

Beijing City Lab

Zhang Y, Zhang X D, 2013, Beijing Transportation and Land Use Integrated Model:
Development and application. Beijing City Lab. Working paper # 14

Beijing Transportation and Land Use Integrated Model Development and Application¹

Zhang Yu² Zhang Xiaodong²

[Abstract] Since an interactive relation exists in transportation and land use, the planning and evaluation of major policies, measures and infrastructures having a long-lasting influence shall focus on the research of the advantages, disadvantages and influence degrees of transportation and land use. Meanwhile, land-use and transportation integrated model is required to complete the research and analysis of urban real estate market, evaluation of planned land-use structure and layout, and the assessment of the effectiveness of planning scheme of urban transportation system. Based on the abovementioned demand, this paper takes Beijing as an example.

Beijing land-use model is established and calibrated on the basis of the transportation model of Beijing. As a result, the construction of transportation and land-use integrated model has been realized. Also, typical model application analysis has been carried out in order to evaluate the harmonious of urban land-use planning and transportation system planning.

[Key words] Beijing; Land-use and Transportation Integrated Model; Development; Application

1. Research Background

Beijing Urban Master Planning (2004-2020) compiled in 2004 has been implemented for nearly 10 years, the construction of Beijing has been rapidly carried out with the guidance of the space strategy conception of “Two Axes-Two Belts-Multiple Centers” proposed in the overall planning. Looking back to the changes in recent years, the comprehensive transportation system planning with rail transit as a representative has played a key regional development guiding role in the urban planning conception of Two Axes-Two Belts-Multiple Centers”. Although the concept of the integrated planning of land use and transportation has been received and reflected in major projects in recent years, the degree of coordinated development of land use and transportation in Beijing has never been quantitatively evaluated yet.

¹ Energy Foundation Project, Project Grant No.: G-0804-10001; G-0909-11471

² Beijing Municipal Institute of City Planning & Design

Thanks to the enhancement of the researches on the interactive relation between transportation and land use, the exploration and case study of quantitative evaluation of transportation and land-use integrated planning in major cities at home and abroad have been gradually increased in recent years. For example, Charlotte, Seattle, Los Angeles, etc. in United States have used PECAS and other relevant software to construct the transportation and land-use integrated models. Besides, Paris uses UrbanSim to construct its transportation and land-use integrated model, Mexico City is using Transus to construct its transportation and land-use integrated model, and Shenzhen is also tend to using Transus to construct the said integrated model. In addition, institutions of higher learning and research institutions including Tsinghua University, Peking University and Beijing Transportation Research Center are carrying out relevant exploration and research on transportation and land-use integrated model. However, there is currently still no transportation and land-use integrated model successfully developed and applied in planning practice in China.

In consideration of the foregoing, this paper will rely on the research achievements of *Research on Beijing Land Use and Transportation Integrated Model* subsidized by the Energy Foundation and discuss Beijing Land Use and Transportation Integrated (BJLUTI) Model established for the first time and available for planning practice in China.

2. Research Background

(1) Macro Transportation Strategic Model of Beijing

Macro transportation strategic model of Beijing (hereinafter referred to as BMI model) is a macro transportation strategic module¹ of Beijing territory updated and completed based on BUTS model created by Beijing Municipal Institute of City Planning & Design in 2000 according to relevant data obtained from Transportation Survey in 2005. The construction of BMI model was completed in 2008. It is one of the few city-territory macro transportation modes in Beijing. In this model, Beijing is divided into 178 transportation zones. The model dimensions include: two family types (CA and NCA), five trip purpose types (home-based work (HBW) trip, home-based school (HBS) trip, home-based other (HBO) trip, non home-based (NHB) trip and employment-based (EB) trip and five trip mode types (Bike, Car, Taxi, Bus and Metro). The

specific structure of the model is shown in Figure 2-1:

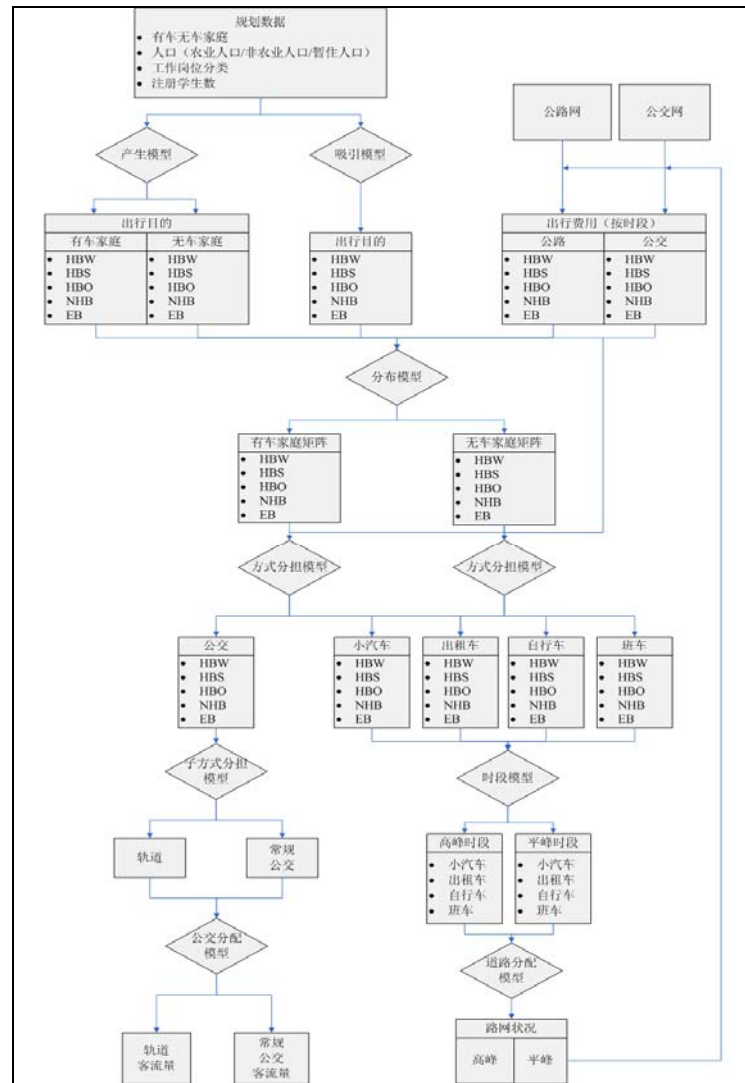


Figure 2-1: Frame Diagram of BMI Model Structure

The establishment of the abovementioned BMI model has laid a transportation sub-model foundation for the construction of this transportation and land use integrated model. In this paper, the land model part of Beijing transportation and land use integrated model, model calibration and the integration method of land model and transportation model will be discussed.

(2) Software

After comprehensively studying the researches of transportation and land use models established in major cities in the world, we discover that different analysis software platforms have been applied in transportation submodel and land use submodel (e.g. UrbanSim+TP+\PECASE+TransCAD). Then, these two submodels will be integrated through external serial

connection. However, such kind of analysis method has influenced the integrity of the model to some extent and the flows feeding back each other are also influenced and restrained.

Based on the considerations above, Cube which developed by Citilabs has been applied in this transportation and land use integrated model. This software is a piece of professional transportation and urban planning forecast model software which has provided favorable model flow establishment interface and flexible script edition method. As a result, the software becomes a generalized transportation model development platform based on transportation demand forecast model. The application of coding based on module in the software can freely realize the establishment of flow and feedback relation of transportation and land use integrated model and avoid the external integration issue arising from different software platforms.

3. Development Purpose and Model Framework

(1) Development Purpose

The development purpose of this model is to discover the interaction rules among three systems, i.e. “Economy-Land Use-Traffic System” and establish relevant integrated model to study the macro rules among these three urban subsystems through the quantitative analysis and study of micro individual behaviors under the condition of market economy.

The specific approach is to establish a simulated model to reflect the interactive relation between transportation and land use under a certain economic background by exploring the patterns of several major individual selection behaviors including regional choice, transportation choice and real estate market development when the residents select places to live. On this basis, the coordination of transportation and land use planning will be evaluated; the revenue of the land planned in a certain transportation system and urban spatial location will be pre-evaluated; the relative relation between planned land use and house price under the transportation system will be estimated; the transportation conditions under planned land use and in the transportation system will be stimulated; the influence on different urban development strategies and policies will be judged in advance.

(2) Model Framework

The actual market behaviors of Beijing are analyzed according to the available data foundation based on the abovementioned development purpose. The research framework of transportation and land use integrated model established in shown in Figure 3-1.

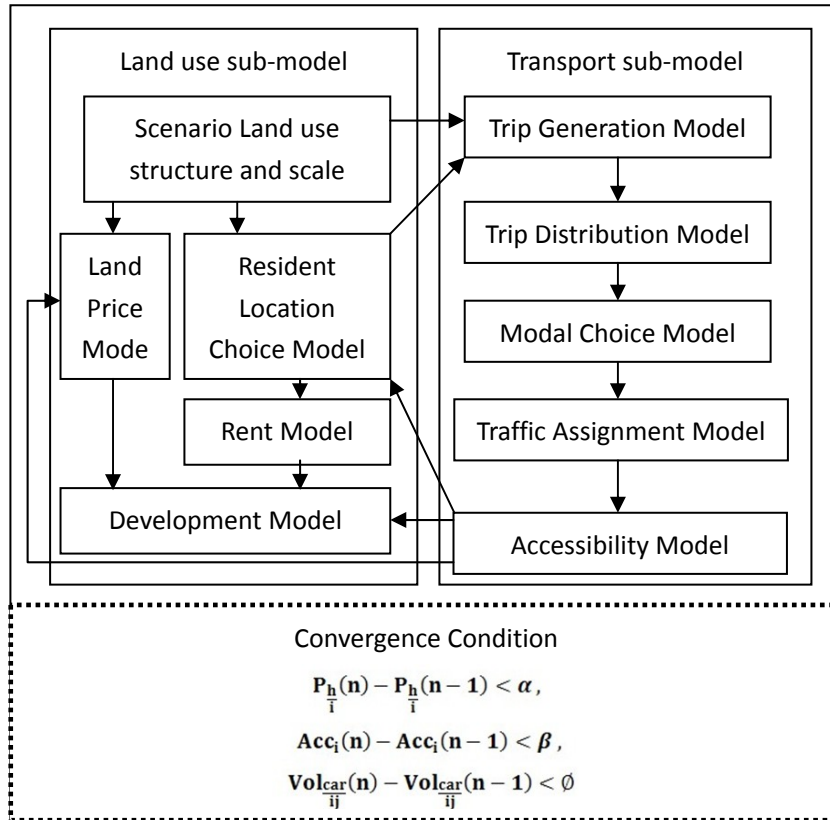


Figure 3-1: Flow Chart of BLUTI Model Framework

The diagram above indicates, the land model part in this transportation and land use integrated model takes the residential real estate market and resident location choice as research object for model establishment without involving enterprise site choice behavior. The main reasons are listed as follows:

The current investigation of enterprise site choice behaviors is relatively insufficient and the accuracy of data available is to be checked;

The enterprise scales differ greatly and it is relatively difficult to select enterprise model analysis unit;

There are relatively abundant policy-dominating factors in the industrial market of Beijing.

