realize automatic management. However, pipeline transportation has limited cargo types and single flow direction, which is mainly used for oil and gas (see Table 1).
Table 1. Comparative Advantages for Each Mode of Transport

| Criteria       | Specific indicators                          | Degree of comparative advantage |
|----------------|----------------------------------------------|----------------------------------|
|                |                                              | Railway | Road  | Waterway | Aviation | Pipeline |
| Economic       | construction cost                           | Railway  | Road  | Waterway | Aviation | Pipeline |
|                | equipment acquisition cost                  | 3       | 2     | 4        | 1       | 5        | 1       |
|                | operation and maintenance cost              | 2       | 4     | 3        | 5       | 1        |
|                | transport price (passenger transport)       | 3       | 2     | 1        | 4       | —        |
|                | transport price (freight)                   | 2       | 4     | 1        | 5       | 3        |
|                | transport capacity                          | 2       | 4     | 1        | 5       | 3        |
|                | transport distance (passenger transport)    | 2       | 3     | 4        | 1       | —        |
|                | transport distance (freight transport)      | 3       | 5     | 2        | 1       | 4        |
| Efficient      | speed                                        | 2       | 3     | 4        | 1       | 5        |
|                | punctuality                                 | 2       | 3     | 4        | 5       | 1        |
| Convenient     | mobility                                     | 3       | 1     | 4        | 2       | 5        |
|                | transfer convenience (passenger transport)  | 2       | 1     | 3        | 4       | —        |
|                | loading and unloading transit time (freight) | 4       | 2     | 5        | 3       | 1        |
|                | reliability (climatic conditions)           | 2       | 3     | 4        | 5       | 1        |
|                | passenger comfort                           | 2       | 3     | 4        | 1       | —        |
| Safe           | accident rate                               | 3       | 5     | 4        | 2       | 1        |
|                | freight loss and damage                     | 5       | 3     | 4        | 2       | 1        |
| Green          | land occupation                             | 4       | 5     | 2        | 1       | 3        |
|                | energy consumption                          | 3       | 4     | 1        | 5       | 2        |
|                | greenhouse gas emissions (passenger transport) | 1       | 2     | 4        | 3       | —        |
|                | greenhouse gas emissions (freight)          | 2       | 4     | 3        | 5       | 1        |
|                | environmental pollution                     | 3       | 5     | 4        | 2       | 1        |

Note: The figures from small to large in the table show the status from good to bad.

2) Main influencing factors for modeling multimodal generalized cost
Main factors influencing the flow distribution of multimodal generalized cost model include transportation time, price, traffic congestion, transportation waiting time, safety and reliability, etc.

a) Transportation time: The transportation time of different transportation modes is mainly affected by speed. The faster the running speed, the shorter the travel time, the higher the probability of transportation demand to choose the path of this mode. The more traffic is allocated, and vice versa. Taking passenger transport as an example, the running speed of motorway, national highway, high-speed railway, ordinary railway and airplane is 80-120 km/h, 40-80 km/h, 300 km/h, 120 km/h, and 600-800 km/h, respectively. The passenger transport speed is different under different modes and conditions. The faster the speed, the higher the probability of selecting the route under certain economic cost conditions.

b) Transportation price: The higher the transportation price, the higher the transportation cost, and the smaller the probability of choosing this mode of transportation. Take passenger transport as an example. The air transport price is the highest, while the ordinary railway transport price is the lowest.

c) Traffic congestion: Traffic congestion refers to the time delay of the mode of transportation caused by the amount of traffic exceeding the transportation capacity. The longer the congestion is, the less likely the route is chosen, and the transportation speed will decrease due to the congestion.

d) Transportation waiting time: It represents the waiting time in the process of transportation, such as the waiting time at the railway station and airport, transfer waiting time, freight marshaling and transferring time, loading and unloading time, etc. The longer the waiting time, the lower the probability of choosing this transportation route.

e) Time value: Different users have distinct sensitivities to transportation time due to various transportation purposes. Some people are time-sensitive, so they choose the transportation modes and routes with shorter transportation time. On the other hand, some users are not sensitive to time, so they choose the transportation modes and routes with longer transportation time.

f) Transportation safety and reliability: Different users have different requirements for comfort, safety and reliability for various transportation modes. This is one of the reasons for deciding whether or not to travel in different ways.

