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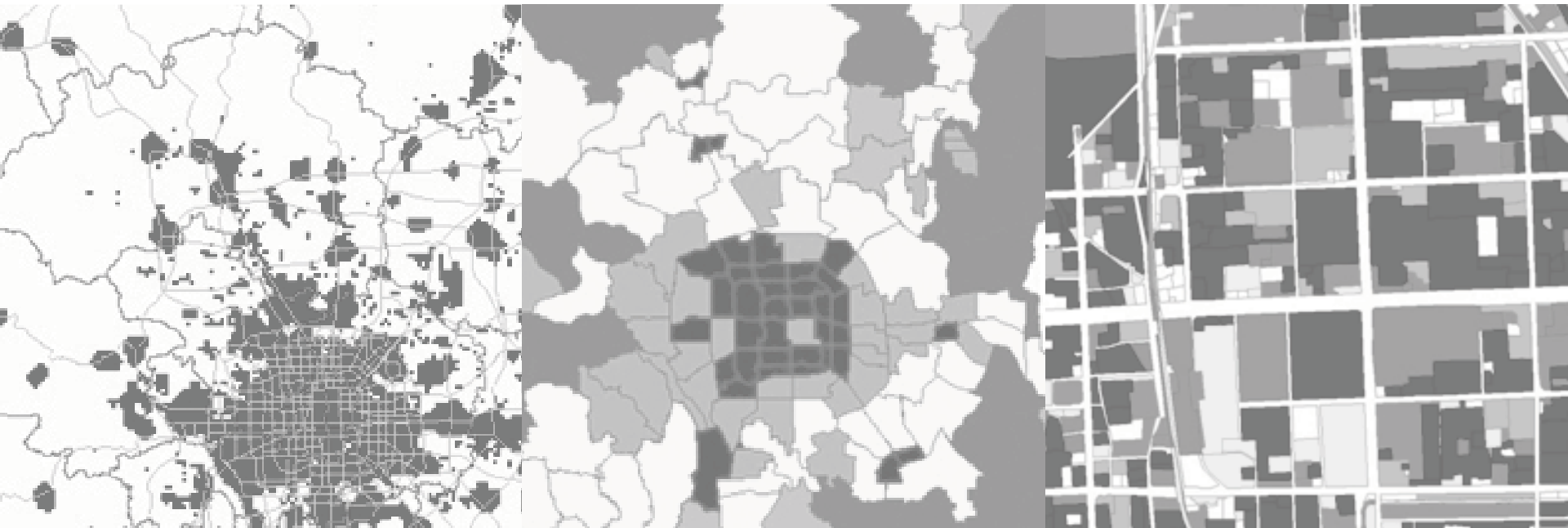
E.g. Long Y, 2014, Automated identification and characterization of parcels (AICP) with OpenStreetMap and Points of Interest, Slides at Beijing City Lab, <http://www.beijingscitylab.com>

Beijing Urban Spatial Development Model Families: From Macro, Meso to Micro Level

LONG Ying, Ph.D., Beijing Institute of City Planning

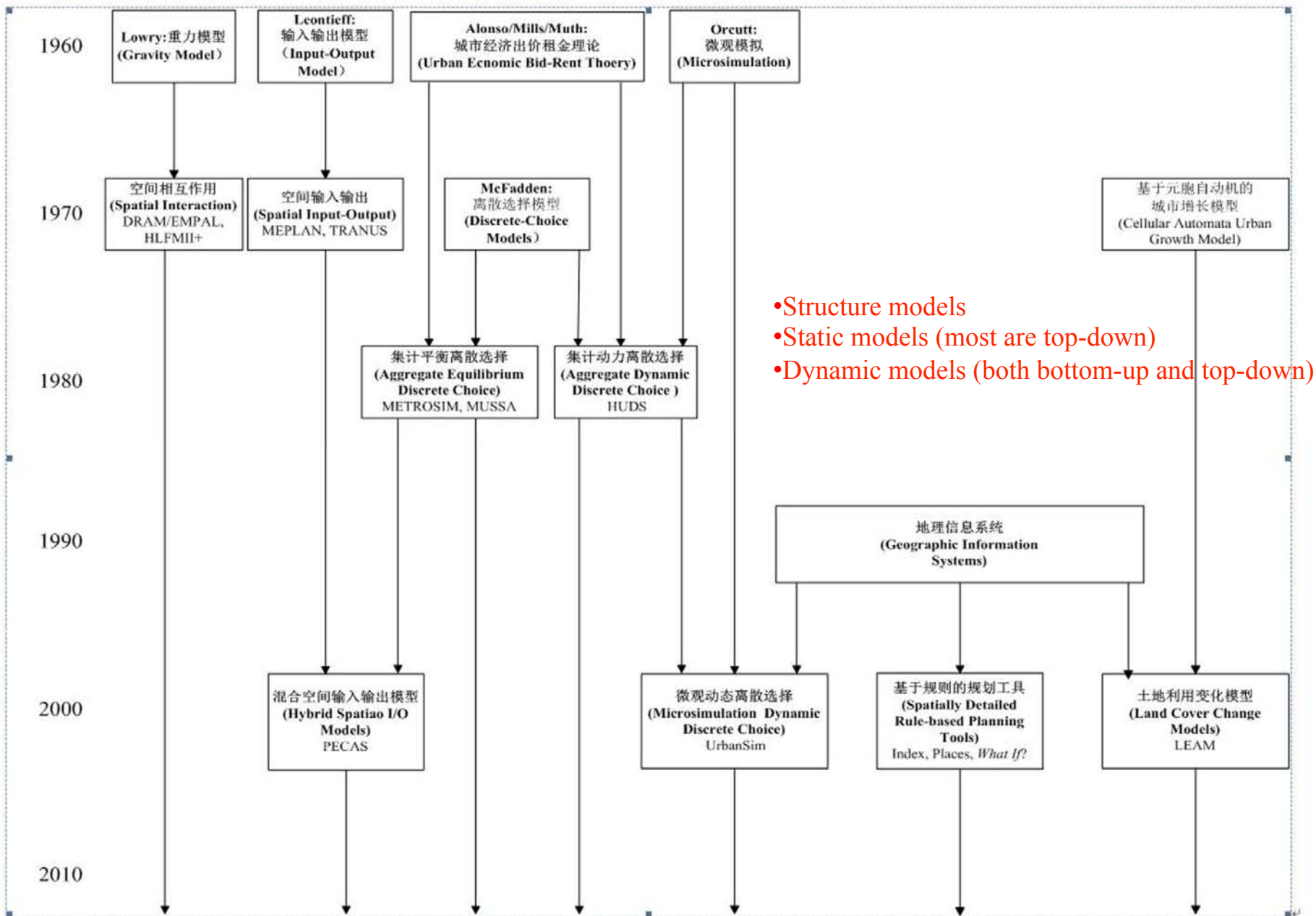
MAO Qizhi, Ph.D., School of Architecture, Tsinghua University

DANG Anrong, Ph.D., School of Architecture, Tsinghua University



Applied urban modelling (AUM)

- ✦ This report falls into the pool of AUM
 - Rather than theoretical urban modelling
- ✦ Increasingly complex urban system
 - Residents, firms, buildings, parcels, policies, laws, standards and regulations
 - Integrated platform required for handling various aspects, giving thanks to the booming of IT
 - **Man brain not applicable any more**, of decision makers, planners even modelers
- ✦ City lab for testing policies
 - Evaluation
 - Forecasting
 - Scenario analysis
- ✦ Dozens of extensively applied approaches in existing researches
 - Various spatial scales
 - Structural, static and dynamic
 - **Top-down vs. bottom-up**



Applied urban modelling: a glance

Adapted from: Dynamic Microsimulation: UrbanSim, Webinar 5 of 8-part TMIP, Webinar series on land use forecasting methods.

Selected applied urban models

ID	NAME	CNTY	SCALE	AGE	DEVELOPER	APPROACH	T	LIT
1	POLIS	美国	小区	1960年代	旧金山湾区政府协会	空间相互作用、离散选择	静态	Association of Bay Area Governments, 2009
2	DRAM/ EMPAL	美国	小区	1970年代	Stephen H.Putman	空间相互作用、离散选择	静态平衡	Putman, 1995
3	TRANUS	委内瑞拉	小区	1982年	Modelistica	空间投入产出	动态平衡	Modelistica, 1995
4	MEPLAN	英国	小区	1984年	Marcial Echenique	空间投入产出	动态平衡	Echenique等, 1990
5	TLUMIP	美国	小区	1990年代	Tara Weidner	空间投入产出	动态平衡	Weidner等, 2007
6	IRPUD	德国	小区	1994年	Michael Wegener	离散选择	动态	Wegener, 1996
7	CUF	美国	DLU	1994年	John Landis	基于规则建模	动态	Landis, 1994
8	DELTA	英国	小区	1995年	David Simmonds Consultancy	离散选择	动态	Simmonds, 1996
9	Metrosim	美国	小区	1995年	Alex Anas	离散选择	动态平衡	Anas, 1994
10	UrbanSim	美国	多尺度	1996年	Paul Waddell	离散选择、微观模拟、基于个体建模	动态	Waddell, 2002

Selected applied urban models (-cont.)

21

ID	NAME	CNTY	SCALE	AGE	DEVELOPER	APPROACH	T	LIT
11	SLEUTH	美国	网格	1997年	Keith C. Clarke	元胞自动机	动态	Clark等, 1997
12	CUF-2	美国	网格	1998年	John Landis和 Ming Zhang	基于规则建模	动态	Landis和 Zhang, 1998ab
13	ILUTE	加拿大	地块、居民、家庭	2004年	Eric J. Miller	微观模拟、 基于个体建模	动态	Miller等, 2004
14	Relu-Tran	美国	小区	2007年	Alex Anas	离散选择	动态平衡	Anas和Liu, 2007
15	PECAS	加拿大	小区	2005年	John Douglas Hunt和John E. Abraham	空间相互作用、 空间投入产出	动态	Hunt和 Abraham, 2005
16	BUDEM	中国	500m网格	2009年	龙瀛	元胞自动机	动态	Long等, 2009
17	MUSSA II	智利	小区	1996年	Francisco Martinez	离散选择	动态平衡	, 1996
18	GeoSOS	中国	多尺度	2011年	黎夏	元胞自动机、 基于个体建模	动态	Li等, 2011
19	Agent iCity	加拿大	地块、居民、家庭	2012年	Suzana Dragicevic	基于个体建模	动态	Jjumba和 Dragicevic , 2012
20	BLUTI	中国	小区	2012	张宇	离散选择	静态平衡	张宇等, 2012

BUDEM Families

📍 Beijing Urban Spatial Development Model

- Applied urban modelling
- Launched in 2007 and in development
- Supported by Beijing Institute of City Planning **and** Beijing Planning Commission

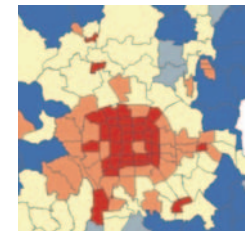
📍 Macro-level (city-scale)

- Urban expansion analysis and simulation
- Cellular automata, 500*500 m



📍 Meso-level (city-scale)

- Land use and transportation integrated simulation
- residential / firm location choice
- Traffic Analysis Zones (TAZ)



📍 Micro-level (parcel-scale)

- Spatial policy / energy / environment evaluation
- Microsimulation, parcels / households / firms

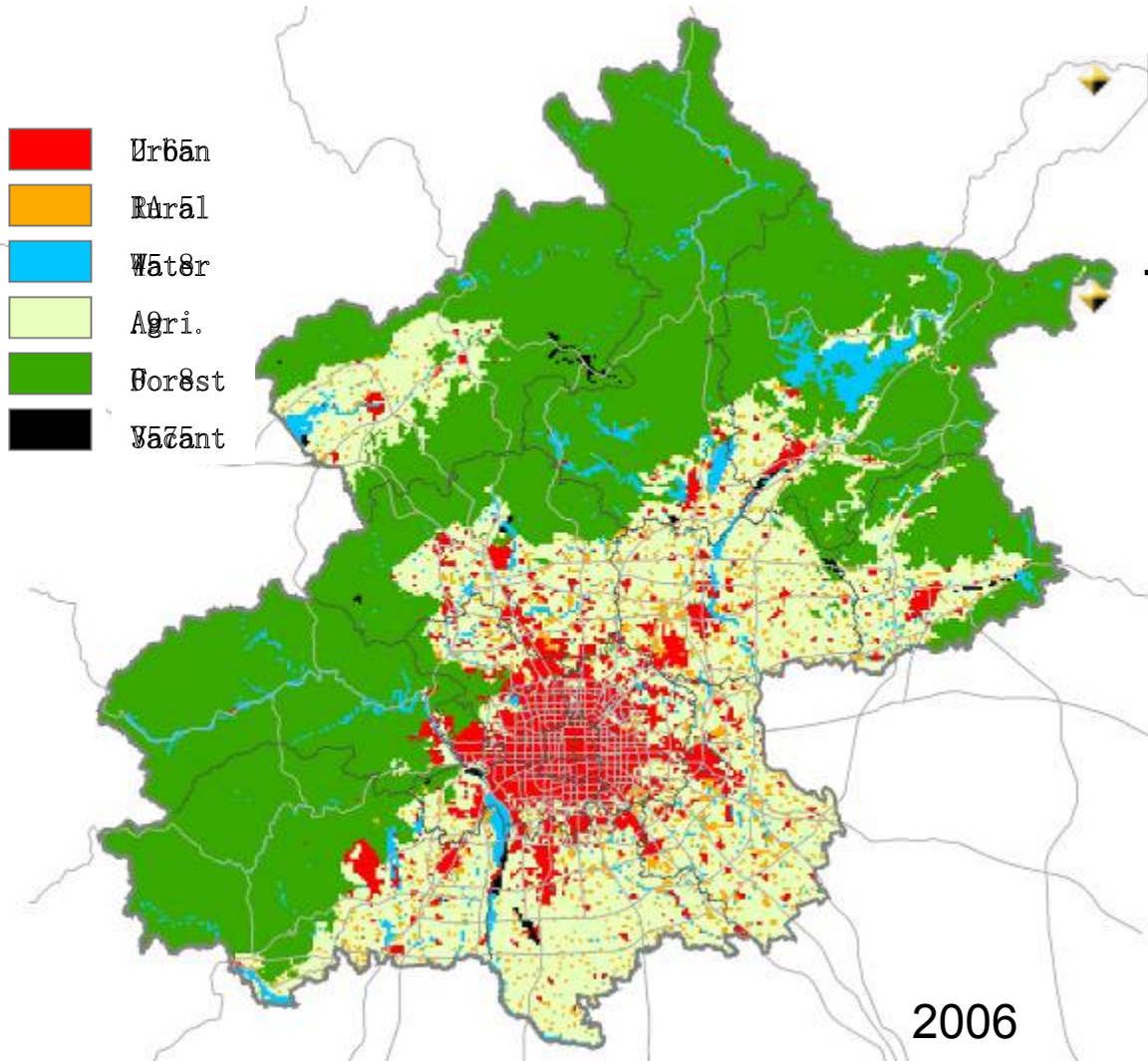


Study area of BUDEM



- ✦ The Beijing Metropolitan Area (BMA)
- ✦ Capital of P. R. China, northern china, adjacent to Tianjin and Hebei
- ✦ 16410 sqkm
 - mountainous:10071 km²
- ✦ 16 district
- ✦ Ring road 2nd, 3rd, 4th, 5th, 6th

Rapid urban expansion in Beijing



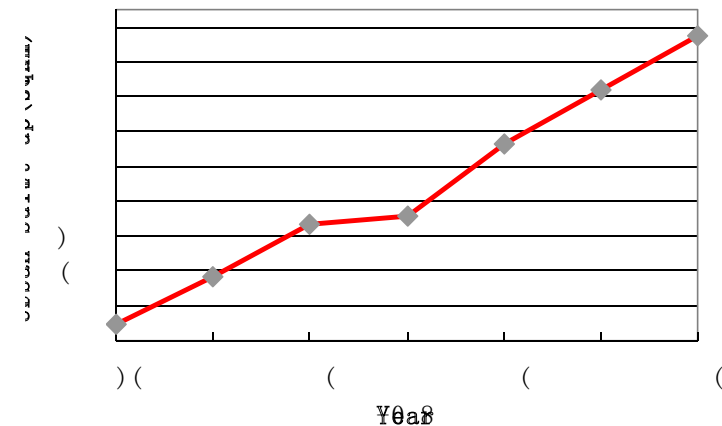
- Urban
- Rural
- Water
- Agri.
- Forest
- Vacant