Therefore, the enterprise site choice is assumed as an exogenous variable in this transportation and land use integrated model (the current year mainly bases on economic census

while the planning year mainly takes the relation coefficient of planned land use and jobs as the calculation basis) to mainly simulate the market behaviors of the residential market.

The land model and the transportation model interact with each other mainly according to the transportation accessibility of different zones obtained from transportation accessibility calculation model and the residential distribution conditions of different types of household provided by resident location choice model.

The model convergence is mainly decided by three factors:

1. The car flow difference between each loop is within the preset threshold scope;
2. The population difference between each loop is within the preset threshold scope;
3. The location accessibility difference between each loop is within the preset threshold scope.

Under the precondition of the satisfaction of the abovementioned three convergence conditions, the model can be judged as convergent and relevant result can be obtained.

4. Sub-model Calibration of Land Use Model

Figure 3-1 indicates there are mainly four submodels involved in the land use model part, namely, resident location choice model, rent model, development model and land price model. The relations among these four submodels are shown in Figure 4-1.

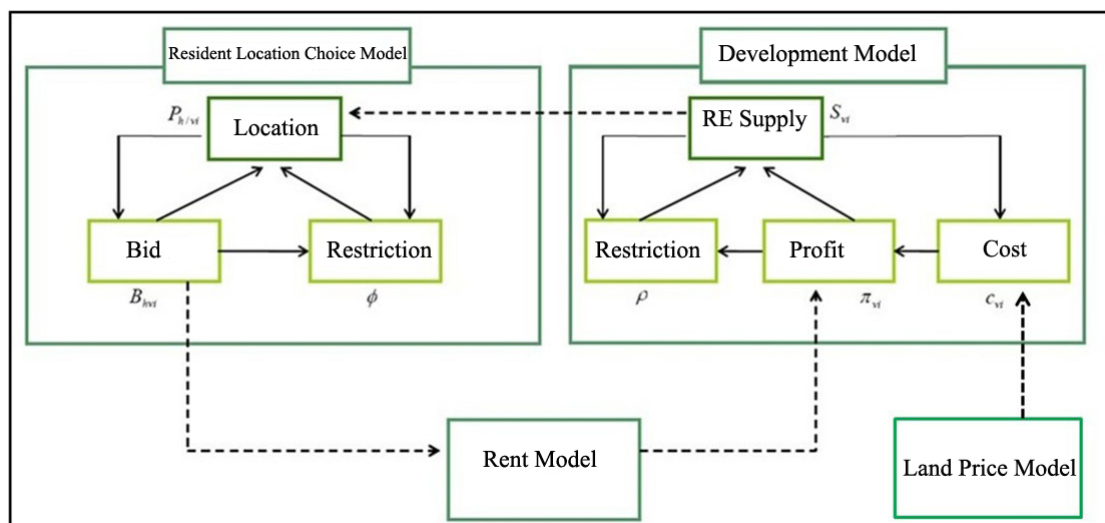


Figure 4-1: Flow Chart of Calculation Relations of Land Use Submodel

Besides, based on the model, the accessibility calculation model shall also be made clear of to realize the interaction between transportation model and land use model.

(1) Model Dimensions

Combining relevant data of Beijing and the dimension conditions of existing transportation model part, the dimensions of land model part are divided into followings:

1. Family Classification:

The family classification is finally subdivided into 5 types based on the original transportation model classification and combining the family differences in residential location choice, namely, low-income family, medium-income family with car, medium-income family without car, high-income family with car, and high-income family without car.

2. TAZ

The division of transportation zones continues to use method stipulated in the existing macro transportation model. 198 transportation zones are divided (178 inner zones);

3. Division of Land Use Types

Since this model is only targeted at the residential real estate market and there is relatively short of basic data, the residential land use types are combined to one type, i.e. common residential land use.

(2) Residential Location Selection Model

The residential location selection model is mainly based on the competitive price lease behavior in the real estate market. In other words, the renting or purchasing group in residential real estate located in a specific location is the highest bidder. The distribution proportions of various kinds of groups in the residences in each location and such groups' willingness to pay (WTP) for such residences can be worked out through the calculation of this model.

This model is a multi-Logit model based on the disperse selection behavior. The parameter calibration process is as follows.