3) Composition of generalized cost of multimodal passenger and freight transport

a) Composition and calculation of generalized cost of multimodal passenger transport

The generalized cost of multimodal passenger transport is the sum of all consumption of consumers in the passenger transport process, which is generally composed of economic cost (money) and non-economic cost (converted into money) [6]. The former is mainly the fare cost of each mode of passenger transport during the journey, while the latter mainly includes the cost of time value, comfort and safety. The generalized cost of multimodal passenger transport is calculated as follows:

\[ C_p = P + T + C + S \]

- \( C_p \): Generalized passenger transport cost of multimodal passenger transport service, RMB/person.
- \( P \): Fare charges for passenger transport services, including fare charges for various modes of transport in the transport services, and interchange transfer time charges for various modes of transport, RMB/person.
- \( T \): Time value charges for passenger transport services, including travel time charges for various modes of transport and connecting transfer time charges between modes of transport.
- \( C \): Comfort cost of passenger transport service, RMB/person;
- \( S \): Passenger transport service security fee, RMB/person;

(1) Passenger fare:

\[ P = \sum_i \alpha_i D_i \]

In the formula,\n- \( P \): passenger transport service fare, RMB/person;
- \( \alpha \): rate for passenger transport service type \( i \), RMB/person *km;
- \( D_i \): transport distance for passenger transport mode of type \( i \), km;

(2) Passenger time value cost:
\[ T = \text{VOT} \times (\sum_i \frac{D_i}{v_i} + t) \]

In the formula, \( T \) - transportation time cost of passenger transportation service, RMB/person.

\( \text{VOT} \) - per capita output value per unit time of passenger travel, RMB/person*h,

\[ \beta = \frac{v_a}{p \times T_a}, \quad Y_a \text{ is the regional GDP, } P \text{ is regional population, } T_a \text{ is average working time of workers.} \]

\( D_i \) - distance travelled by the type \( i \) mode of transport, km;

\( v_i \) - travel speed for the type \( i \) mode of transport, km/h;

\( t \) - total connecting transfer time between modes of transport, h.

(3) Comfort expense:

\[ C = C \times C \]

In the formula, \( C \) - comfort cost of passenger transport service, RMB/person;

\( \gamma \) - travel comfort monetary value, RMB/person;

\( C \) - passenger rating of overall comfort of transport service, \( 0 < C < 1 \), dimensionless.

(4) Security cost:

\[ S = \frac{N \times A \times C}{TV} \]

In the formula, \( N \) - annual number of traffic accident deaths for a certain mode of transport, with the unit of person;

\( A \) - per capita annual output value, with the unit of RMB/person per year,

\( TV \) - annual transport turnover of the mode of transport.

b) Composition and calculation of multimodal freight generalized cost

The generalized cost of multimodal freight is the sum of all the costs in the process of goods transportation, which is generally composed of economic cost (money) and non-economic cost (converted into money). The former is mainly the freight charges in the process of transportation, while the latter mainly includes the cost of time value of goods, and the risk cost of safety loss of goods. The generalized cost of multimodal passenger transport is calculated as follows:

\[ C_f = P + T + S \]

\( P \): freight charges, RMB/t;

\( T \): time value cost of goods, RMB/t.

\( S \): safety loss fare in cargo transportation, RMB/t.

(1) Freight charges:

\[ P = \sum_i a_i \times D_i \]

In the formula, \( a_i \) - freight charges, RMB/t;

\( D_i \) - freight rate for the \( i \) type mode of transport, RMB/t*km;

\( D_i \) - transport distance for the \( i \) type mode of transport, km.

(2) Time value cost of goods:

\[ T = \text{VOT} \times (\sum_i \frac{D_i}{v_i} + t) \]

In the formula, \( T \) - the transit time cost of freight transport, RMB/T;

\( \text{VOT} \) - time value per unit of freight transport, RMB/person*h.

\[ \beta = \frac{(P + C_L) \times R}{365 \times 16} \]

\( P_r \) is the average value of goods [7], \( C_L \) is the cost of logistics and storage, and \( R \) is the social discount rate.

(3) Cargo loss risk expense:

\[ S = \gamma \times S \]

In the formula, \( S \) - cost of loss risk in cargo transportation, RMB/t;
\[ \gamma = \text{money value of transport costs, RMB/t}; \]
\[ s = \text{evaluation grade of cargo transport loss risk, in consideration of cargo loss risk and cargo loss risk, } 0 < c < 1, \text{ dimensionless.} \]

3. Results

3.1. Construction of generalized cost model concerning multimodal comprehensive transportation

Traffic flow distribution is the most important step in the process of traffic demand forecast. Combined with the multimodal technical and economic features, traffic flow assignment is unified to the essential function of passenger and freight transport, through the multimodal passenger and freight transport generalized cost assignment model in the super distribution on the transportation network, based on the exact route and mode interchange, transit costs, and synchronization of mode selection in the distribution process, thus innovating modal split forecasting methods.