Land use of Beijing

- Interpreted from Landsat TM/ETM/MSS

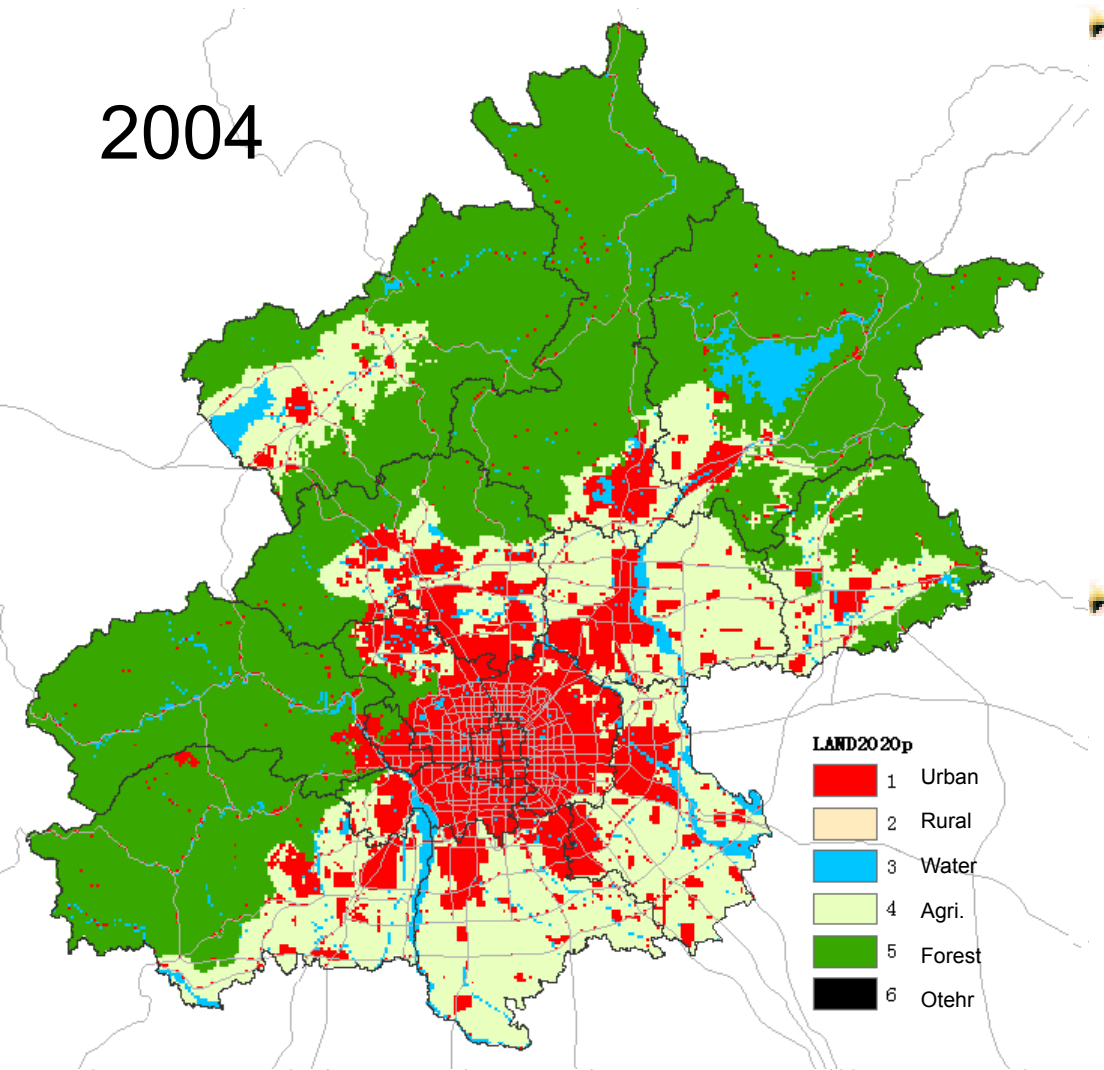
The near future

- Both expansion and redevelopment
- Increasing urban redevelopment
 - Opportunity for micro model



Master plans in the BMA

2004



Urban master planning of Beijing metropolitan area, as the capital city, since the foundation of P. R. China

- 2004
- 1992
- 1982
- 1973
- 1958

The new master plan might be compiled in 2013

All focusing on *spatial*

- ✦ Urban growth / expansion, redevelopment
- ✦ Urban form / urban structure
- ✦ Strong relationship between urban spatial organization and CO2 emission
 - Owens, 1987, Anderson et al., 1996; Banister et al., 1997

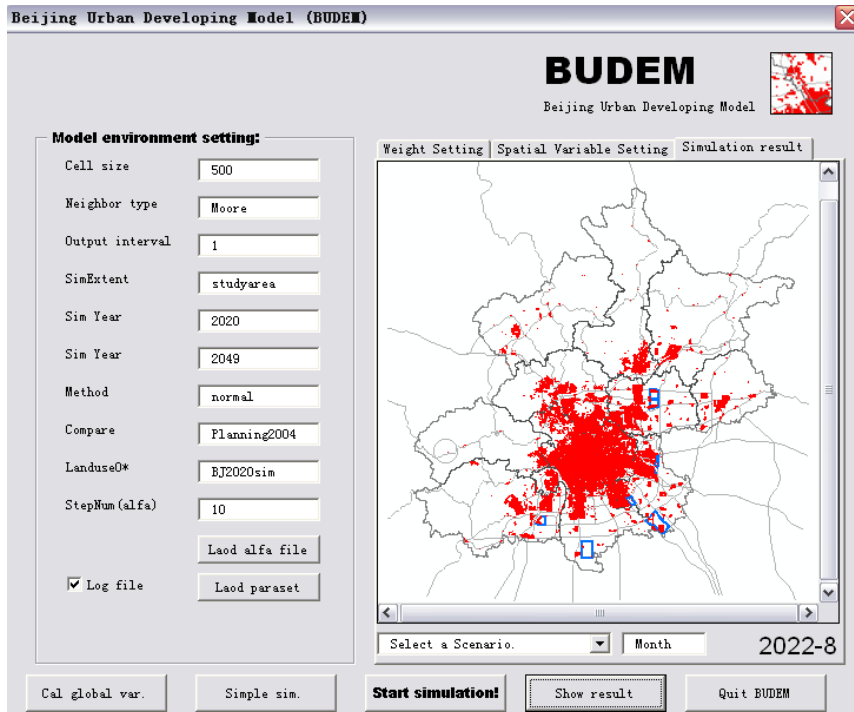
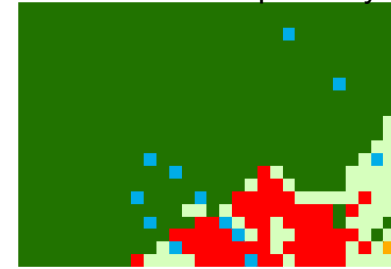
Macro BUDEM (2006-)

- ✦ Identifying driving force of urban expansion in various historical phases
- ✦ Evaluating the effectiveness of urban master plans in urban expansion
- ✦ Retrieving policies required to implement master plan for 2020
- ✦ Simulating urban growth scenarios with different policies set in 2049
- ✦ Planning support system for practical urban planning and management (various developing policies)

Long Y, Mao Q, Dang A, 2009, "Beijing urban development model: Urban growth analysis and simulation" *Tsinghua Science and Technology* 14(6) 787-794

An applied CA model

Urban growth from undeveloped to developed only



CA settings:

- Cells**
 - 500m * 500m
 - 65628 cells
- Cell States**
 - V=1 urban built-up
 - V=0 none urban built-up
- Status Transition Rule**
 - Multi-criteria evaluation, MCE
 - Retrieved by logistic regression
- Neighborhoods**
 - Moore
 - 3*3, rectangle, 8 adjacent cells
- Discrete Time**
 - 1 iteration/step = 1 month

Approaches

1. Constrained cellular automata (CA)
2. Logistic regression
3. Regional sensitivity analysis

Driving forces of urban expansion

Select spatial factors using hedonic model

Location

- Minimum distance to hierarchical urban center
 - Tian an men d_{tam} important new city d_{vcity} new city d_{city} important town d_{vtown} town d_{town}
- Minimum distance to wetland d_{river}
- Minimum distance to regional road d_{road}
- Minimum distance to ward (town level) boundary d_{bdtown}
- Regional attraction of greater Beijing area f_{rgn}

Neighborhood

- Developing intensity in neighborhood $neighbor$

Government

- Urban master planning $planning$
- Cultivating suitability $landresource$
- Constrain zoning
 - Constructing forbidden area con_f

$$\begin{aligned}
 V_{i,j}^{t+1} &= f\{V_{i,j}^t, Global, Local\} \\
 &= \{V_{i,j}^t, LOCATION, GOVERNMENT, NEIGHBOR\} \\
 &= f \left\{ \begin{array}{l} V_{i,j}^t, \\ d_{tam_{i,j}}, d_{vcity_{i,j}}, d_{city_{i,j}}, d_{vtown_{i,j}}, d_{town_{i,j}}, \\ d_{river_{i,j}}, r_{road_{i,j}}, d_{bdtown_{i,j}}, f_{rgn_{i,j}}, \\ planning_{i,j}, con_f_{i,j}, landresource_{i,j}, \\ neighbor^t_{i,j} \end{array} \right\}
 \end{aligned}$$

Model calibration

Logistic regression result of various historical phases

Variable	B(2001-2006)	B(1996-2001)	B(1991-1996)	B(1986-1991)
		*)	(
)		
		-	**	
)
			-	**
)*	((
	())	
	())	*)
)	()	(
)	*
	()	-	*
		-*	--	*

*Significant at 0.001 level

Model validation: The simulation in 1986-2006 well replicates historical urban expansion, in terms of Kappa and spatial pattern.

- Variable in different phases differ greatly (market and government balancing, macro-policy)
- Common character: road directing developing, constructing forbidden area protected
- **2001-2006** river>new city>region
- **1996-2001** new city developing, slow town developing, negative regional influence
- **1991-1996** center city>city, planned area developing, agricultural land with high suitability encroached
- **1986-1991** new city promoted, agricultural land protected, planning promoted

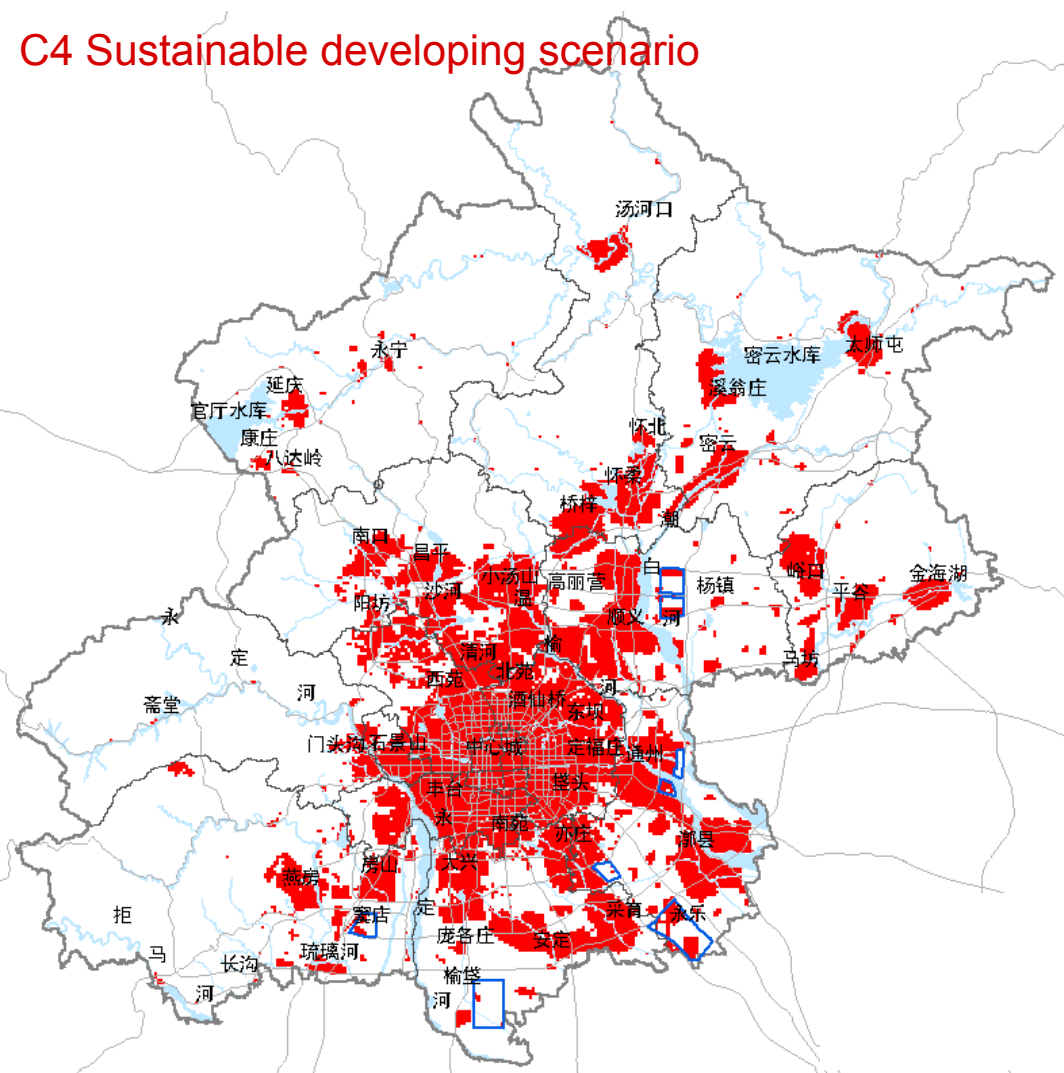
- Layers**
- FG
 - Results
 - virtualspace
 - Virtual Space
 - HISTORY
 - BUDEM3
 - BEIJING2020
 - BEIJING2049
 - SUITABILITY
 - BOUNDARY
 - POLYCYZONE
 - ROAD
 - PLANNING
 - LANDUSE
 - Location
 - conf
 - CONSTRAIN
 - LANDRESOURCE
 - HISTORICAL_LANDUSE
 - STUDYAREA
 - DEM+HILLSHADE



Display Source Selection

1 Urban expansion scenario analysis for 2049

C4 Sustainable developing scenario



A. Macro socio-economic policy simulation

B. Planning scheme simulation

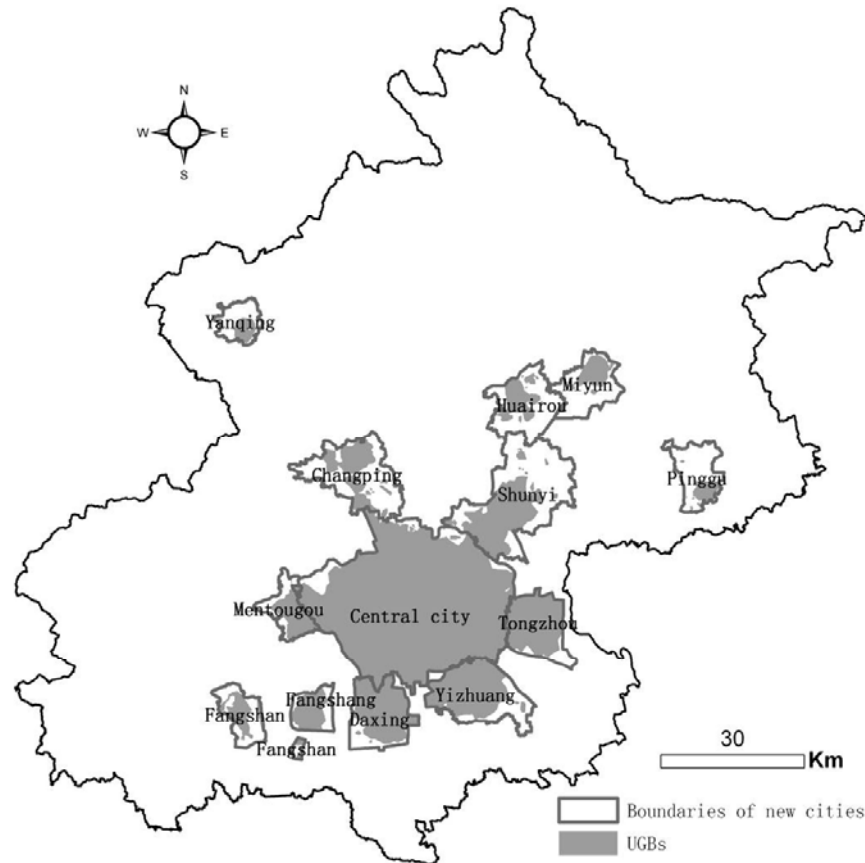
- B1 Ring road 7th
- B2 New eco-protection area
- B3 City center shifting

C. Urban growth policy simulation

D. Specific policy simulation

- Second international airport
- Backup urban land develop

2 Establishing urban growth boundaries (UGBs)



- ✦ UGBs for the central city and 11 new towns, 142 towns not included
- ✦ Significant differing from planned UGBs in the master plan, with
 - Less expansion in the north
 - Different new towns layout
- ✦ High probability to be broken for planned UGBs in coming years

3 Urban planning implementation effectiveness

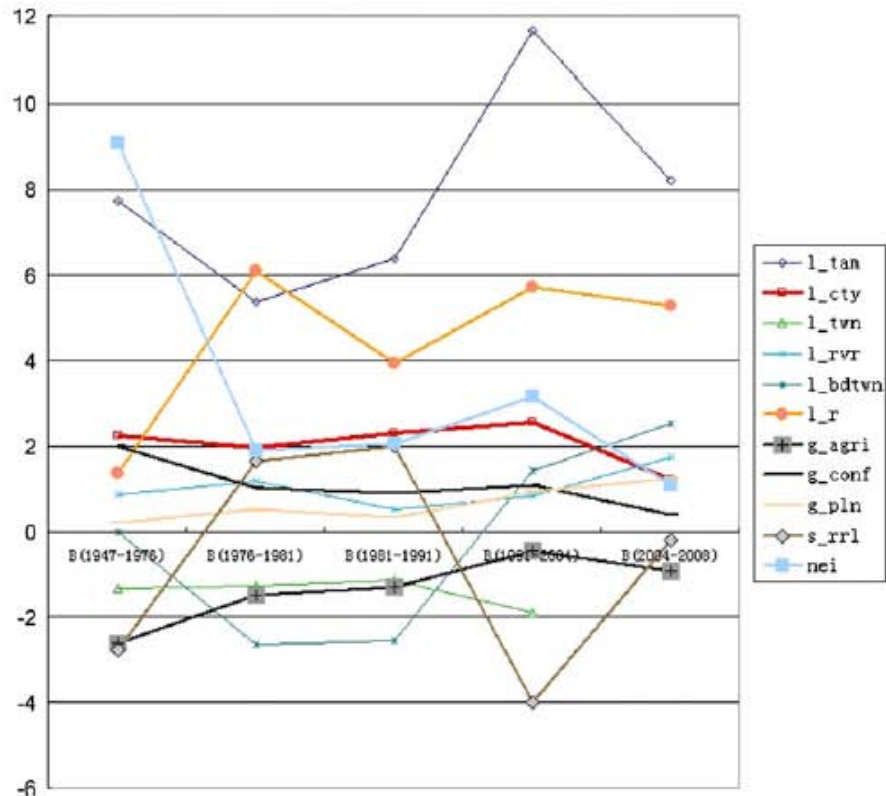


Fig. 3. Coefficients of all factors in various periods.