1. Analysis on Dependent Variable House Price Distribution Samples in Base Year

The spatial interpolation method is used to obtain the house prices of common residences and apartments of each community model in the base year (2005) according to 626 common residence samples investigated by the research group in 2005. See Figure 4-2 as follows:

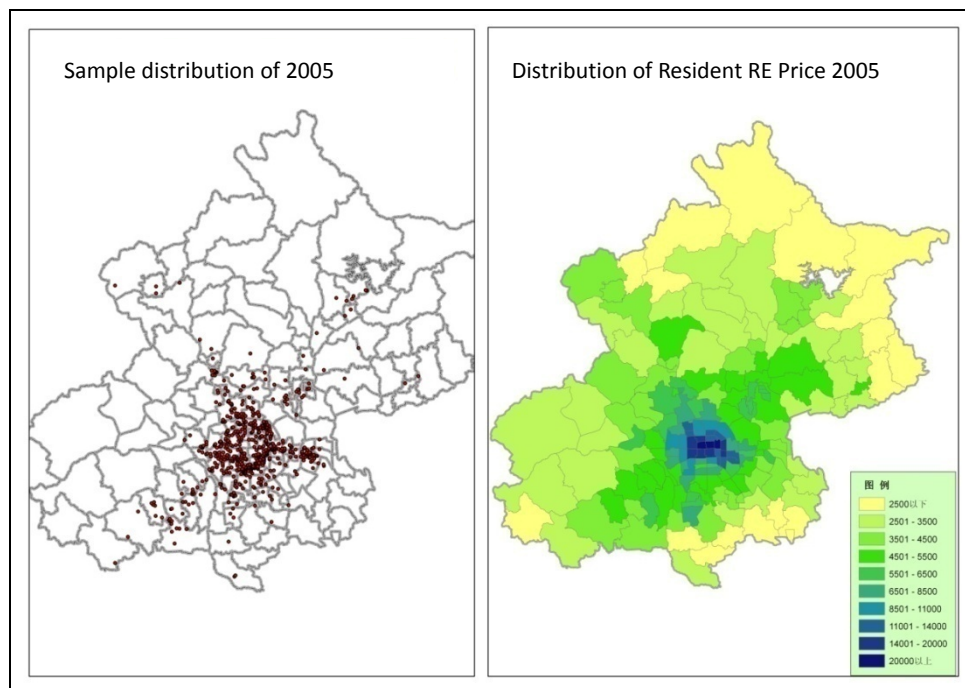


Figure 4-2: Distribution Diagram of Resident RE Price in Beijing in 2005

2. Selection of Independent Variables of the Model

According to the characteristics of the residential location choice of residents in Beijing and through the qualitative investigation and analysis, residents will mainly consider the following factors when selecting their residences:

Convenience degree of commuting in location, i.e. location accessibility in the independent variables of the model;

Distribution of education resources around the location, i.e. the distance from the transportation zone considered in the model to any of top-50 primary schools and middle schools;

Humanistic environment around the location, i.e. the distance from the transportation zone considered in the model to the nearest scaled university campus;

Natural environment around the location, i.e. the distance from the transportation zone considered in the model to the nearest park or greenbelt;

Medical environment around the location, i.e. the distance from the transportation zone

considered in the model to the nearest third-level and grade-A hospital

To sum up, the independent variables of parameters selected in residential location selection model are summarized in Table 4-1:

Table 4-1: List of Independent Variables of Parameters Needing Calibration in Residential Location Selection Model

Name of independent variable	Meaning	Unit
PriDist	Nearest distance from the centroid of the transportation zone to any of the top-50 primary schools in Beijing	Km
MidDist	Nearest distance from the centroid of the transportation zone to any of the top-50 middle schools in Beijing	Km
ParkDist	Nearest distance from the centroid of the transportation zone to any of 53 city parks registered in Beijing	Km
UniDist	Nearest distance from the centroid of the transportation zone to any of 54 university with the campus area exceeding 10 hectares in Beijing	Km
HospDist	Nearest distance from the centroid of the transportation zone to any of third-level and grade-A hospitals in Beijing	Km
Acc	The location accessibility of the transportation zone can be expressed by distance from the location to the employment area in terms of convenience.	—

Besides the abovementioned six independent variables, the scale independent variable, i.e. total volume of each family type is introduced in to residential location selection model in order to reflect the proportional differences of different family types in the model due to the use of bid rent theoryⁱⁱ with the purpose of better revealing the influence of the change of scales of various family types in the planning year on the residential location selection model.

3. Parameter Calibration of the Model

Based on the multi-Logit model, the form of the utility equation of residential location selection model is as follows:

$$B_{hvi} = Asc_h + \alpha \times \ln(ScI_h) + \beta_h \times PriDist_i + \gamma_h \times MidDist_i + \delta_h \times ParkDist_i + \rho_h \times UniDist_i + \sigma_h \times HospDist_i + \theta_h \times Acc_i + \varepsilon$$

Where,

B_{hvi} represents the WTP of group h for class-v real estate type in transportation zone I;

Asc_h represents a constant of WTP function of group h. The value is to be calibrated.

Scl_h represents the population scale of group h;

The independent variables of the remaining WTP functions are shown in the above table.

$\alpha \setminus \beta_h \setminus \gamma_h \setminus \delta_h \setminus \rho_h \setminus \sigma_h \setminus \theta_h$ is the parameter to be estimated while ε represents random independent variable.

According to the form of the equation above, BIOGEME will be used to carry out model calibration after the abovementioned independent variables are standardizedⁱⁱⁱ. The results are shown in Table 4-2:

Table 4-2: Parameter List of Calibration Results of Residential Location Selection Model

Family type	Asc_h	α	β_h	γ_h	δ_h	ρ_h	σ_h	θ_h
1. Low-income family	0	0.679	-0.00471	-0.46	-0.373	-0.575	-0.00055	0.473
2. Medium-income family without car	-0.0809		-1.05	-0.678	-1.56	-0.621	-1.17	1.27
3. Medium-income family with car	0.276		-0.123	-1.2	-0.469	-0.741	-0.624	0.467
4. High-income family without car	-0.603		-2.05	-1.29	-1.36	-1.69	-1.75	1.28
5. High-income family with car	-0.522		-1.77	-1.37	-1.24	-1.37	-1.66	1.17

The estimated values in the base year of the abovementioned calibration results and the observed values are compared in Figure 4-3.

