

The Model Research of Urban Land Planning and Traffic Integration

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Abstract. The urban spatial layout, traffic demand forecast, and traffic planning cannot work without the support of system science. There is the interaction between the urban spatial layout and the traffic demand. The former is the generating source of the latter, and the latter has a guiding role on the former. Specific performance is that public transport (especially the rail transit in the Chinese big city) guides urban spatial layout and structural adjustment. It has been verified in many cities at home and abroad and its effect is obvious. Taking Shanghai as an example, this paper analyzes and puts forward the internal relationship of the urban spatial layout, the land use and the traffic demand to provide the references for the city traffic infrastructure planning and construction.

The Functional Structure

Shanghai urban spatial layout and traffic demand integration model can be divided into three big functional modules, such as the analysis of urban land use, the analysis of the traffic demand and the evaluation of traffic system and so on. Compared with other models, this model pays more attention to the interaction among the three, namely the land, demand and facilities. It achieves the balance between systems by iterative calculation for many times.

The key indicator of integration between the land and the traffic is transportation accessibility. The indicator of transportation accessibility includes the traffic time, transportation costs, alternative types of traffic mode and so on. we can calculate the balance between urban land use and transportation by determining the scoring criteria of these indicators. We consider that the model mainly focuses on macro-level research, so we select the traffic time as the evaluation indicator of transportation accessibility in this model.

The Functional Structure of Land Module. Land module is used to study the historical evolution law and the future trends of Shanghai urban spatial layout. And it includes location, form, , area, population, jobs and other submodules.

Location, Location is one of the basic characteristics of urban land. The location refers to we use the Geography concept to describe the social and economic attributes of urban land. It includes geographical location, land rent, transportation, population density, post density and other indicators. We consider the actual availability of these indicators, we select population density and post density as the evaluation indicator of Shanghai location.

Form, Form refers to the structural characteristics of the urban land-use spatial layout. The sub-models select the concentric circle, the axis, the ribbon, the star and other four kinds of urban layout as the possible future trends of Shanghai city. The evaluation indicator of the urban layout includes population density, post density and so on.

Area, Area is one of the natural attribute of the urban land, and it includes the land area and construction area of all kinds of construction land and other indicators. In the circumstances of determining the total amount of the land area and construction area of all kinds of construction land,

it calculates the spatial distributions of all kinds of construction land area combining with the form of urban layout. It is also important precondition for determining population distribution and post distribution.

Population Distribution, Population distribution is one of the social and economic characteristics with urban layout. In the circumstances of determining the whole city's total population size, it calculates the spatial distributions of population combining with the form of urban layout. It is also an important indicator for determining post distribution.

Post Distribution, Post distribution is one of the social and economic characteristics with urban layout. In the circumstances of determining the whole city's total post scale, it calculates the spatial distributions of post combining with the form of urban layout.

We can sketch a picture of the basic appearance of Shanghai urban land layout by analyzing the above five indicators.

The Functional Structure of Traffic Module. Traffic module contains two big submodules, namely traffic demand and traffic facilities. The point with balance between traffic demand and traffic facilities is the balance of demand and supply. We consider that the model mainly focuses on macro-level research, so we select the degree of saturation as the evaluation indicator of transportation accessibility in this model.

The Traffic Demand, The submodules of traffic demand are used to calculate the travel of people, the travel of vehicles, the travel of goods and the travel characteristics with all kinds of traffic demands, including travel generation, travel distribution, travel mode and so on.

Travel Generation, There are two endpoints in a travel, namely the travel generation point and the travel attraction point. The travel generation is used to calculate the total amounts and spatial distributions of the travel generation point and the travel attraction point respectively. The total amount of travel generation and travel attraction should be the same.

Travel Distribution, Travel generation only determines the number and distribution situation of the travel's two endpoints. The travel distribution determines the relationship between travel generation and travel attraction further. That is to say, which generation and which attraction form a travel. It has a close relationship with the land-use structure in traffic zones where travel's two endpoints locate, the traffic impedance between two zones (time consumption, cost, distance, etc), people's living habits and so on.

The Algorithm Function

The Algorithm Function of Land Module. The algorithm function of land module includes the methods for statistics and calculation of location, form, area, population distribution, post distribution and other indicators.

Location, The urban layout belongs to the macro-level research. Therefore, according to the usual practice of international description about the metropolitan location, we make the district of Shanghai City be divided into four districts, namely Central Business District (CBD), central urban district, the surrounding suburban district and the remote suburban district. And we take the population density and the post density as quantitative indicators of every district.