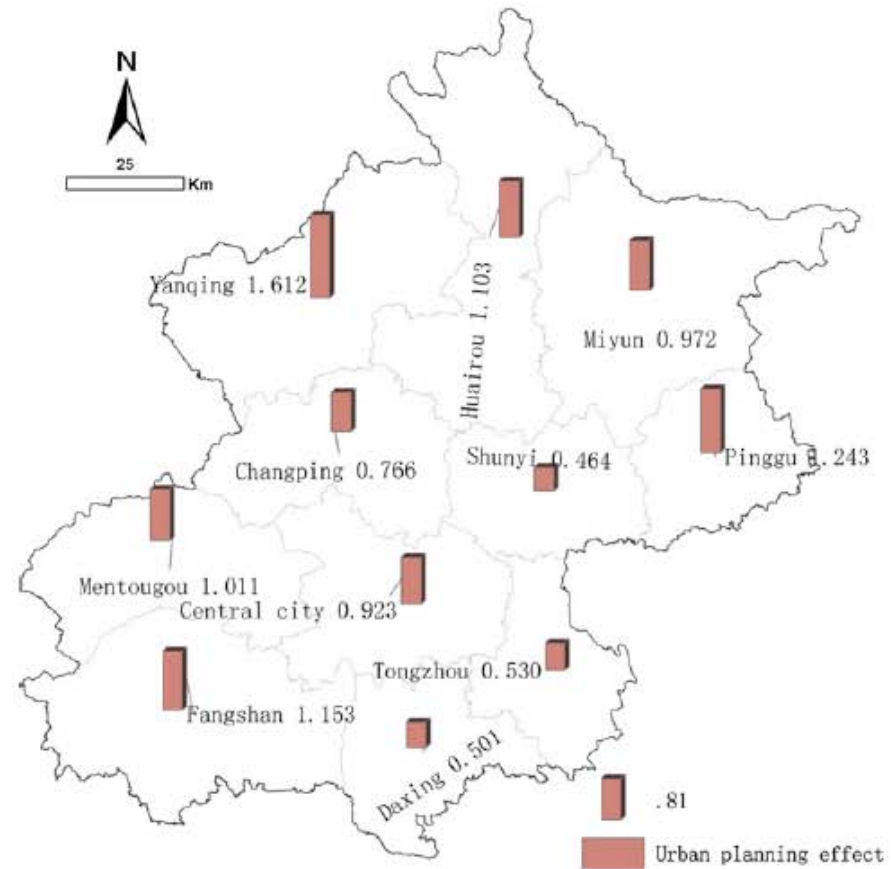


Fig. 4. Comparison of urban planning coefficients in various districts.

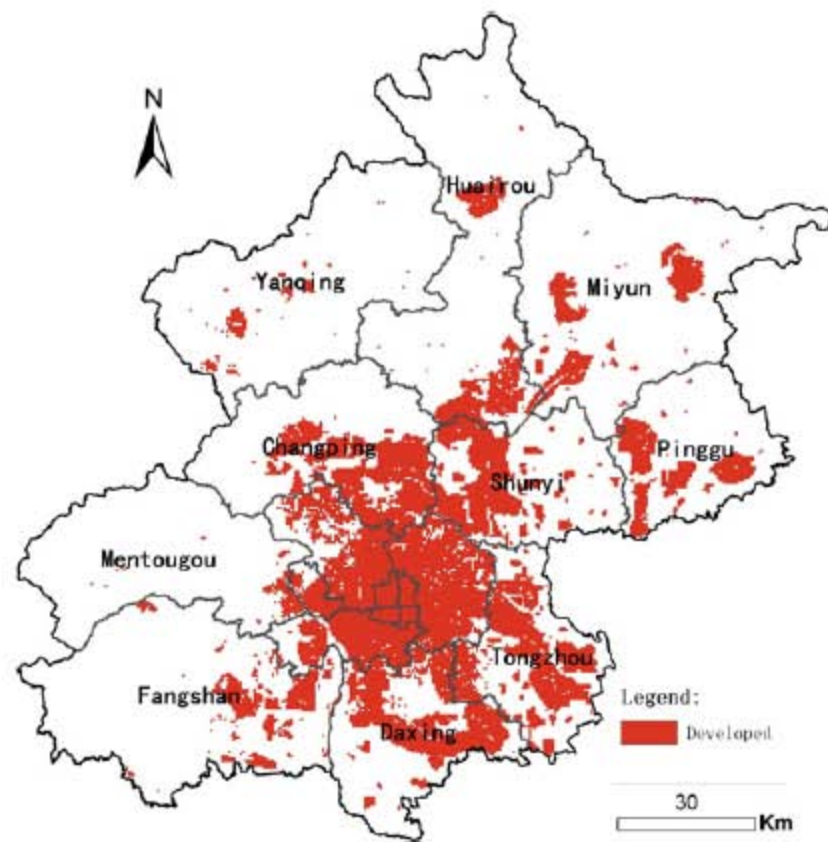
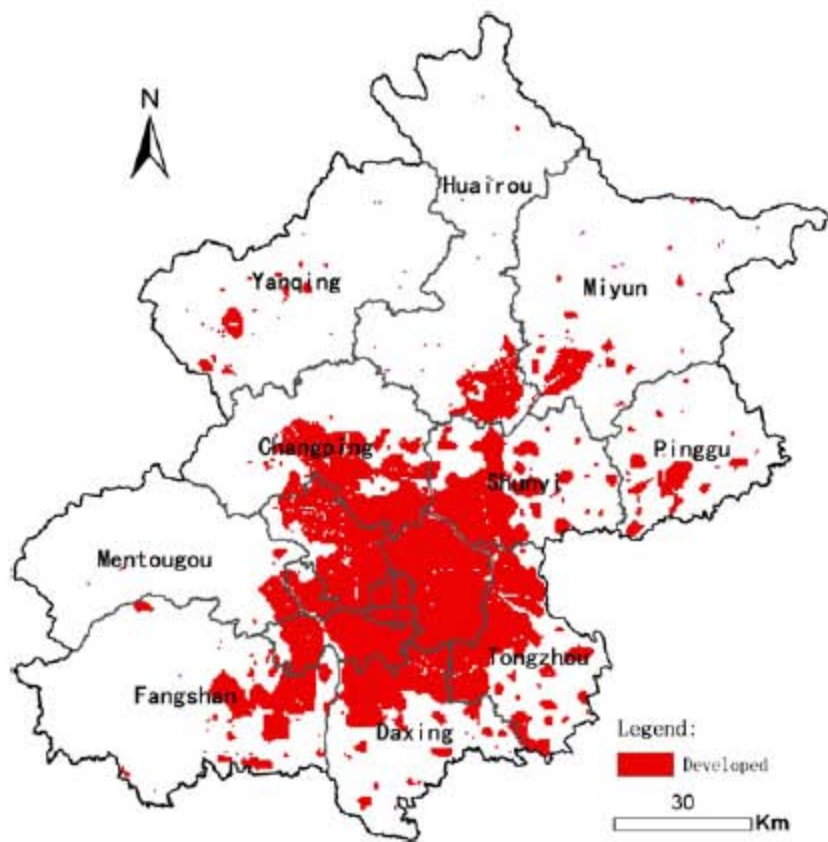
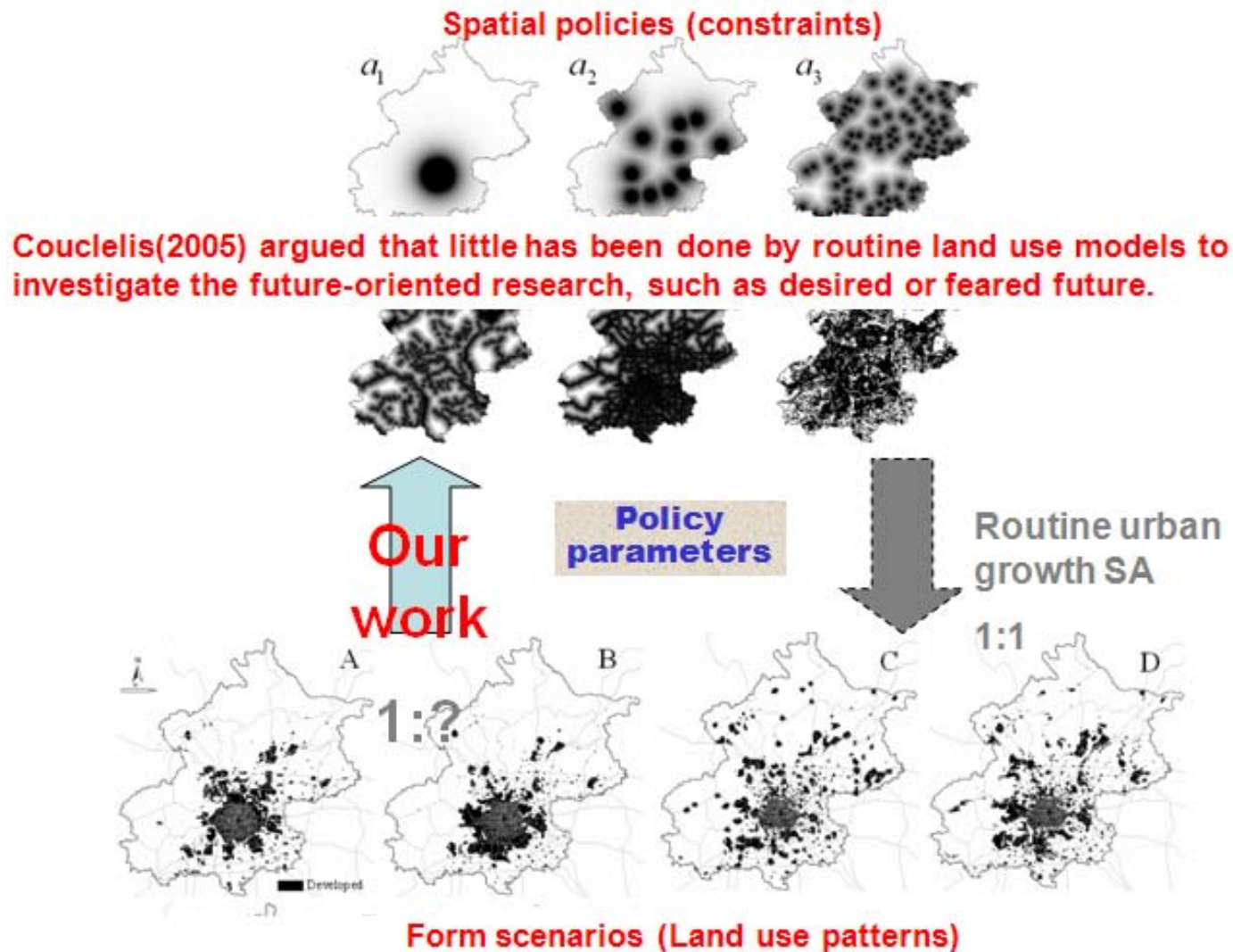
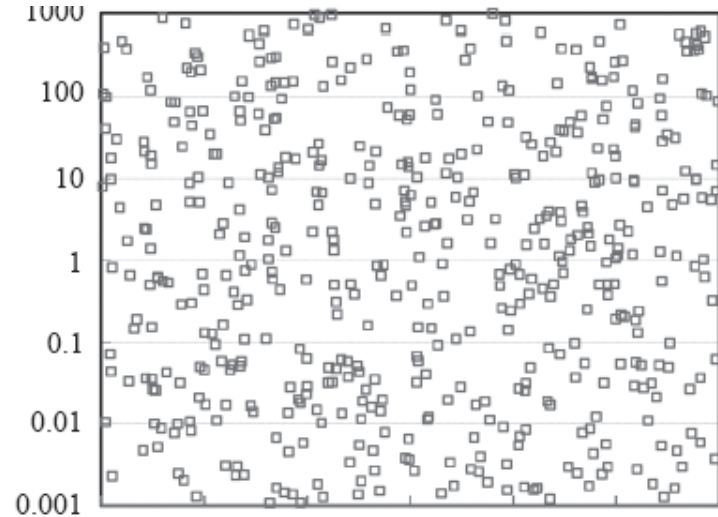


Fig. 5. Simulated urban forms by adjusting urban planning coefficient in BUDEM: the baseline scenario (left) and planning-strengthened scenario (right).

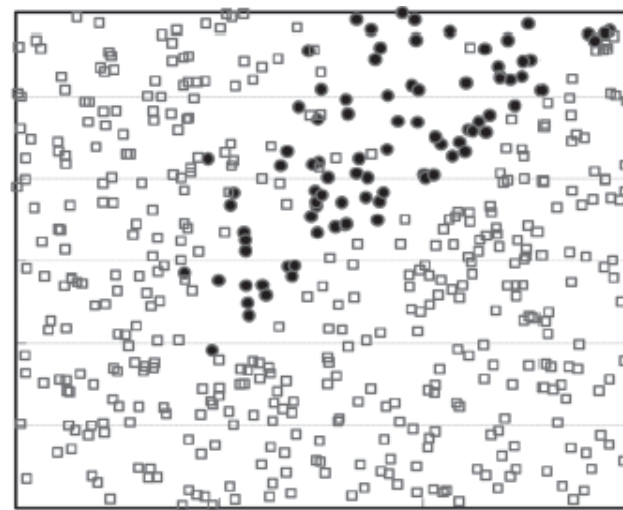
4 Identifying policy parameters for spatial plans



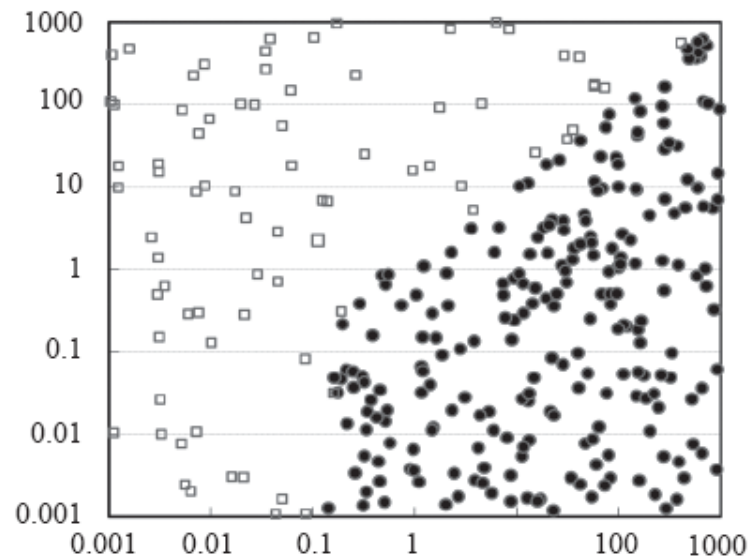
Long Y, Shen Z, Mao Q, 2012, "Retrieving spatial policy parameters from alternative plans using constrained cellular automata and regionalized sensitivity analysis" *Environment and Planning B: Planning and Design* 39(3) 586-604.