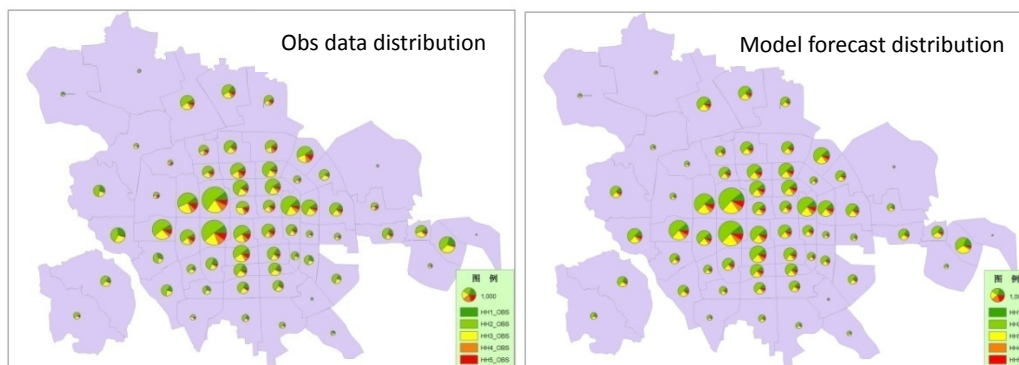


Figure 3: Diagram of Comparison and Analysis of Calibration Results of Residential Location Choice Model and Observed Values

From the comparison between the model forecast results and observed values of each zone in the diagram above, we can see the family structure proportions observed are basically in line with the forecast values, indicating a relatively favorable current condition restoration result of the model. Therefore, the model is available.

(3) Rent Calculation Model

The rent calculation model is mainly based on the distribution of WTP of the residents calculated by demand model. Combining the house price distribution, the model is used to calibrate the relationship between WTP and house rent.

When Hedonic model is used to calibrate, the specific calculation formula is as follows:

$$\ln(\text{Price}_i) = \text{Asc} + \alpha \times B_{hvi}$$

According to the sample distribution of the investigated data, 71 transportation zones with relatively high reliability will be selected to conduct parameter regression calibration. The specific calibration result is shown as follows:

$$\ln(\text{Price}_i) = 7.397 + 0.791 \times B_{hvi}$$

R^2 is 0.68, indicating a relatively good model fitting effect.

The house prices in various transportation zones in Beijing in base year are calculated according to the formula above. Compared with the house prices of common residences in each area, the investigation and summarization results are shown in Figure 4-4.

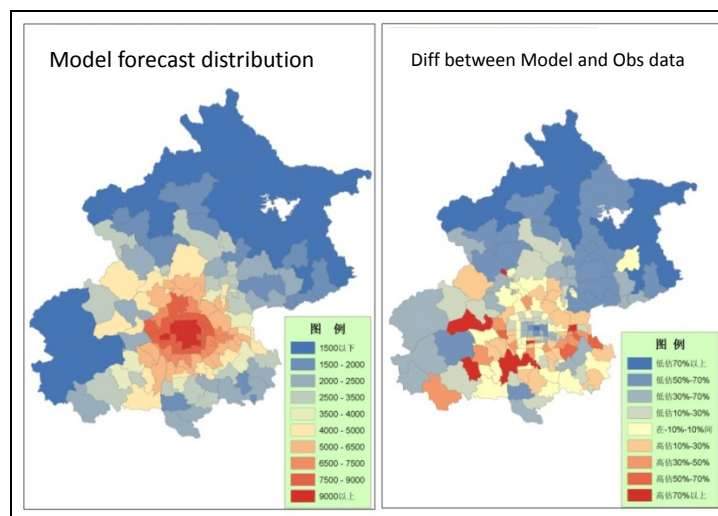


Figure 4-4: Distribution Diagram of Comparison Differences between House Prices Obtained from Model Fitting and Investigated House Prices

From the diagram above, we can see the distribution trend of house prices forecast by using the model is relatively favorable and presents an obvious center-to-outward spreading direction which is high in north and low in south. The result of the comparison between forecast value and observed value indicates the model forecast in central city is slightly lower than the observed value in an overall manner and the forecast value of outward regions is slightly higher than the

observed value. The accuracy of the overall forecast is relatively acceptance and thus the model is available.

(4) Land price model

The land price model mainly aims to provide the land cost of real estate development for the development model and reflect the relation between the land price and its influencing factors.

1. Analysis on Land Price Distribution in Base Year

The transaction data and knock down prices of 407 residences from 2002 to 2010 are equivalently converted to 2005 to obtain the house prices in each area in 2005. See Figure 4-5:

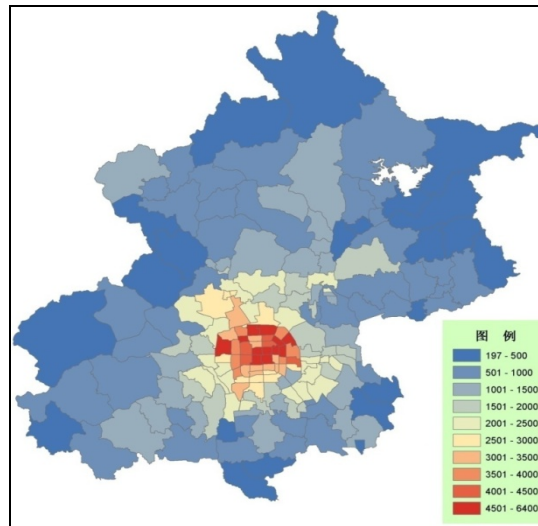


Figure 4-5: Distribution Diagram of Relevant Land Prices of Residences in Beijing in 2005

2. Selection of Independent Variables

After investigation and survey, we know the land price is mainly influenced by factors like location, humanistic and social environment around and supporting facilities. The influencing factors are finally selected after analyzing the autocorrelation of variables of various influencing factors and the land price correlation in the base year. See Figure 4-3.