The regional areas of CBD between the three metropolises, Tokyo, New York and London are relatively close. And the variation between them is 23-42 square kilometers. The regional post density of CBD in Tokyo, New York is very high. And they are respectively 57,000 per square kilometers and 86,000 per square kilometers. The regional population density of central urban district in Tokyo, New York is relatively close. And they are respectively 13,800 persons per square kilometers and 9,500 persons per square kilometers.

We use the statistical indicators of the above several cities for reference and considers the present situation with the characteristics of population density and post density in Shanghai's actual built-up area.

If the post density of the districts is more than ten thousand people per square kilometers, these districts are the district of CBD in Shanghai. If the population density of other districts outside CBD is more than ten thousand people per square kilometers, these districts are central urban districts. If the population density of other districts outside CBD and central urban district is 0.3-1.0 ten thousand people per square kilometers, these districts are the surrounding suburban districts. Other districts except the above three areas are the remote suburban districts.

Form, This model still selects the population density and post density as the main indicators to distinguish the concentric circle, the axis, the ribbon, the star and other four kinds of urban layout forms.

Area, We mainly use The land area and the construction area of various types of land mainly use the detailed planning from the establishment unit of central urban district and the overall planning data from suburban districts and counties to calculate the present areas of all kinds of lands, the areas of all kinds of lands for the future development and so on.

Population Distribution, We consider the availability of actual data in Shanghai and we make this model simplify DRAM and we can get the basic form of population distribution model. The simplified basic form of population distribution model can be seen as follows:

$$N_i = \lambda \cdot [\sum_j W_j f(c_{ij}) / \sum_i \sum_j W_i f(c_{ij})] + (1 - \lambda) N_{i(t-1)} \quad \text{Formula 1}$$

N_i : Number of forecast population in community i;

$N_{i(t-1)}$: Population number of current situation in community i;

W_i : $W_i = L_i \cdot (1 + x_i)$, x_i is the ratio of area of undeveloped planning residential land and area of developed residential land in current situation in community i;

$f(c_{ij})$: Forecasting annual travel costs function going from community i to community j.

$$f(c_{ij}) = a \cdot c_{ij}^b \cdot e^{-c \cdot c_{ij}}$$

Post Distribution, Likewise, we make this model simplify this model simplifies DRAM and we can get the basic form of post distribution model. The simplified basic form of post distribution model can be seen as follows:

$$E_i^k = \lambda \cdot [\sum_j W_j f(c_{ij}) / \sum_i \sum_j W_i f(c_{ij})] + (1 - \lambda) E_{i(t-1)}^k \quad \text{Formula 2}$$

E_i^k : Forecasting post number of the k^{th} kind in community i;

$E_{i(t-1)}^k$: Current-situation post number of the k^{th} kind in community i;

W_i : $W_i = L_i \cdot (1 + x_i)$, x_i is the ratio of area of undeveloped planning residential land of the k^{th} kind and area of developed residential land of the k^{th} kind in current situation in community i;

$f(c_{ij})$: Forecasting annual travel costs function going from community i to community j.

Algorithm Function of Traffic Accessibility. For quantitative description of traffic accessibility, the common formula is Hansen accessibility expression:

$$X_i = \sum_j F_j f(c_{ij}) \quad \text{Formula 3}$$

X_i : Accessibility measurement of community i;

F_j : Activity level indicator of community j;

We consider the visual effect of the indicator selection, we select the uses traffic time consumption c_{ij} to describe traffic accessibility of this model.

Algorithm Function of Traffic Module. Algorithm function of traffic module includes algorithm functions of traffic demand such as travel generation, travel distribution and travel modes and so on and analogue functions of traffic facilities such as line-net structure, operation management and so on.

Travel Generation, We consider that the model focuses on macro-level research, so we simplify the travel purpose and other things, and we add the analysis of location and traffic accessibility. The basic form of model algorithm with travel generation can be seen as follows.

$$P_{ni} = P_{ni} \cdot x_n \cdot \left[\frac{\sum_j f(c_{nij})}{\sum_i \sum_j f(c_{nij})} \right] \quad \text{Formula 4}$$

P_{ni} : Forecasting annual travel generation rate in community i of the n^{th} location.

x_n : The ratio of forecasting annual travel generation rate and current-situation travel generation rate in the n^{th} location.