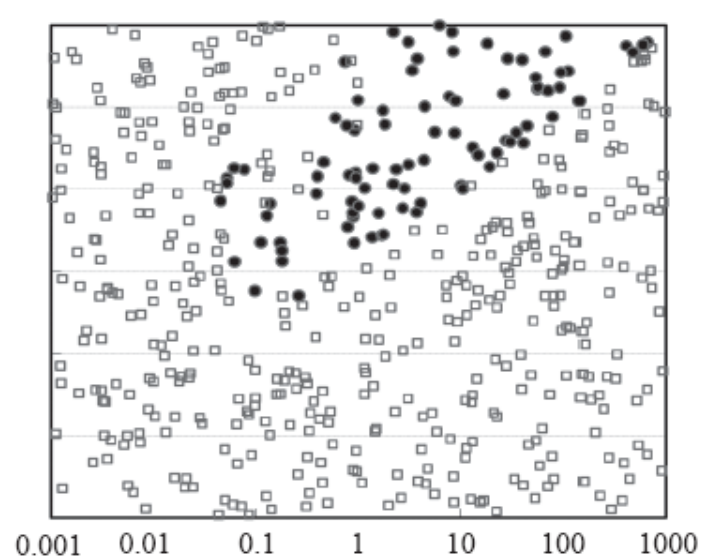
(a)



(b)



(c)



(d)

● Accepted

□ Rejected

Figure 6. Scatter plots of policy parameters identified for two combined constraints in the virtual space, when the x axis is x_1 , y axis is x_2 and ‘accepted indicates’ $\kappa \geq 80\%$. (a) Form 1, possibility of the urban form $P = 0\%$; (b) form 2, $P = 17.8\%$; (c) form 3, $P = 46.4\%$; (d) form 4, $P = 17.8\%$.

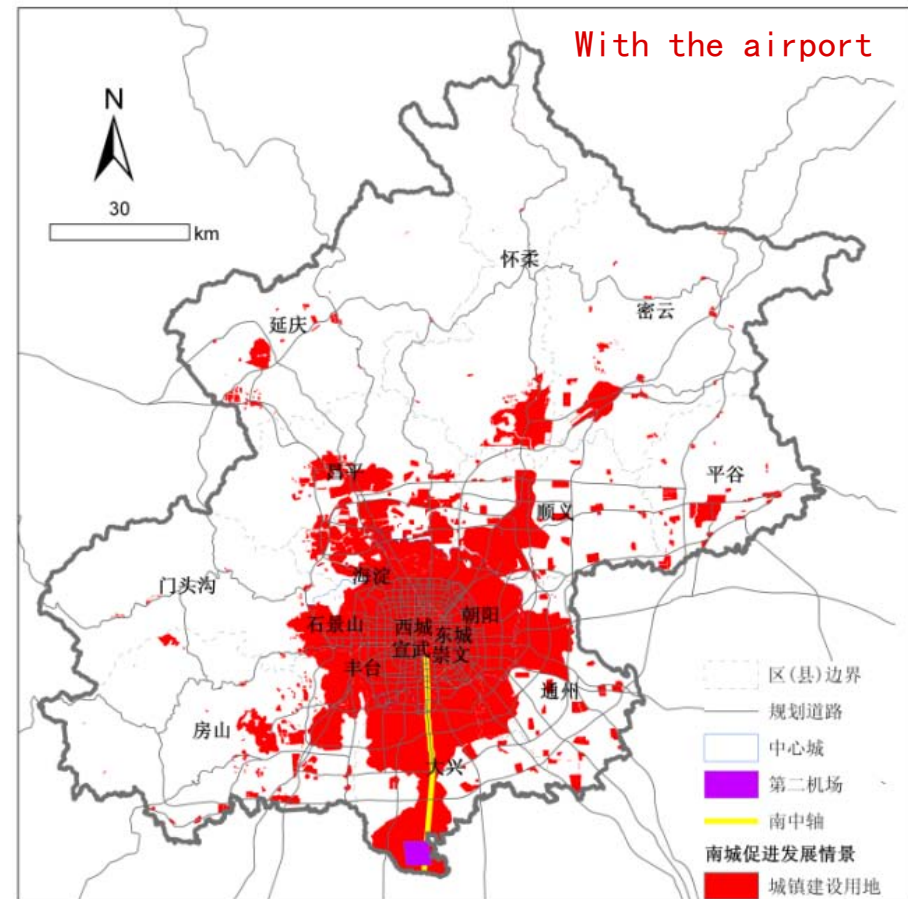
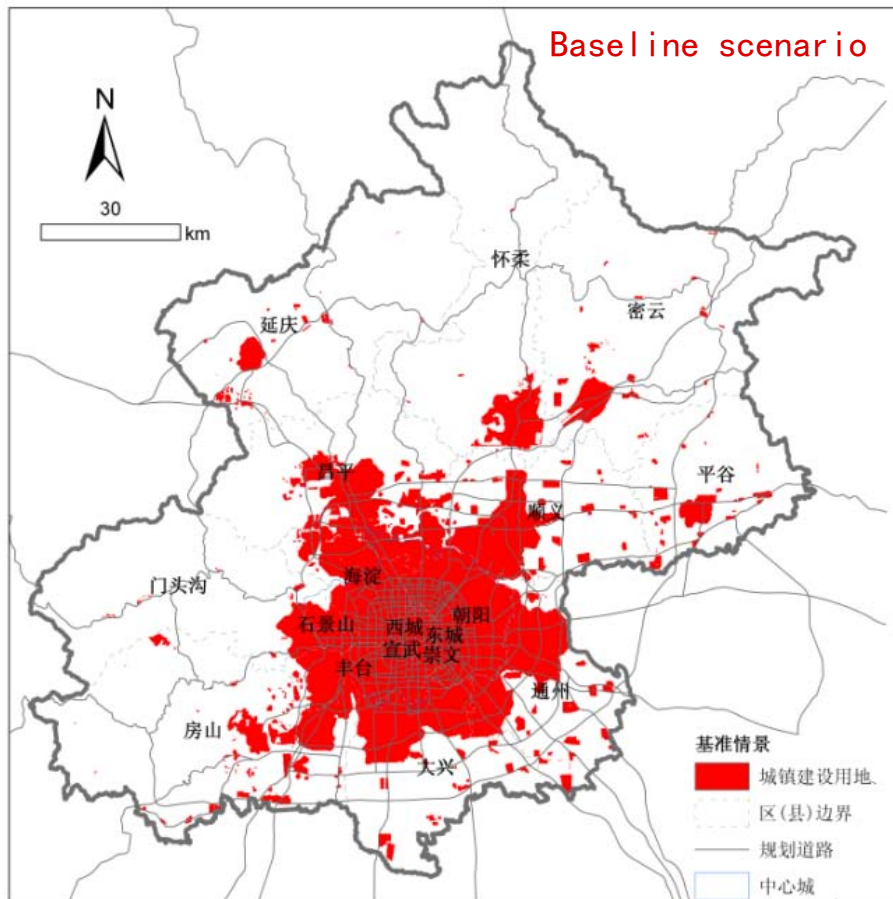
Our findings:

- Under current spatial policy settings, the spatial layout of master plan for 2020 could not be implemented.
- This module of Macro BUDEM could facilitate planners compiling a spatial plan with higher possibility to be implemented.

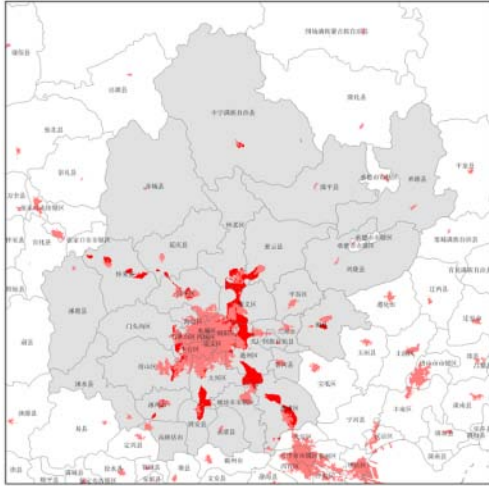
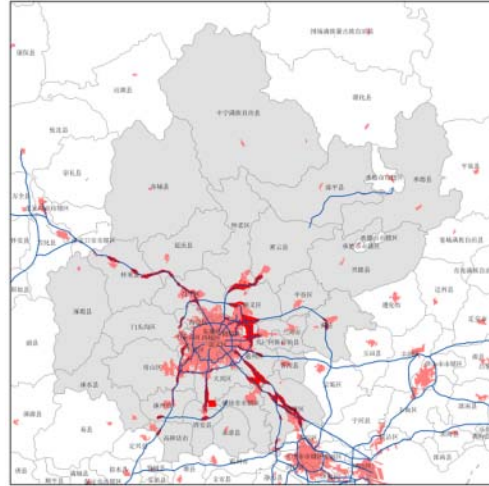
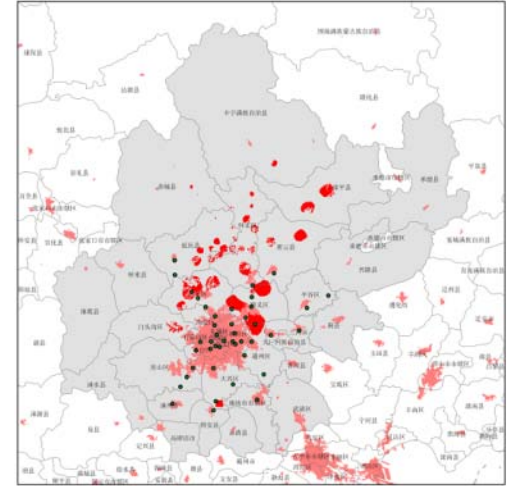
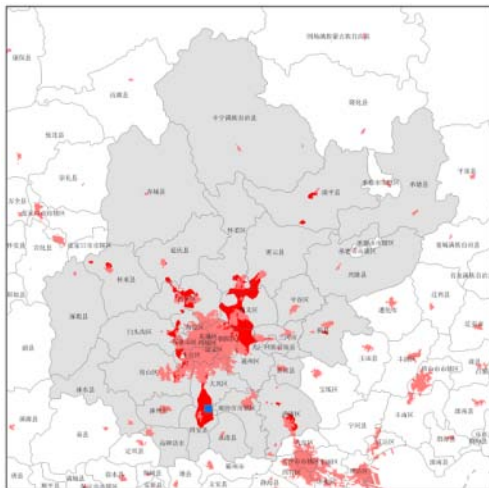
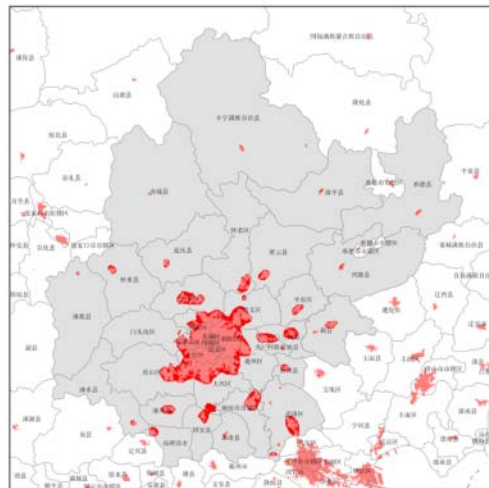
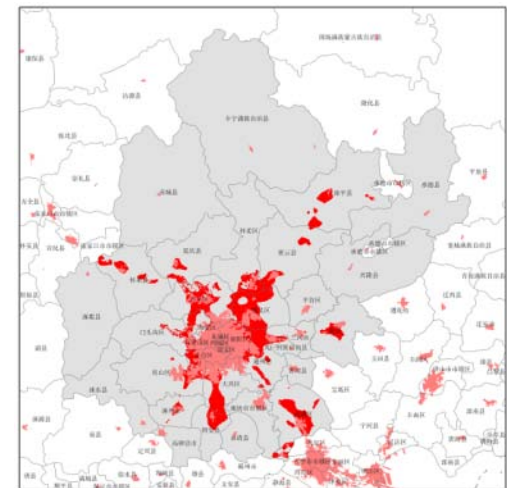
Backgrounds:

- Planned layout is occasionally broken through in China due to lack of consideration of economy factors
- Empirical studies in Beijing, Guangzhou, and Shanghai (Han et al, 2009; Xu et al, 2009; Tian et al, 2008)

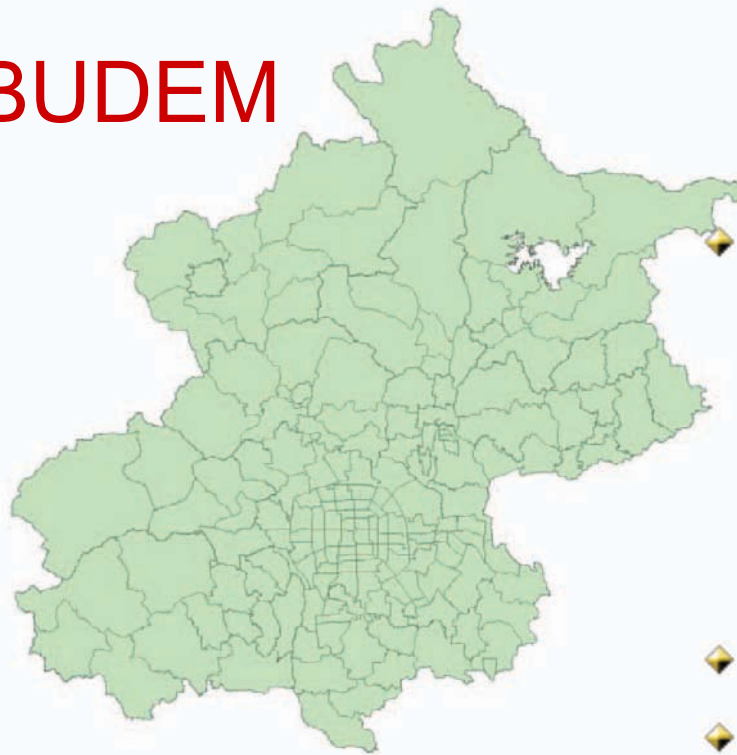
5 The second international airport location choice



6 Extended to the Greater Beijing Area

A1**A2****A3****A4****A5****A6**

Meso BUDEM



Beijing Land-use and Transportation Integrated Model

- BLUTI v1.0
- Developed in 2009
- Long term forecast (2020)
- Based on Cube

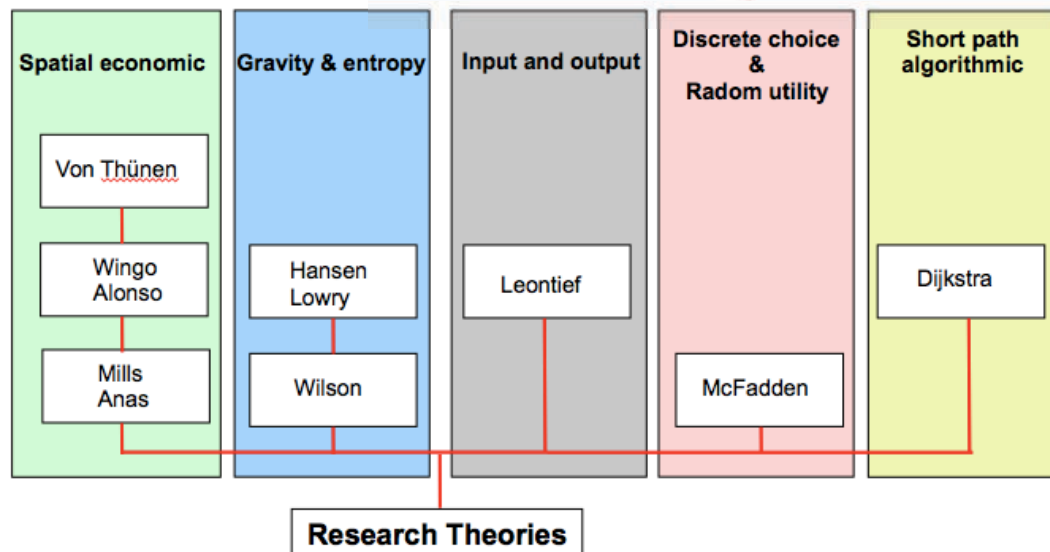
◆ 178 TAZs

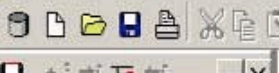
◆ Applications in urban planning practices

- 3A Hospital site planning assessment
- Influence of subway Line 5 on housing location choice

◆ Contributors

- ZHENG Meng, ZHANG Xiaodong, ZHANG Yu, ZHANG Xin in Department of Transportation Planning, BICP