1) Modeling multi-modal generalized cost of integrated transport

Based on the aforementioned research and analysis of the multimodal generalized cost, the components involved in passenger and cargo transportation are normalized according to the calculation method and standard of the generalized cost composition. The biggest innovation of the multimodal generalized cost model is to increase the parameters in consideration of the transfer cost of passenger and freight transportation between different modes, and reasonably determine the distribution path, based on the GIS platform, which truly embodies the planning concept of developing transport modes according to their relevant advantages and disadvantages, therefore effectively meeting the technical requirements of “Planning Research”, and making the boundary conditions more compatible with reality. The following basic assumptions are mainly made in modeling:

a) In order to simplify model calculations, this model highlights economy and timeliness. Generalized passenger and cargo transport cost = transportation cost + time value. The generalized cost simulation is mainly combined with the transportation distance, the time of transportation, transfer and transit time and time value of each mode. Furthermore, some factors affecting comfort and safety are integrated into these two parts.

b) Freight: Divide the future transportation demand into a fixed part of the transportation mode and a competitive selection part, for different modes of transport. For example, in freight transportation, the future growth of bulk materials is adopted as a fixed part of railways, which is less competitive with roads, while road transport and railway transport compete with each other for bulk and other types of goods.

c) Waterway freight is largely restricted by natural conditions, with fixed transport routes. As the intermediate link of transportation, waterway freight is not the final destination for the occurrence/attraction of the goods. Most cargo needs to enter the port by rail or road, or be sent from the port to the destination by other means of transport. In addition to locally produced goods, most of the waterway freight is reflected in road and rail transportation. Waterway transportation demand is taken into account for the multimodal transport assignment. However, waterway transportation routes are not allocated. The freight network distribution mainly involves two modes of transport (road and rail), thus highlighting the characteristics of freight routes and network.

d) Passenger transportation: According to the future income structure of the population, the passenger travel structure is divided, in combination of the current passenger transportation mode structure. It is assumed that the middle and high-income people mainly travel by high-speed railway and airplane (high-income people pay more attention to comfort and safety), while low income people mainly choose ordinary railways and highways for mobility. This passenger transportation distribution network mainly considers three modes: road, rail and air, highlighting the characteristics of the line network.
In the formula:

\[ gC_{m} = \sum_{i \in A_{OD}^{m}} \left\{ VOC_{m} \cdot VDF(t_{a}, c_{a}, \ldots) + F T_{a}^{m} \right\} + \sum_{a \in M_{OD}} MT_{i}^{m} \]

In the formula:

- \( gC_{m} \) = generalized cost between the starting and ending points of transport mode \( M \)
- \( m = \) Modes of transportation (including road, railway, civil aviation)
- \( a = \) various road sections
- \( OD = \) origin-destination
- \( A_{OD}^{m} = \) the set of all segments on the shortest path from point \( O \) to \( D \) for mode \( M \)
- \( VOC_{m} = \) corresponding time value of passenger and freight transport for mode \( M \)
- \( t_{a} = \) transport time of section \( A \)
- \( c_{a} = \) maximum transportation capacity of section \( A \)
- \( F T_{a}^{m} = \) corresponding transportation price of section \( A \) under mode \( M \)
- \( M_{OD} = \) all nodes (hub nodes) based on the road section between starting and ending points corresponding to mode \( M \)
- \( MT_{i}^{m} = \) passenger and cargo transfer price at node \( I \) for mode \( M \), including passenger transfer, freight turnover assembly and warehousing
- \( VDF = \) transport delay function

The VDF function usually adopts the DELAY function of the US Highway Administration:

\[ T = t_{f} \left( 1 + \alpha \left( \frac{X_{a}}{C} \right)^{\beta} \right) \]

\( t_{f} = \) free flow running time for the section
\( X_{a} = \) passenger and freight capacity of section \( A \)
\( C = \) maximum transportation capacity of the section
\( \alpha = \) parameter
\( \beta = \) parameter

The multimodal generalized cost function comprehensively considers such influencing factors as passenger and cargo transportation time, transportation price, traffic congestion, transportation waiting time and time value, and makes normalization, and then transforms it into the generalized cost, thus forming a combinable and measurable transportation cost function among multiple modes.