In a similar way, the basic form of model algorithm with travel attraction can be seen as follows.

$$A_{ni}^k = a \cdot A_{ni}^k \cdot y_n^k \cdot \left[\frac{\sum_j f(c_{nij})}{\sum_i \sum_j f(c_{nij})} \right] \quad \text{Formula 5}$$

A_{ni} : Forecasting annual travel attraction rate of the k^{th} kind of post in community i of the n^{th} location.

y_n : The ratio of forecasting annual travel attraction rate and its current-situation travel attraction rate of y^{th} kind of post in the n^{th} location.

Adjustment factor, Travel Distribution Model.

We use gravity model method in this model. And the basic form of calculation formula can be seen as follows.

$$T_{ij} = P_i \cdot \frac{f(c_{ij}) \cdot A_j}{\sum_j f(c_{ij}) \cdot A_j} \quad \text{Formula 6}$$

The time consumption of travel in community i is the product of minimum value of travel time consumption and coefficient going to the neighboring traffic community. The coefficient is got according to actual experience value in Shanghai.

The Model of Travel Mode, We use two stages to calculate travel mode structure in this model.

The first stage: we should decide travel mode proportion with three modes which are walk, bike(moped) and motorization and the change relationship of travel distance. We build experience function and the algorithm function can be seen as follows.

The second stage: Suppose that people can choose freely about using public traffic or coach in 2020, the people who own private cars will use travel mode of public bus and couch according to current situation. We build the mode transformation curve after adjustment. The algorithm function can be seen as follows.

$$PRO_{ij} = \frac{k}{1 + a \cdot e^{-b \cdot w_{ij}}} \quad \text{Formula 7}$$

w_{ij} : The ratio of couch traffic accessibility and public bus traffic accessibility.

$$w_{ij} = \frac{f(c_{ij}^{car})}{f(c_{ij}^{transit})}$$

Distribution Model of Flow Quantity, We use distribution technology of single vehicle kind in the road flow quantity distribution of this model. Distribution of single vehicle kind adds OD meter

of vehicle kinds to the road net respectively according to a certain sequence. This distribution method only considers the influence that the first distribution vehicle kind imposes on the second one. Therefore, forecasting result is affected by distribution order. Distribution technology of multi vehicle kind fully simulates the road mutual influence on all kinds of vehicle flow in distribution process. It reflects the actual situation of mixed vehicles running more accurately and decreases human factors which decide the forecast result. The basic target function of the two kinds of vehicle flow distribution are:

$$\min Z = \sum_{a \in A} \int_0^{V_a} S_a(X) dx \quad (\text{single vehicle kind}) \quad \text{Formula 8}$$

We use the method of optimal strategy choosing in the distribution of public-bus guest flow of this model, namely the optimal line choosing and multi probability calculation method. The basic principle is that we use probability calculation of several lines of public bus. Firstly, we decide lines which passengers may take according to the principle of minimum overall travel cost(time and cost). Then we decide the priority level of passengers choosing lines according to the factors such as line driving interval. We suppose that the chosen probability of short interval line is higher than others. The target function of the method of optimal strategy choosing reflects that the sum of road section's overall people per hour and node's overall waiting-bus people per hour is minimum. The detailed formula can be seen as follows:

$$\min \left\{ \sum_{l \in L} t_l V_l + \sum_{i \in I} W(L_i) V_i \right\} \quad \text{Formula 9}$$

l —— fracture surface of public bus; V —— passenger flow quantity of public bus;
 I —— station; t —— time;
 L —— overall fracture surface of public bus; $W(L_i)$ —— weighting time of station;
 I —— all the stations of public bus.

The Simulation of Traffic Facility, This model simulates line-net structure, operation management and other things of traffic facilities. We use road network editing function module of software EMME/3 in this model.

Conclusion

We preliminarily put forward Shanghai urban layout and traffic demand integration model. Function structure can be divided into three big functional modules, such as the analysis of urban land use, the analysis of the traffic demand and the evaluation of traffic system and so on. Compared with other models, this model pays more attention to the interaction among the three, namely the land, demand and facilities. It achieves the balance between systems by iterative calculation for many times.

We put forward that the land use module is used to study historical evolution law and future development trends of spatial layout of Shanghai urban land use. It includes sub-modules such as location, form, area, population, post and so on. Traffic module contains two big submodules, namely traffic demand and traffic facilities. The point with balance between traffic demand and traffic facilities is the balance of demand and supply. We consider that the model mainly focuses on macro-level research, so we select the degree of saturation as the evaluation indicator of transportation accessibility in this model.

We put forward three algorithm functions which are land use module, traffic accessibility, and traffic module by using mathematical methods. In addition, we verify them with actual data of four megalopolises which are Tokyo, London, New York and Shanghai.

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