BMI_Model.cat

Scenarios

- Base

Applications

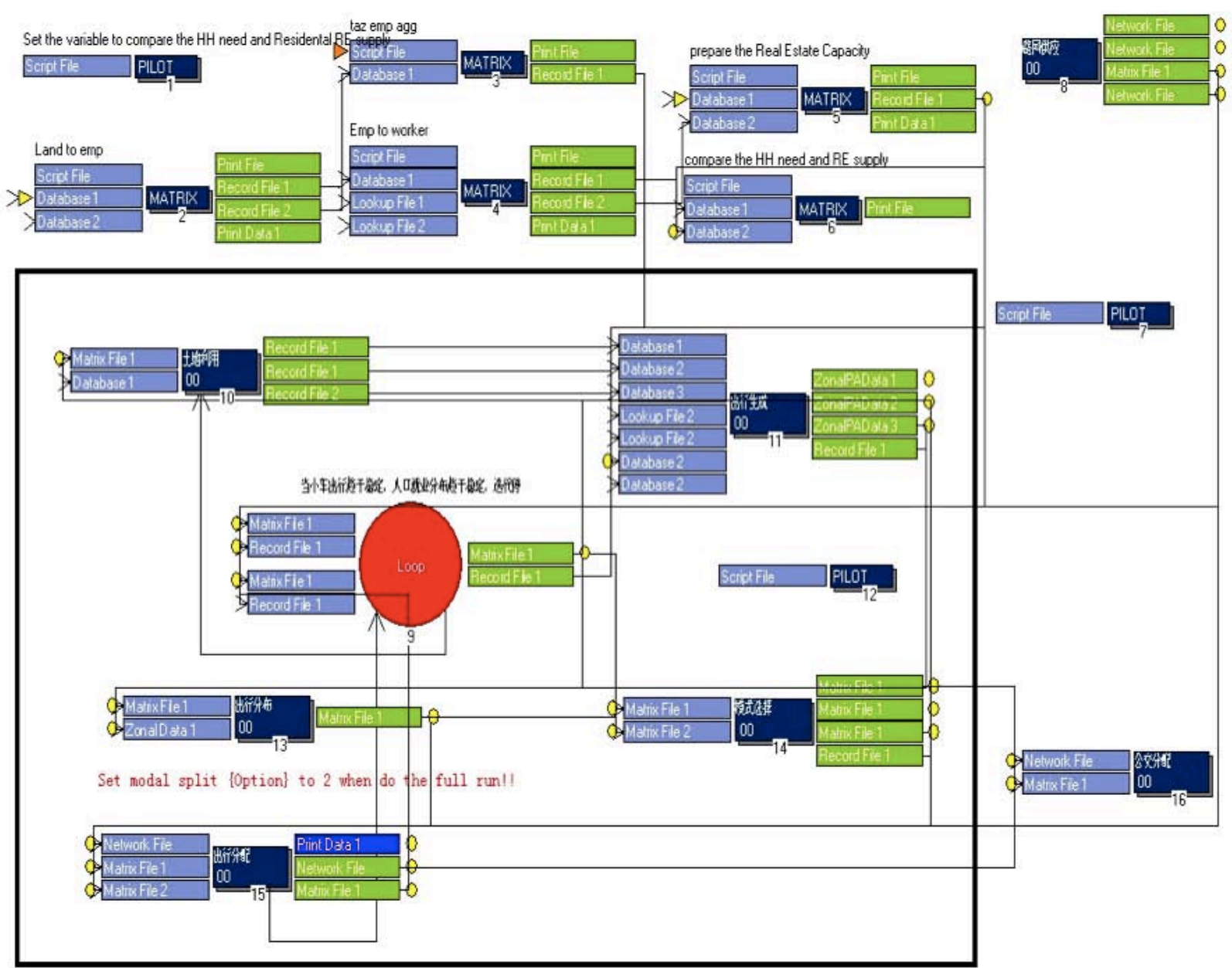
- 北京模型

Data

- Inputs
- Outputs
- Reports

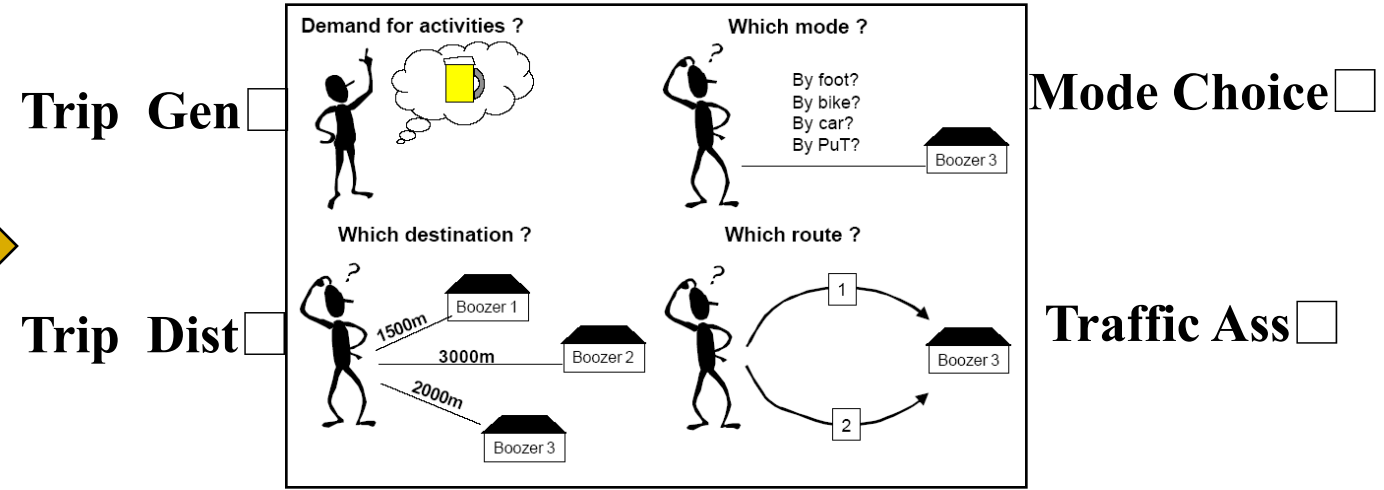
Keys

Key	Value
Scen. Name	Base
Plan_Year	2004
Land_Use	推?dbf
Zones	374
Internal_Zones	178
RateColumn	2

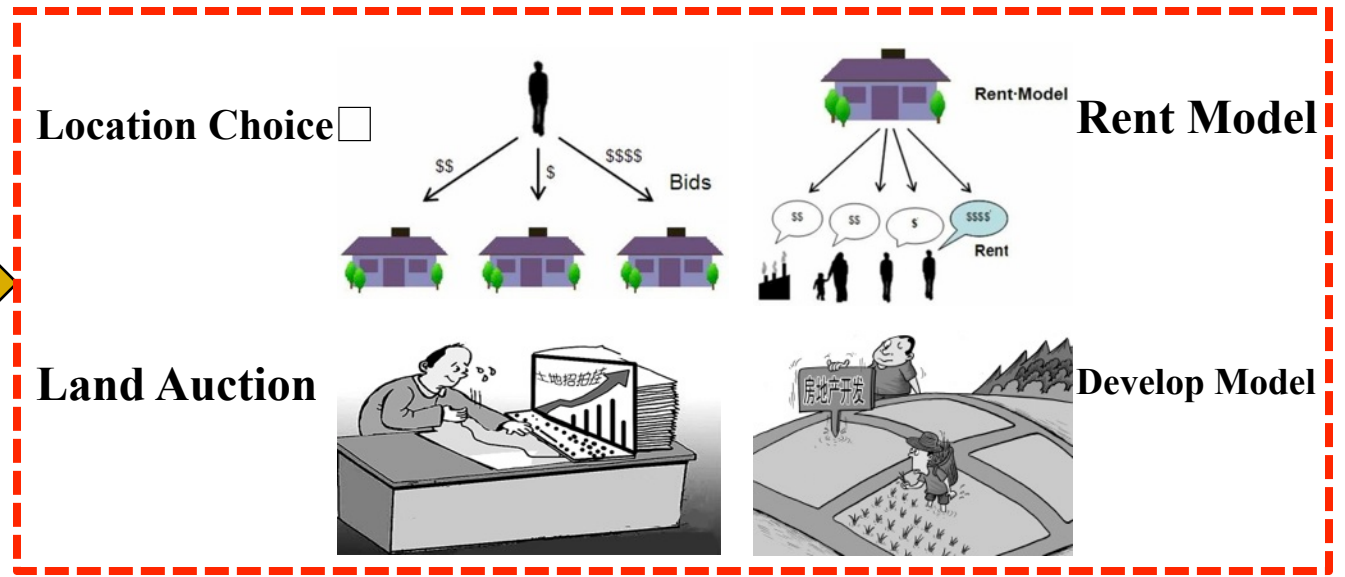


System structure of meso BUDEM□

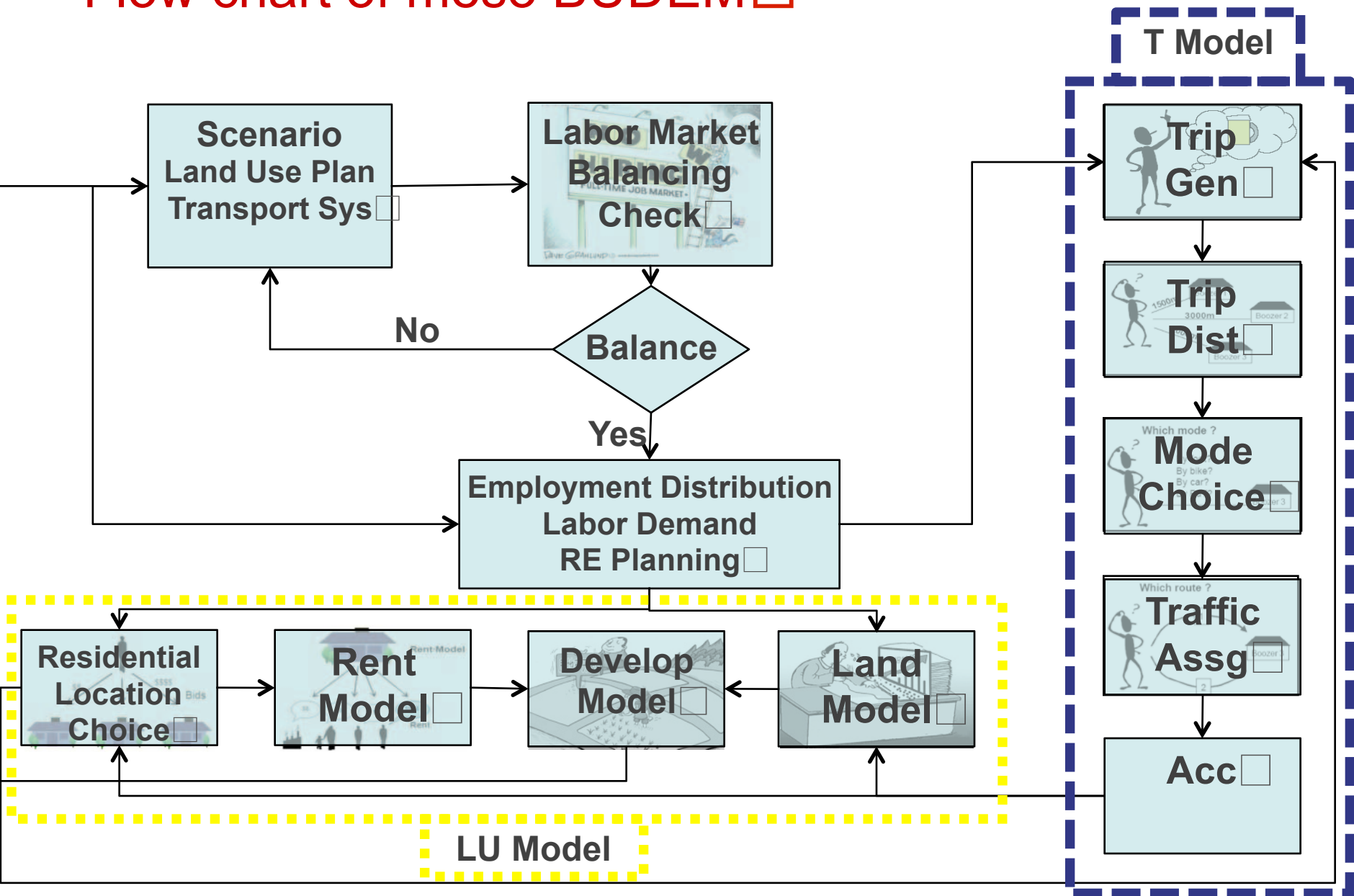
Transportation sub-models



Land use sub-models



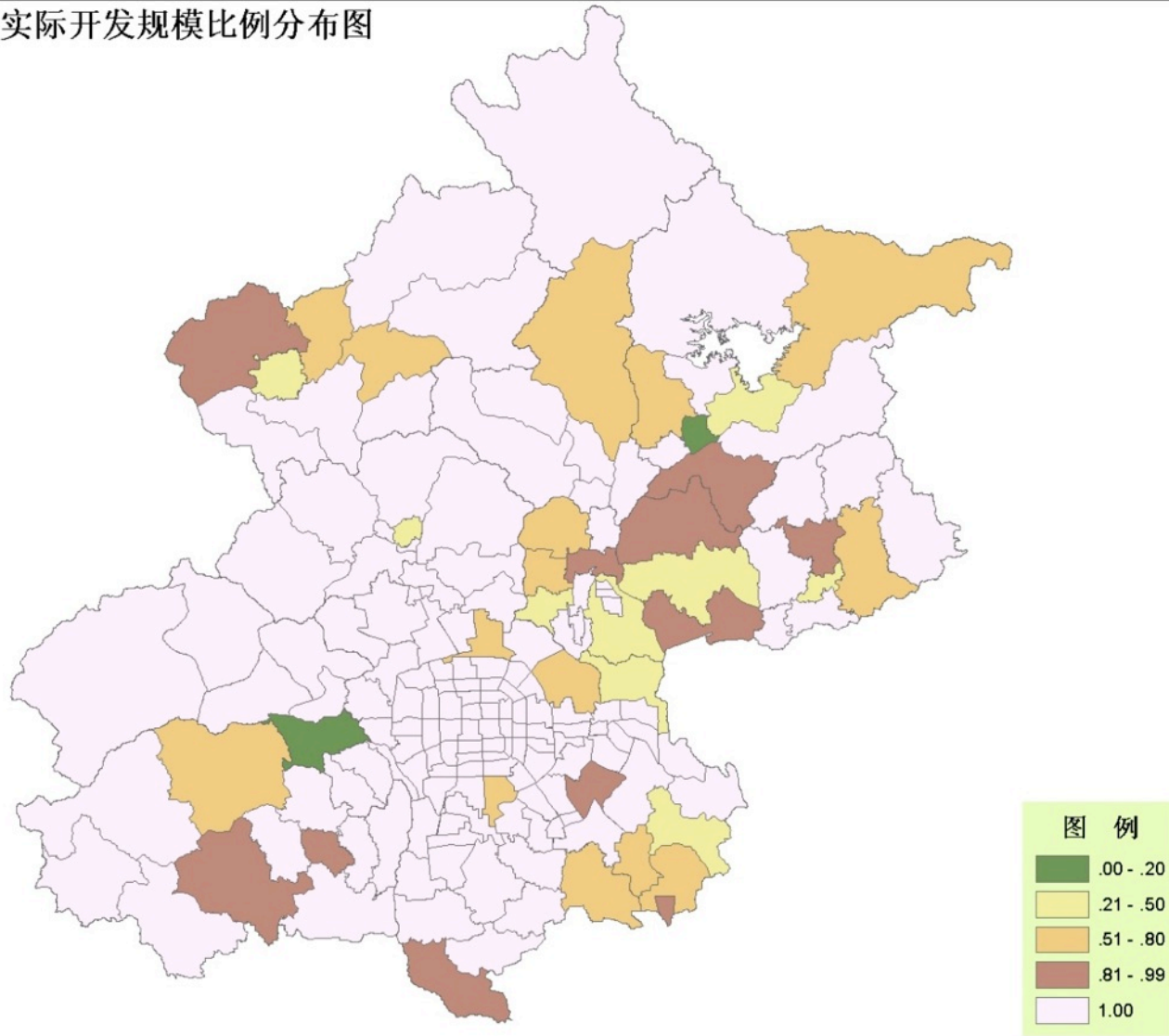
Flow chart of meso BUDEM□



Applications:

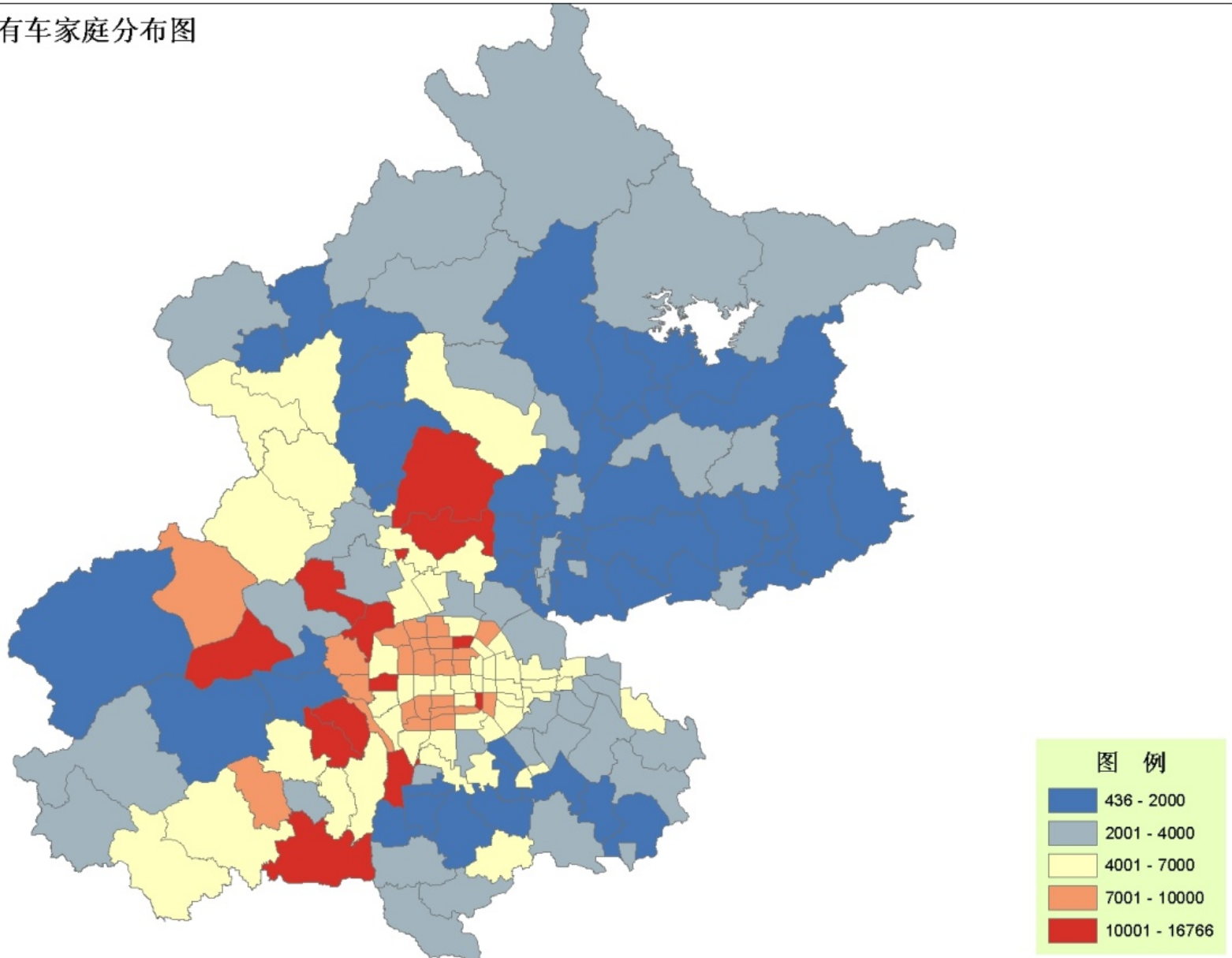
1 Residential land scale and distribution appraisal

规划住宅用地实际开发规模比例分布图

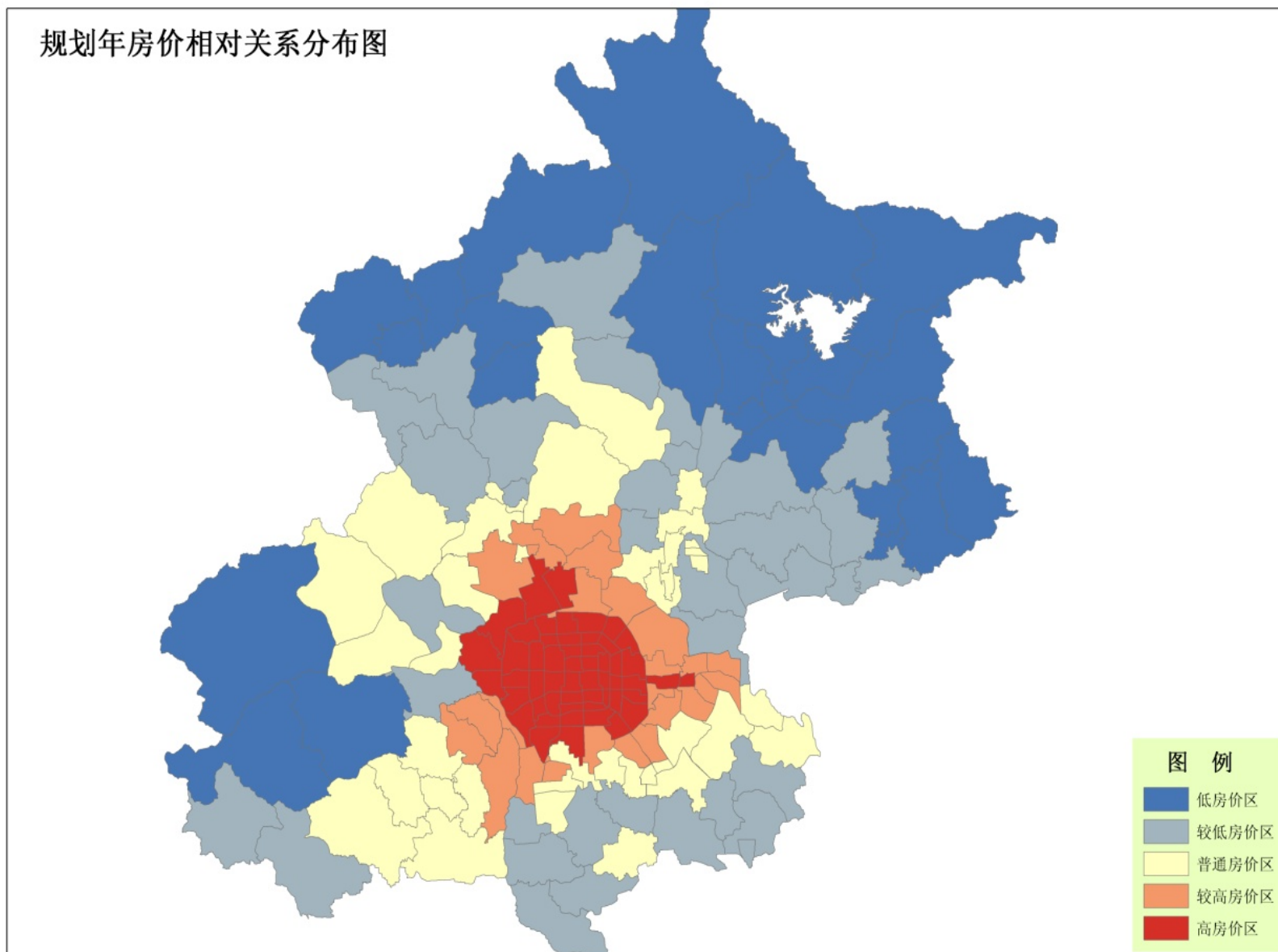


2 Forecasting the distribution of different household type

高收入有车家庭分布图

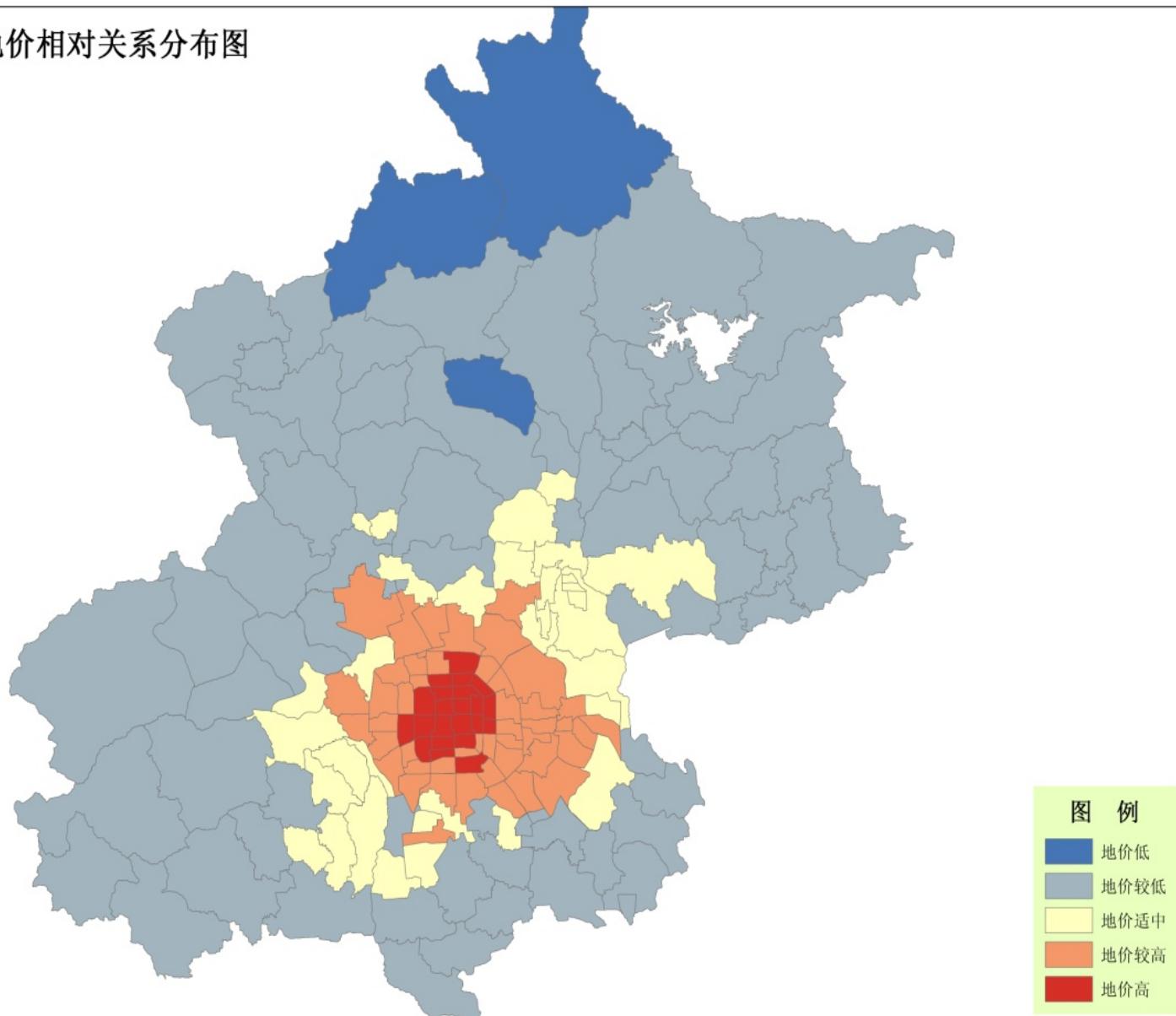


3 Forecasting the distribution of rent price



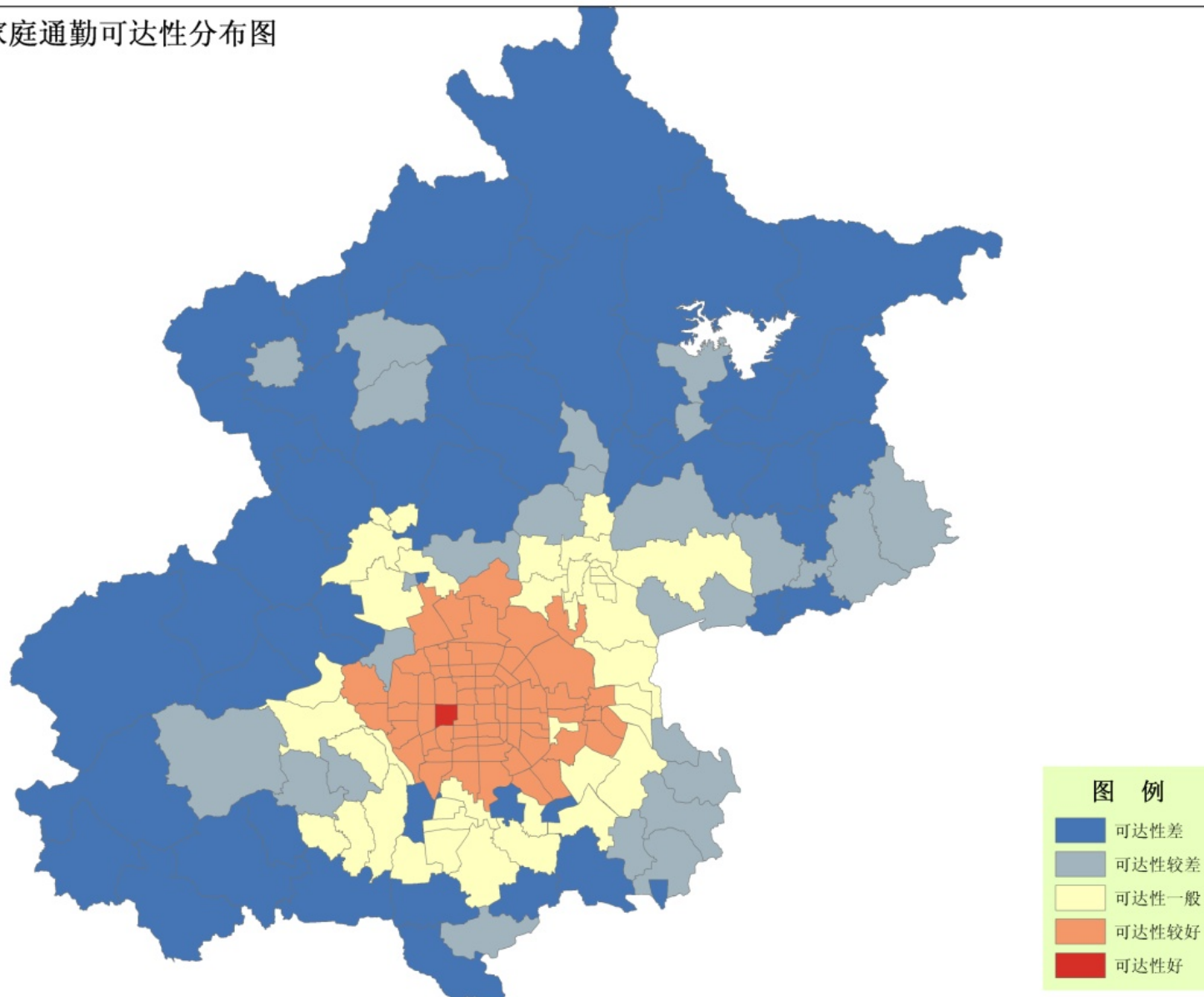
4 Forecasting the distribution of land price