Table 4-3: List of Independent Variables in Land Price Related Factor Analysis Model

Name of independent variable	Meaning	Unit
PriDist	Nearest distance from the centroid of the transportation zone to any of the top-50 primary schools in Beijing	Km
ParkDist	Nearest distance from the centroid of the transportation zone to any of 53 city parks registered in Beijing	Km

Acc	The location accessibility of the transportation zone can be expressed by distance from the location to the employment area in terms of convenience.	—
-----	--	---

3. Model Calibration

The Hedonic model is used to conduct model calibration on the land price and relevant influencing factors mentioned above. The result is shown in the following formula:

$$\ln(\text{Land}_{\text{price}}) = 2.207 - 0.021 * \text{Pri}_{\text{dist}} - 0.007 * \text{Park}_{\text{dist}} + 0.535 * \text{Acc}$$

R^2 is 0.738, indicating a relatively good model fitting effect.

Compare the model calibration result with the observed value. See Figure 4-6.

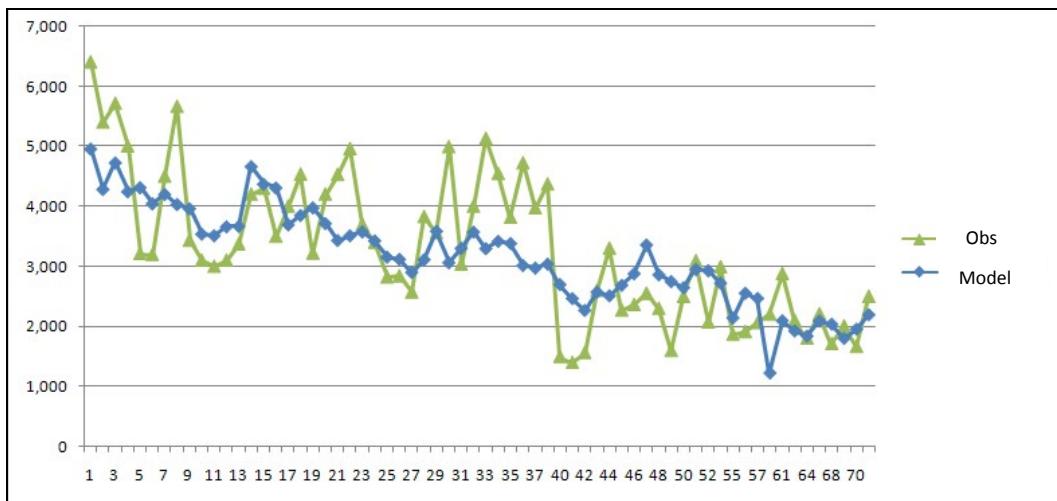


Figure 4-6: Diagram of Comparison between Estimated Value by Using Land Price Model and Real Value

Figure 4-6 indicates the trends of estimated value by using the model and the real value are basically similar. However, certain differences existing in the forecast of individual values.

(5) Real Estate Development Model

The establishment of development model mainly simulates the development behaviors of the real estate market. It is regarded that the developers tend to select land available for development with highest profits to carry out the real estate development of relevant types within the whole region so as to to maximize their profits. A mathematical formula can be used:

$$\max(\text{Price} - \text{Land}_{\text{cost}} - \text{Con}_{\text{cost}})$$

Where, Price represents the sales price of the house; $\text{Land}_{\text{cost}}$ represents the land purchase

cost; Con_{cost} represents the house construction cost. In the model, the independent variable of land purchase cost is obtained from the abovementioned land price model. The house construction cost in the base year is temporarily set as RMB 800 Yuan/m².

Under the precondition that the total development volume of the development model is already known (obtained from the exogenous total residence demand scale of the model), the development scale of each transportation zone can be calculated by using the development profit model composed of house price, land price and construction cost. The specific mathematical formula can be represented as follows:

$$S_i = H * P_i = H * \frac{\exp(\pi_i)}{\sum_1 \exp(\pi_1)}$$

The utility equation is represented as:

$$\pi_i = \alpha * (r_i - Land_{price_i} - Const_i) + \delta_i$$

BIOGEME is used to calibrate the development model. The calibration result of the equation is as follows:

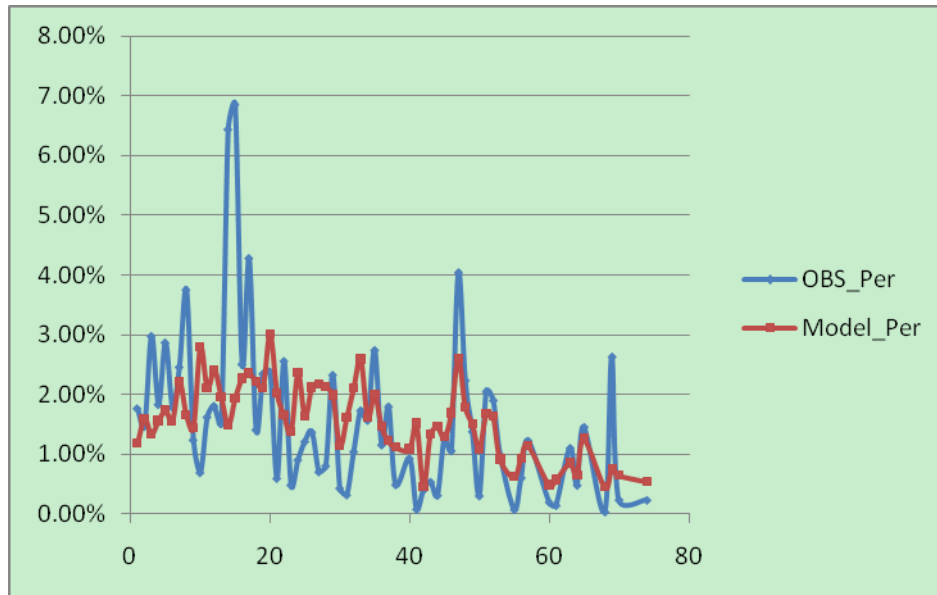


Figure 4-7: Diagram of Comparison between Simulated Data in Development Model and Investigated Data

The diagram above indicates that the overall trends of the data result simulated in the development model and the investigated data are relatively matched. Besides, the errors in most transportation zones are relatively small, which proves the validity of the the parameters of the

development model.

(6) Accessibility Calculation Model

In order to reflect the influence of transportation system on the land use in a more objective way, the employment accessibility index of the application area is used to reflect the influence on the residential location selection so as to affect the real estate development behaviors. Meanwhile, the location accessibility is also used as the basis for the establishment of land price in order to comprehensively reveal the influence of transportation system on the land use.

The comprehensive transportation cost calculated by using BMI model is used in this accessibility variable. Combining the trip mode structure of different family groups and the regional distribution of jobs, the calculation is carried out. The calculation formula is as follows.

$$Acc_{hi} = \sum_{j \in J} \ln \left(\frac{Emp_j}{\sum_{k \in K} GC_{kj} \times Per_{kh}} \right)$$

Where, Acc_{hi} represents the employment transportation accessibility of family h in Zone i; Emp_j refer to the jobs in Zone j; GC_{kj} represents the generalized trip cost from Zone i to Zone j under the trip mode k; Per_{kh} refer to the ratio of trip mode k related to family h.

5. Analysis of A Model Applied Case-Decentralization of 3A hospitals

BLUTI model staged completed after correction based on the calibration of the abovementioned submodels. In this section, the influence of decentralization of 3A hospitals on the residential distribution and land development changes is taken as an example for discussion.

Currently, there are totally 44 3A hospitals in Beijing which are representative the best medical level in Beijing even in China. Now, there all located in center of Beijing. Almost all located Inside the fourth ring road. See Figure 5-1 for details.

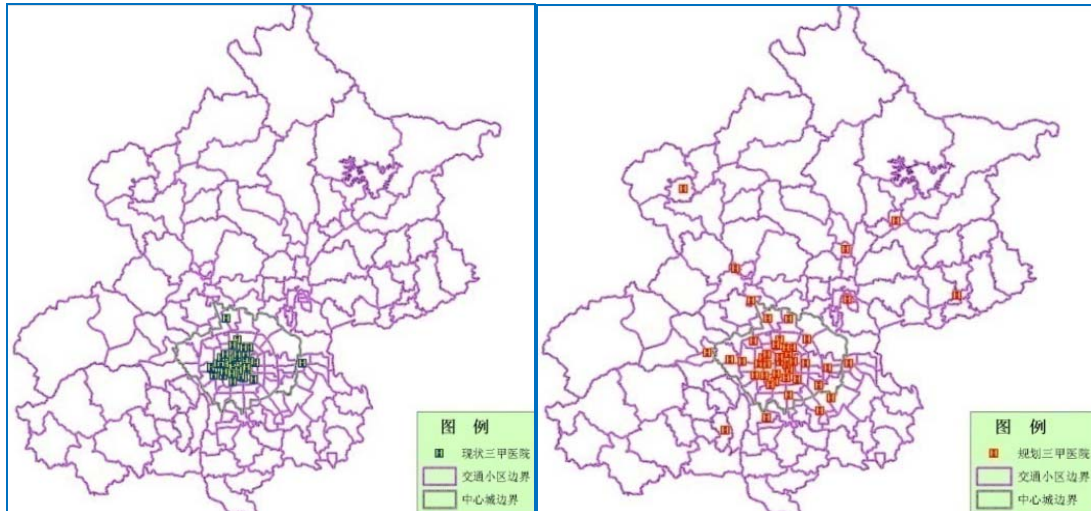


Figure 5-1: Current Distribution of 3A Hospitals and Planned decentralization of 3A hospitals

In consideration of the obvious influence of medical resources on people's residential location selection, based on the population evacuation in the central part of Beijing, and according to the phenomenon of excessive centralization of current advantaged medical resource, Beijing's government proposes the idea of decentralization of advantaged medical resources in the medical resource integration planning and plans to enable each new town to own at least one 3A hospital.