3.2. Integrated traffic logit assignment Modeling based on super transport network

On the basis of the unified analysis and prediction of comprehensive traffic demand on the super traffic network, the multimodal transport generalized cost route (transportation cost + time cost) is analyzed from origin to destination (via the generalized cost function), which forms the foundation of traffic volume distribution. It is a mature method to adopt logit model base on super network to predict the traffic flow share ratio of each route in the transportation corridor. The logit model and utility function are used to study the traffic flow share ratio under the condition of multimodal generalized cost, and the stochastic equilibrium state of the transportation network is finally realized through iterative calculation. The following assumptions are made for fast convergence modeling:

1) Allocate routes which make the railway station, the motorway toll station and ordinary highway, connect with the county-level administrative centers within 15 minutes’ drive. Make relevant connection and calculate the distance.

2) Based on the hub connection theory of super transportation network, the utility value is converted for different levels of hub setting modes.

\[ P(k) = \frac{e^{V(k)}}{\sum_{k=1}^{n} e^{V(k)}} \]
\[
\sum_{k=1}^{n} P(k) = 1
\]

In the formula: \( P(k) \) — the sharing rate of the selected \( K \) line, \( k=1, 2, \ldots, n \);
\( V(k) \) — the utility function for selecting \( K \) line
\[
V(k) = \sum_{k=1}^{n} \omega_{i} \cdot X_{i}(k)
\]

In the formula: \( \omega_{i} \) — the weight of the \( i \) type influencing factor, \( i=1, 2, \ldots, m \);
\( x_{i}(k) \) — generalized cost function of influencing factors \( I=1,2, \ldots, m \) of the \( K \)-th transportation mode.

3.3. Verification of the comprehensive transportation multimodal generalized cost model

Based on the current road network, the 2018 National Highway Cross-sectional Traffic Volume and Railway Statistical Yearbook are adopted to verify the distribution of generalized passenger and freight cost model.

80 lines and 645 cross sections of the railway have been checked (according to the 2018 Railway Statistics Yearbook). The average section length is 64 kilometers, and the accuracy rate is 75% (Figure 3).

**Figure 3.** Comparison chart of freight statistics and distribution data for the Beijing-Baotou Railway

On the basis of the cross-section traffic flow of the highway interchange station (converting the cross-section traffic flow into passenger and cargo traffic), the assignment of about 6,100 kilometers of national highways have been checked. According to the distribution and assignment of traffic survey stations, the checked road sections are generally controlled within 100 kilometers, with an approximate accuracy rate of 75% (Figure 4).
Figure 4. Comparison chart concerning G4 Beijing-Hong Kong-Macao Motorway intersection observation data and model distribution data

4. Conclusions
The Research innovatively establishes a unified analysis framework. For the first time, 2,540 county-level comprehensive transportation zones have been established nationwide, combined with the national population and industrial layout to predict the distribution of traffic demand. Based on the GIS platform, the geographic and attribute information of the current transportation network have been input, and the planned transportation network has been reasonably assumed. For the first time, a super multimodal transportation network has been built with various transport hubs.

Based on the in-depth study of the current OD distribution of each mode, this paper analyzes the technical and economic characteristics of each transport mode, normalize the economic and non-economic costs of its transportation, build a multimodal generalized cost model. Combined with the actual routes of the super transportation network, the combined efficiency and comparative advantages of the modes have been fully utilized, and the multimodal generalized cost flow distribution has been carried out, and the model has been verified, thus innovating the forecasting method for the comprehensive multimodal transportation network, reflecting the concept of developing transport modes, according to their relevant advantages and disadvantages.

References
[1] Shao Chun Fu, Dong Chun Jiao, Zhao Dan, Meng Meng, Wang Bin Bo. Trip Behavior Analysis and Theoretical Method for Multimodal Collaborative Organization on Urban Transportation System. Beijing: Publishing House of Electronics Industry, 2018.
[2] Lu Huapu. Theory and Method in Transportation Planning. Beijing: Tsinghua university press, 2007.
[3] Yang Tao. The Plan of Highway Network. Beijing: China Communications Press, 2004.
[4] Zhou Ronggui, Zhong Lian’d. China Highway Capacity Manual. Beijing: China Communications Press, 2017.
[5] Zhang Huaping, Tan Siqi. On the Direct Relationship and Conversion between Freight Volume and Traffic Volume. Highway Traffic Science and Technology, vol. 7, pp. 7: 72-76, 2004.
[6] Jia Shun Ping. Economics of Traffic and Transportation. *Beijing: China Communications Press*, 2015.

[7] Wang Hai-yang, Zhou Wei, Wang Yuan-Qing. Research on Methods for Value of Time Determination for Freight Transport. *Journal of Highway and Transportation Research and Development*. 