规划年地价相对关系分布图

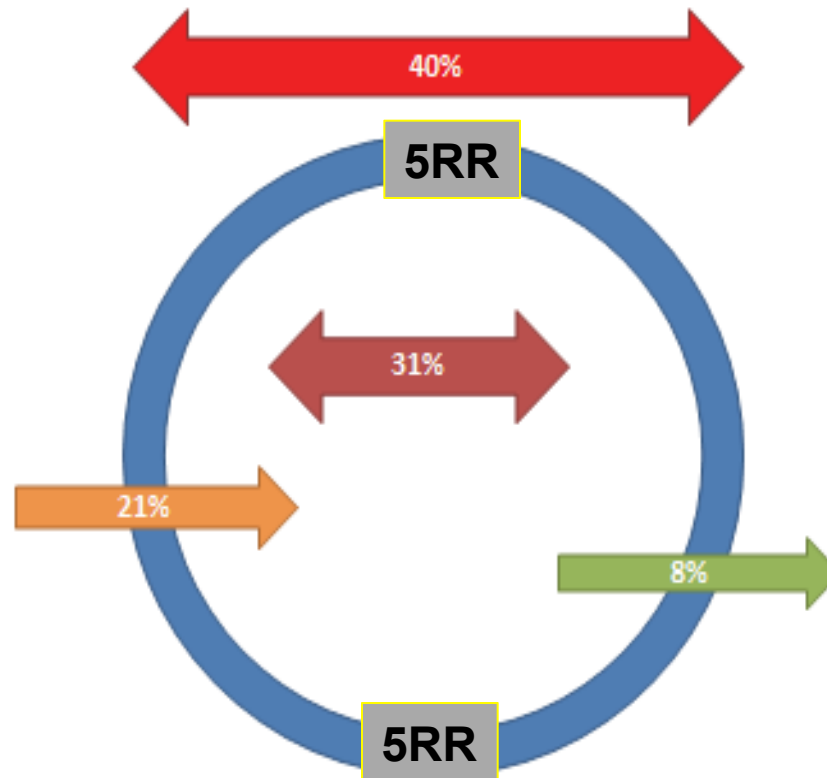


5 Forecasting the accessibility

高收入无车家庭通勤可达性分布图

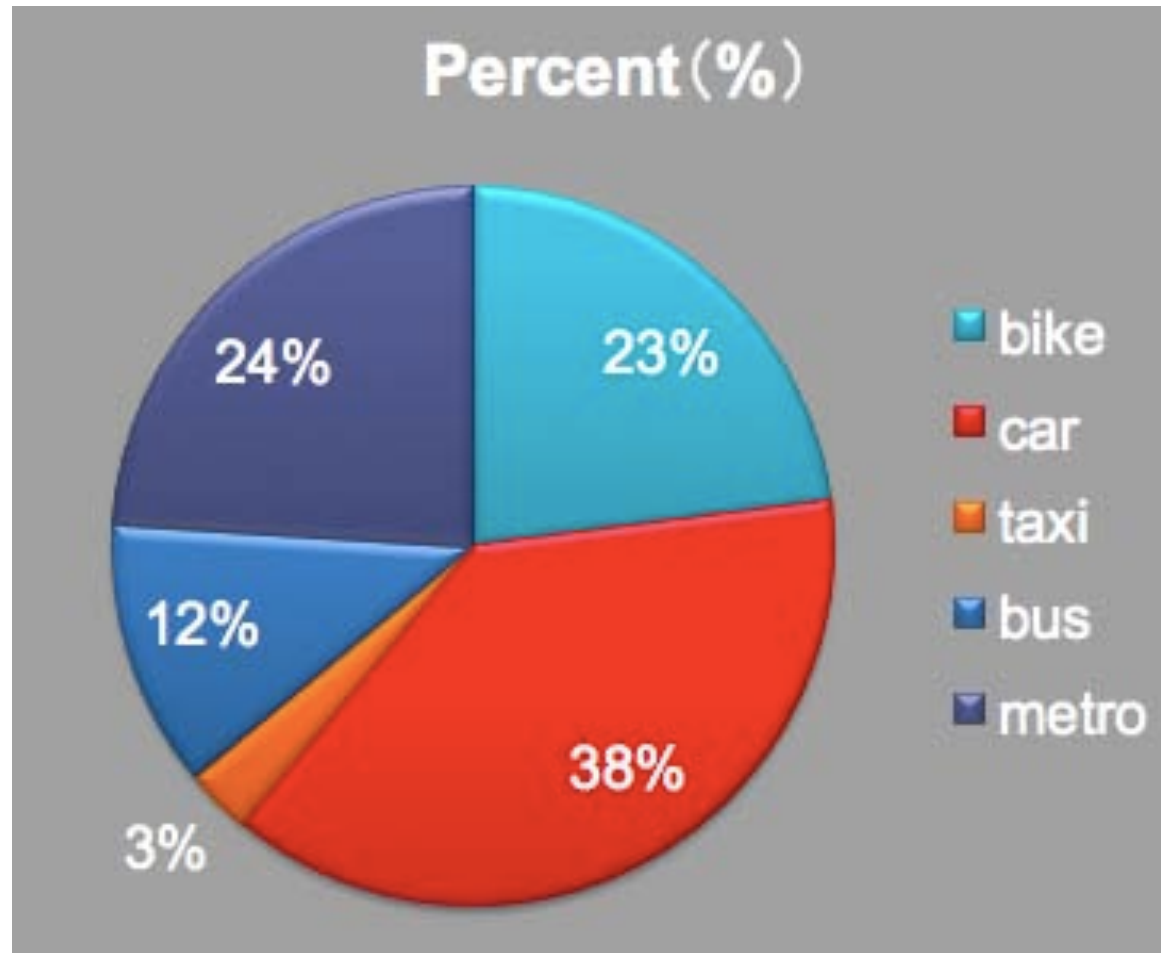


6 Forecasting the distribution of trips



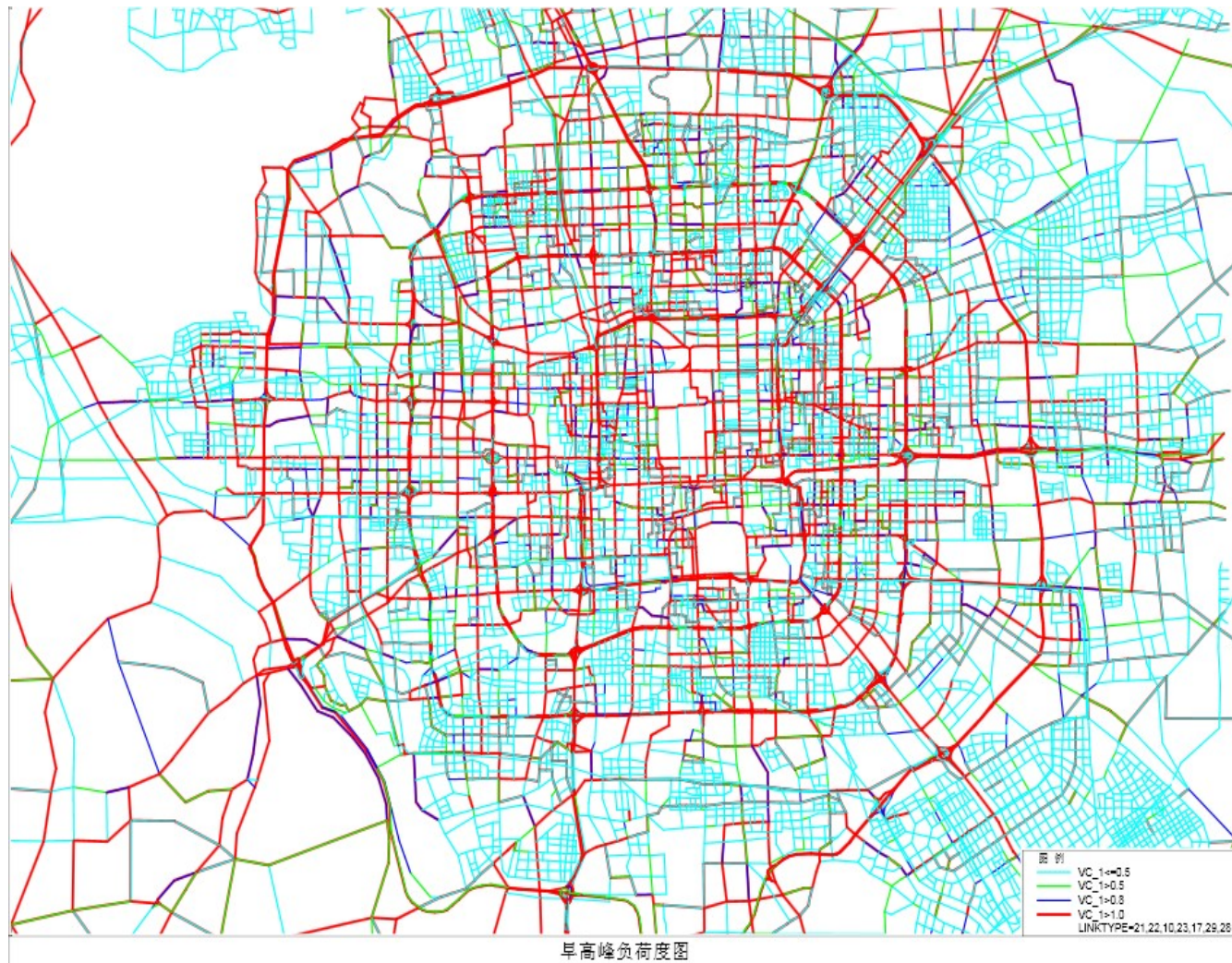
AM Peak-Hour PCU DISTRIBUTION

7 Forecasting the traffic modal split



AM PH Modal split result

8 Forecasting the traffic volume through assignment



AM PH VC ratio of Planning Year

9 Balance between the labor demand and supply appraisal



Labor demand: 10 million



Pop demand: 18.6 million

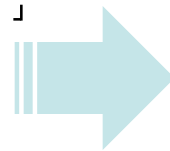
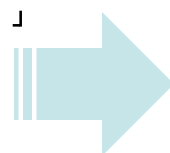


HH demand: 7.2 million



Balance

HH supply: 7.6 million



In upgrading to 1911 TAZs using UrbanSim,
focusing on residential and firm location
choice



$$\begin{aligned} \text{Probability} = & \beta_0 + \beta_1 \text{LnPOTENTIAL} + \beta_2 \text{LnACC} + \beta_3 \text{LnD_SUBWAY} \\ & + \beta_4 \text{U_PRICE} + \beta_5 \text{O_DUMMY} \end{aligned}$$

Micro BUDEM

- ✦ An ongoing project (**city lab for testing policies**)
 - 2012-2014
 - Expected to continue during the academic visit to University of Cambridge from March 2013 to March 2014
 - ✦ A fine-scale model for the whole Beijing Metropolitan Area
 - Rather than limited to typical neighborhoods based on questionnaire
 - Static parcels
 - ✦ Supported by macro and meso BUDEMs
 - Providing exogenous variables for micro BUDEM
 - ✦ Proposal a fine-scale model for
 - Establishing micro-level data infrastructure (**BEIJING100%**)
 - Present
 - Environment, energy consumption, CO2, spatial policy
 - Short-term
 - Demographic evolution, residential location choice, job location choice, land use layout scenario analysis
- Not applicable for long-term forecast or scenario analysis**

BEIJING100%

Parcels

- Existing, planned and permits

Population

- Households / residents

Human mobility

- Daily activities and all-modal trips

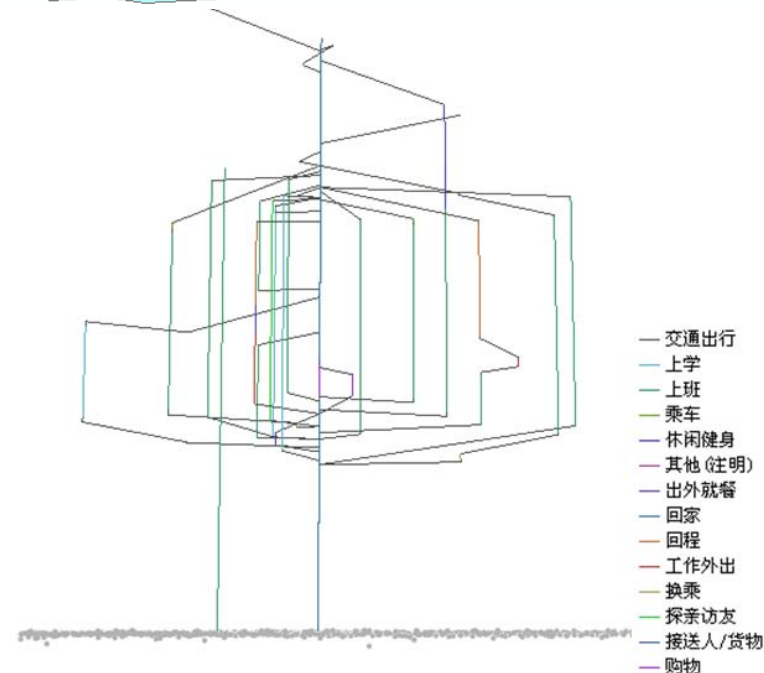
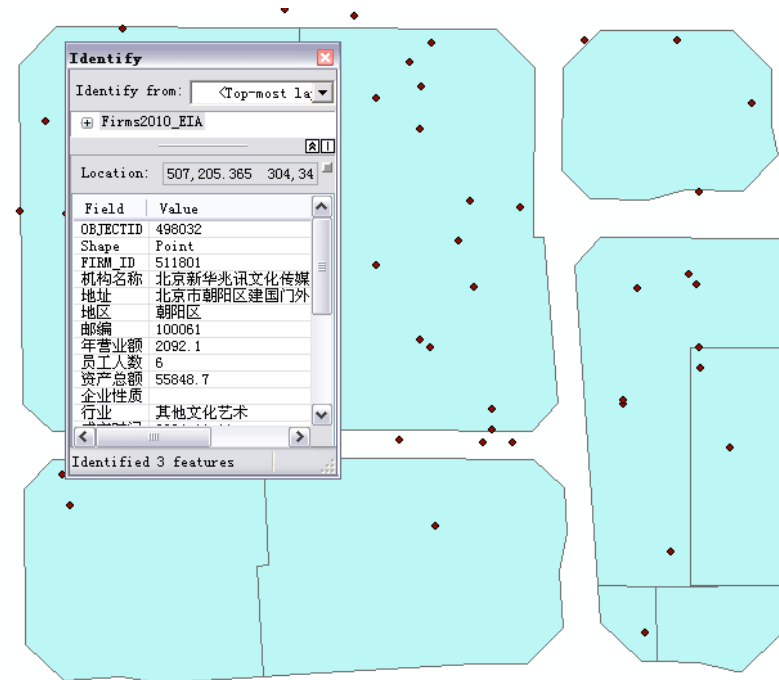
Firms

- All sectors

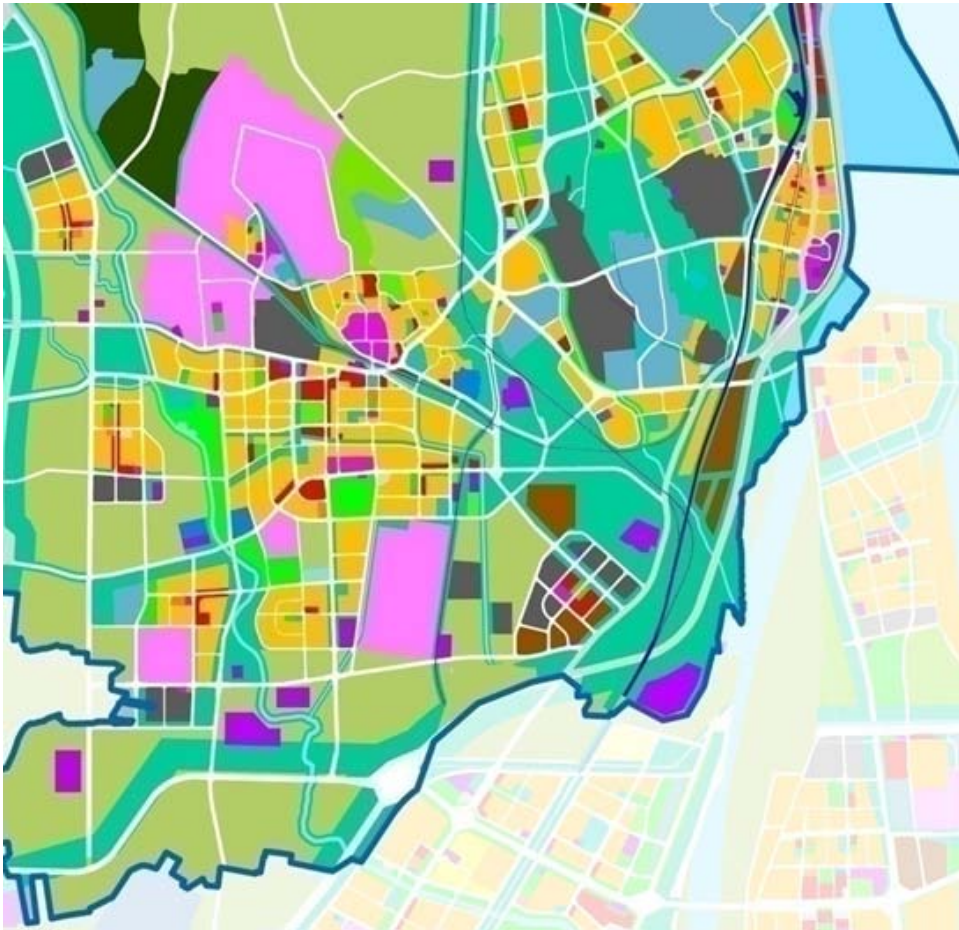
Housing

- Both commercial and affordable
- Location, price and rent

BEIJING100% is 2010 based, and an extra evolution submodel will be proposed for short-term data synthesis in the near future.



BEIJING100%: **Parcels**



Buildings

- Footprint & #floor
- Within 6th ring road
- 2004/2006/2008/2010
- 254 million buildings in 2010

136638 existing parcels

- Floor area, land use type, resident count, job count

100912 planned parcels

- Land use type, FAR, maximum building height,

139886 cadastres

- Within 6th ring road

38894 land use permits

- 1950-2011
- Land use type, developer, issue date

BEIJING 100%: Population

📍 19.1 m residents and 8.0 m households in the BMA

📍 Input datasets:

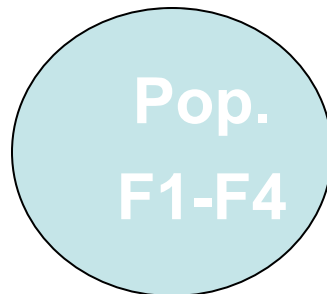
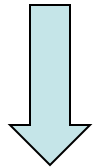
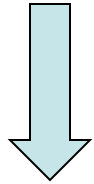
- Samples (116,142 residents / 46,900 households)
- The 6th population census of Beijing
- Existing researches regarding statistical characteristics of population attributes and relationships among attributes

📍 Population synthesis

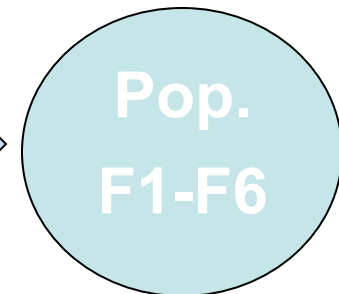
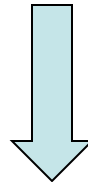
- PopGen: based on samples and marginal
 - Developed by Arizona State University
 - <http://urbanmodel.asu.edu/popgen.html>
- Agenter: does not need samples
 - Developed by Ying LONG
 - Long Y, Shen Z, 2012, “Disaggregating heterogeneous agent attributes and location from aggregated data, small-scale surveys and empirical researches” Computers, Environment and Urban Systems (Revision under review)