In order to test the influence of this planning scheme on the residence supply and population distribution, the BLUTI model is used to test and compare the practices of maintaining the current locations of 3A hospitals unchanged in the planning year and implementing the decentralization planning concept. The test results of residential real estate develop and household distribution are shown in Figure 5-2 and Figure 5-3 respectively.

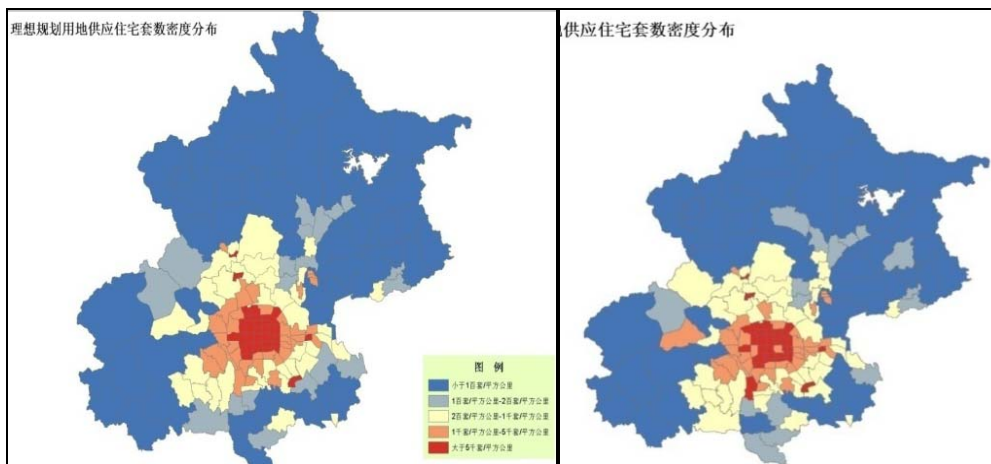


Figure 5-2: Comparison Diagram of Changes of Planned Residence Supply Density Based on Change of Distribution of 3A Hospitals

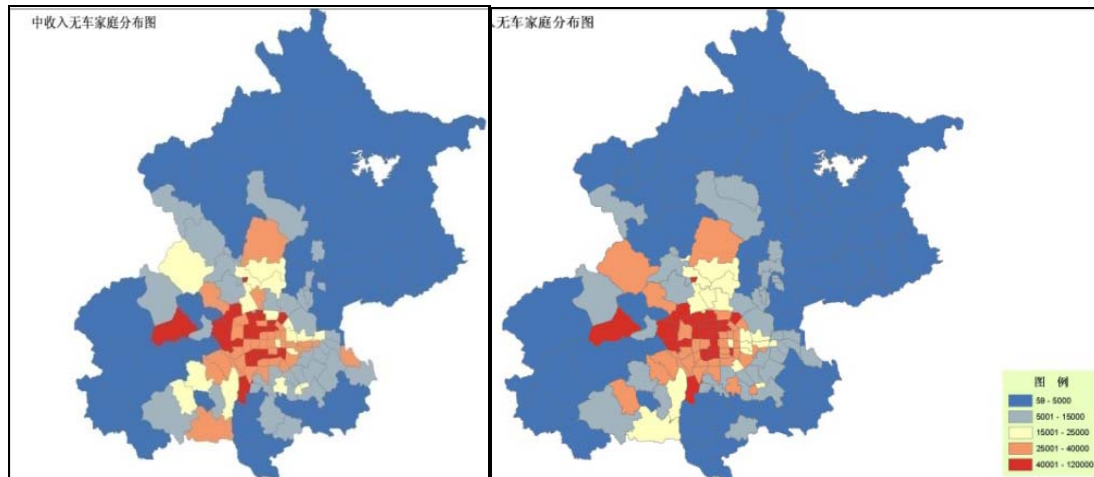


Figure 5-3: Comparison Diagram of Changes of Population Distribution Based on Change of Distribution of 3A Hospitals

From Figure 5-2 to Figure 5-3, we can see the decentralization of 3A hospitals as planned has a certain promoting effect on the residential development and outward relocation of the population, thus beneficial to the evacuation of population in central Beijing. However, the population evacuation effect brought by 3A hospitals alone is not very obvious. It is recommended to adopt other policies as well.

6. Main Research Achievements

The main achievement of this research is the completion of the calibration of Beijing transportation and land use integrated model for the first time based on the traditional transportation model of Beijing and land use related investigation data. We also try to do some application of the model, for example the effect of 3A hospital decentralization.

Furthermore, it has provided a set of relatively feasible and effective quantified analysis tools for the evaluation of the Master planning of Beijing in the next round, the scheme testing related to urban land use planning and transportation system planning, and related policy analysis and strategy research.

Finally, thank you for the support of Francisco Martinez (Professor of Chile University). We can't completed this article without his help.

[References]

ⁱBeijing Municipal Institute of City Planning & Design and MVA. Final Report of Updating Research of Beijing Municipal Transportation Model, 2008.8

ⁱⁱModelling the choice of residential location, Daniel McFadden

ⁱⁱⁱBierlaire,M.(2003). BIOGEME: a free package for the estimation of discrete choice models. In Proceedings of the 3rd Swiss Transportation Research Conference, Ascona, Switzerland.
www.strc.ch

Resume of the Author:

Zhang Yu, Male, Master of Traffic Planning, Engineer, currently working in Beijing
Municipal Institute of City Planning & Design

Mailing address: No. 60, Nanlishi Road, Xicheng District, Beijing (10045)

Tel.: 010-88073749

Fax: 010-68056173

Email: zy_jts@aliyun.com