BEIJING100%: Population

- **Samples**
- **Aggregated data**

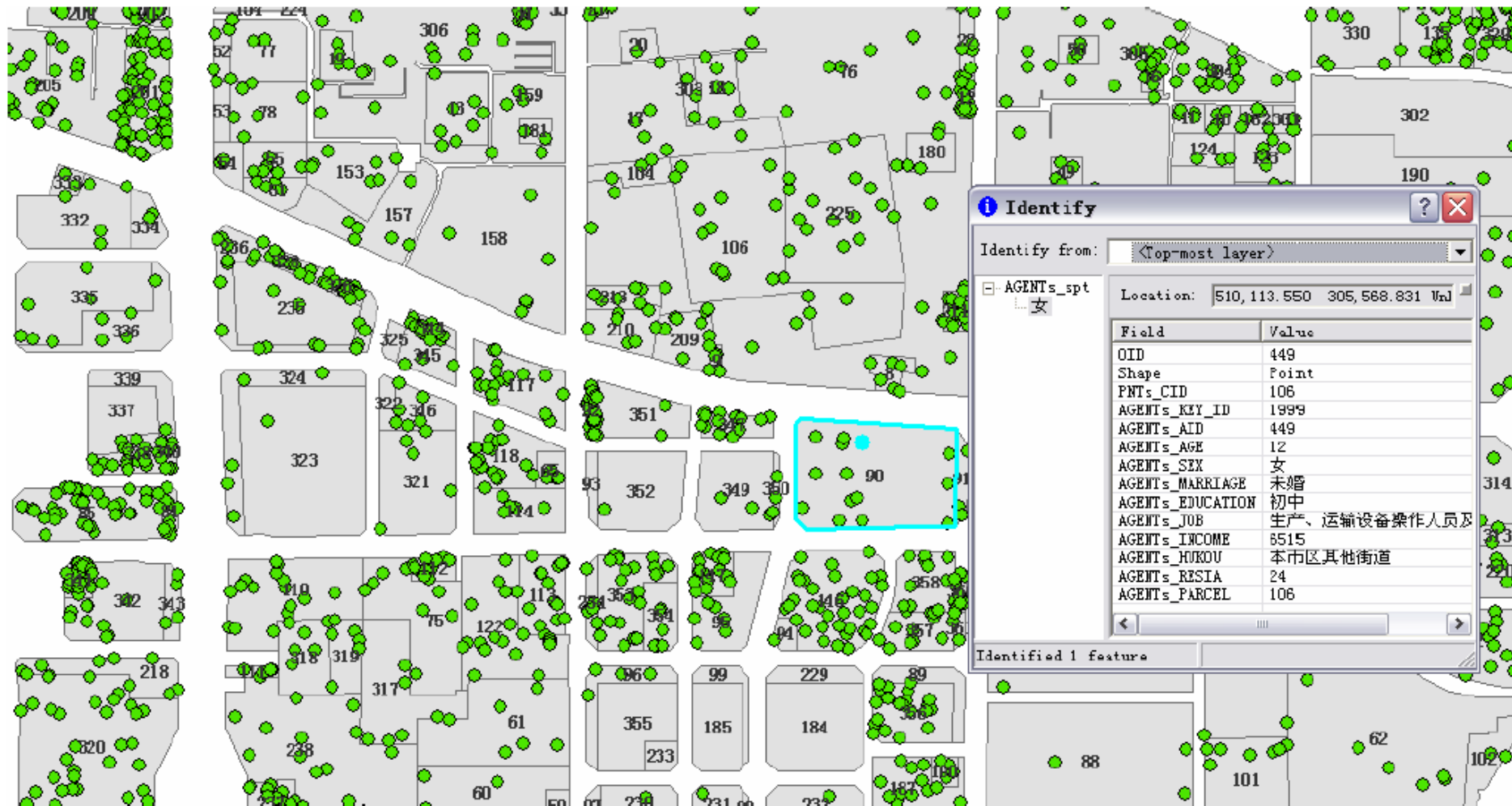


- **Aggregated data**
- **Existing researches**



Samples F1, F2, F3, F4
Aggregated data F1, F2, F3, F4, F5, F6
Pop. = Households + Residents

Synthesized population



Resident attributes: age, gender, education, marital status, job, nation

Household attributes: size, income, location

A demographic sub-model to be developed to synthesizing short-term population.

BEIJING100%: **Human mobility**

Travel purposes

Work

School

Returning home

Shopping

Entertainment

Daily life

Business

Other

The Beijing Household Travel Survey in 2010

- 46,900 households / 116,142 persons surveyed
- 253,584 trips (52,640 commuting from housing to job)
- Information including
 - Socio-economic attributes of households and persons
 - One-day travel diary of each person (mode, purpose, OD, departure and arrival time, etc.)

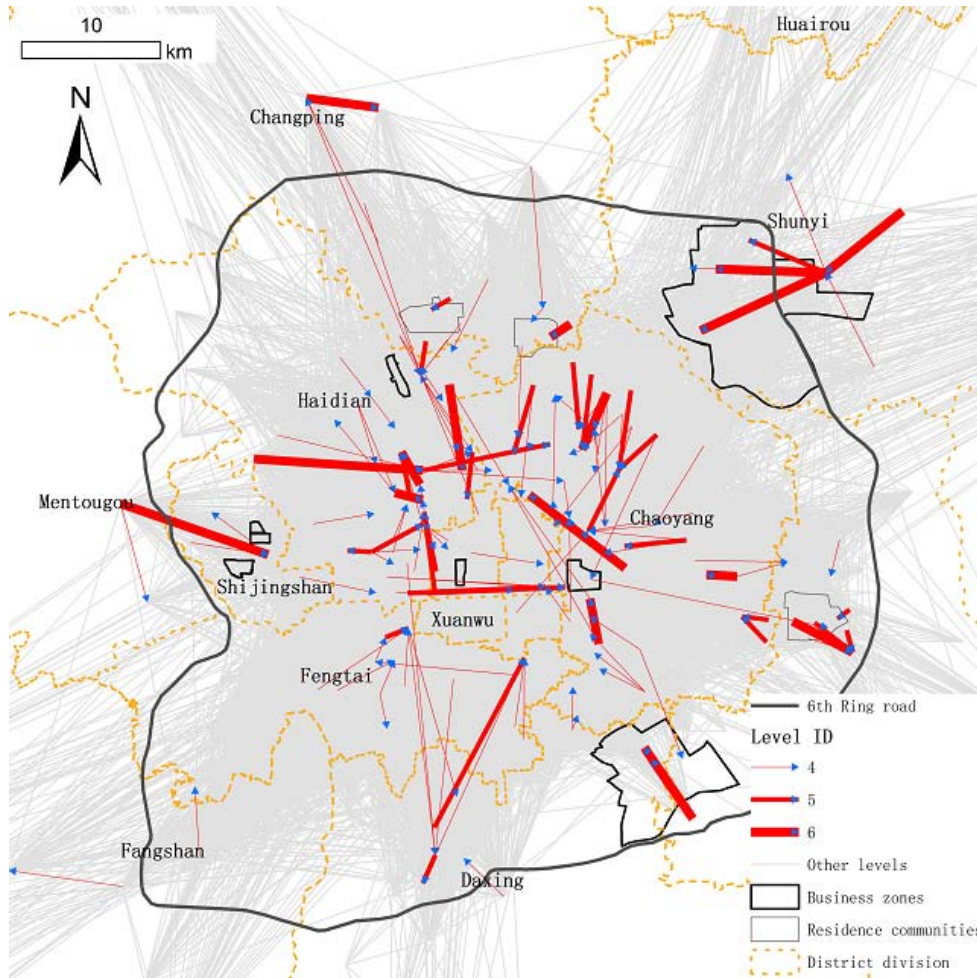
Converting trips to activities

- 75032 persons' 287027 activities

The 2005 version

- 81,760 households / 208,290 persons surveyed
- 831,076 trips

-- Inferring urban activities from big data



Smart card data of Beijing in 2010

- Bus and metro ridings
- 10.9 million cards
- Over 100 million swaps
- Finishing identifying commuting trips

Crawled from Weibo

- China “Twitter”
- Check In

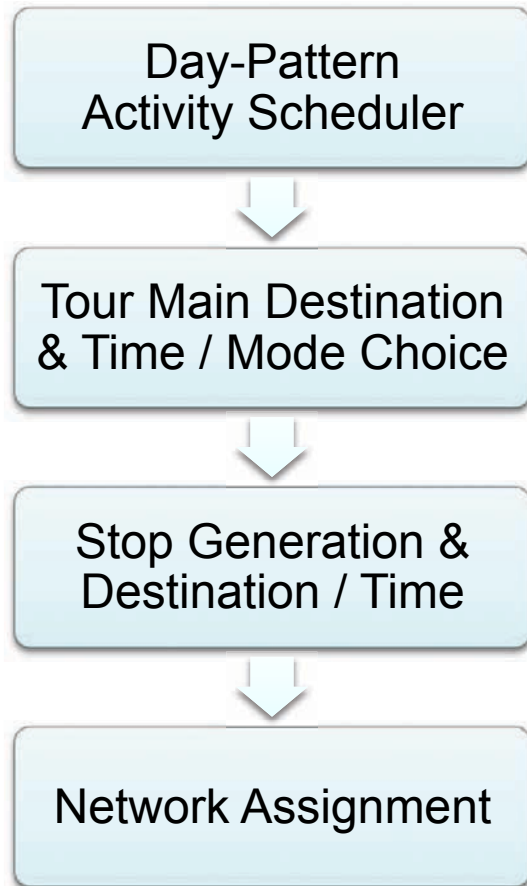
Taxi trajectories

- Microsoft Research Asia (MSRA)
- 30,000 taxis

Combined with POIs

- Over 100,000 categorized POIs

-- **Activity-based travel model** based on BEIJING100%



- ✦ **Increasing attention**
 - An alternative of conventional four-phase method
- ✦ **Based on one-day travel chain in the individual or group level**
 - E.g. home to work, shopping after work, backing home

All households

> Having-car households

> No-car households

> Worker

> Student

> Others

> Worker

> Student

> Others

Trip chains of no-car workers

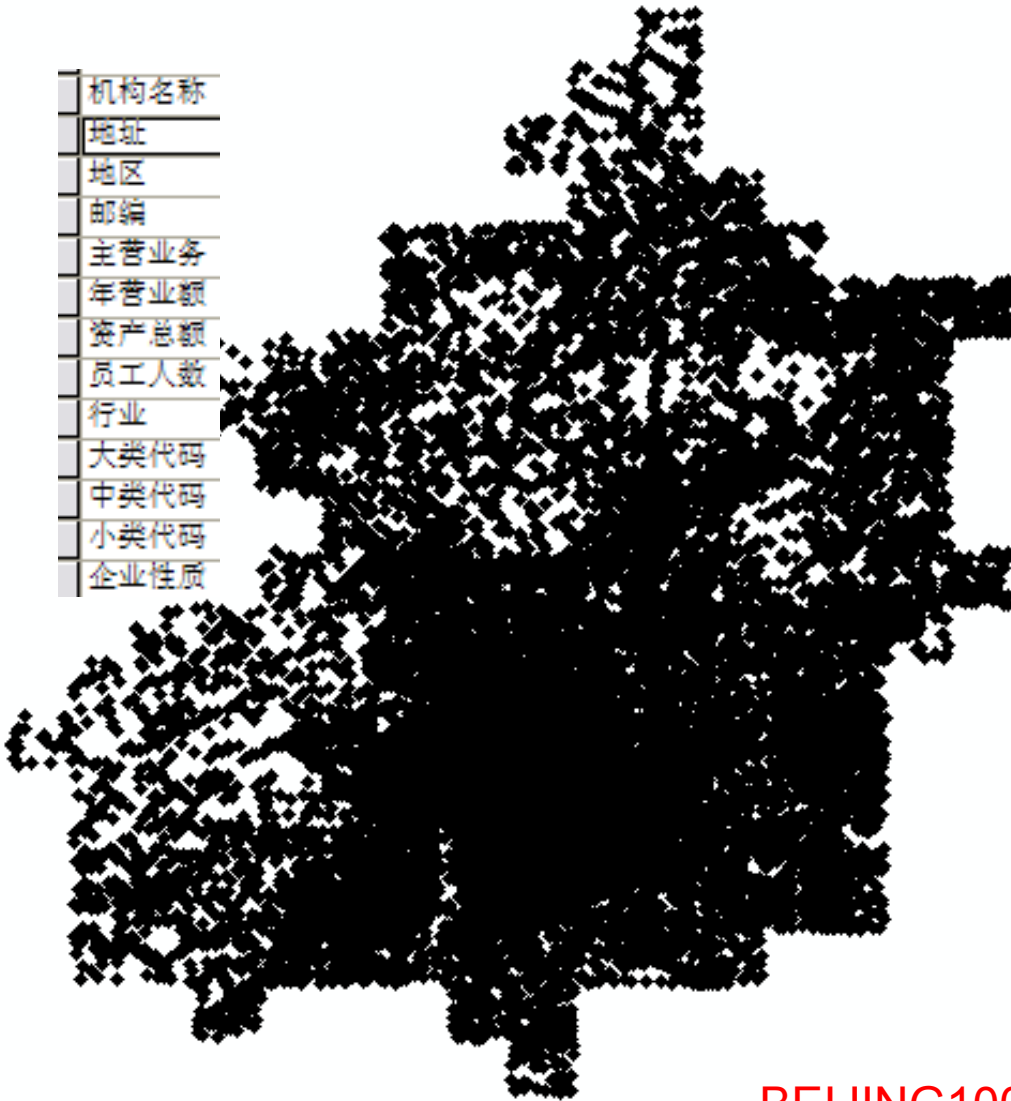
ID	Chain	Ratio (%)	Note
1	HWH	62	家-单位-家
2	HWHWH	7.9	家-单位-家-单位-家
3	HWEWH	2.9	家-单位-就餐-单位-家
4	HSH	2.7	家-购物-家
5	HWSH	1.8	家-单位-购物-家
6	HOH	1.7	家-其他-家
7	HWHS	0.8	家-单位-家-购物-家
8	HWHLH	0.7	家-单位-家-娱乐-家
9	HLH	0.7	家-娱乐-家
10	HPWH	0.5	家-接送-单位-家
11	HPWPH	0.5	家-接送-单位-接送-家
N = 29774, Sum of ratios = 82%			



H=Home, W=Work, E=Eat, S=Shopping, P=Pick up, L=Entertainment, O=Others

BEIJING100%: Firms

机构名称
地址
地区
邮编
主营业务
年营业额
资产总额
员工人数
行业
大类代码
中类代码
小类代码
企业性质



630 thousand firms

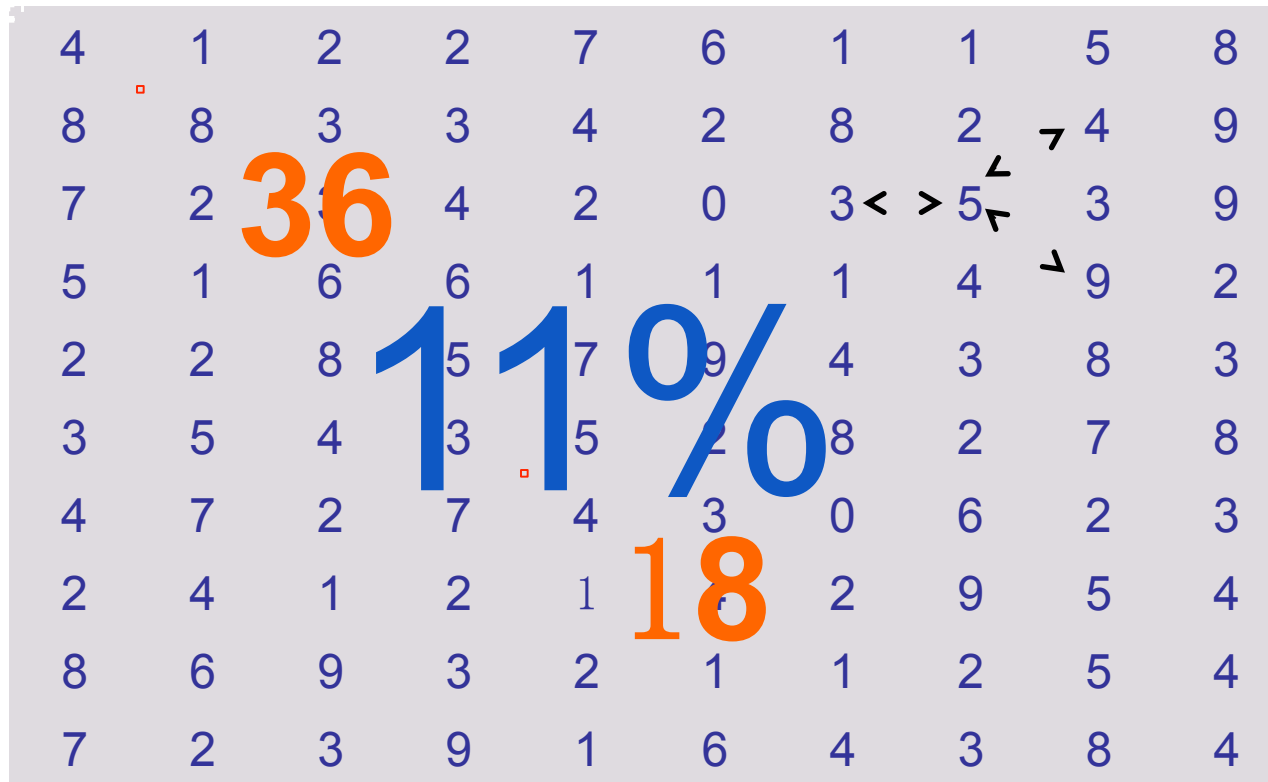
- In 2010
- With 14.5 m job positions

Attributes

- Location
- Sector (all sectors 1-98 of China)
- Revenue
- Employee count

BEIJING100% also applicable for the meso BUEM.

Microsimulation / microanalysis for macro policy evaluation



Policy (spatial or not)



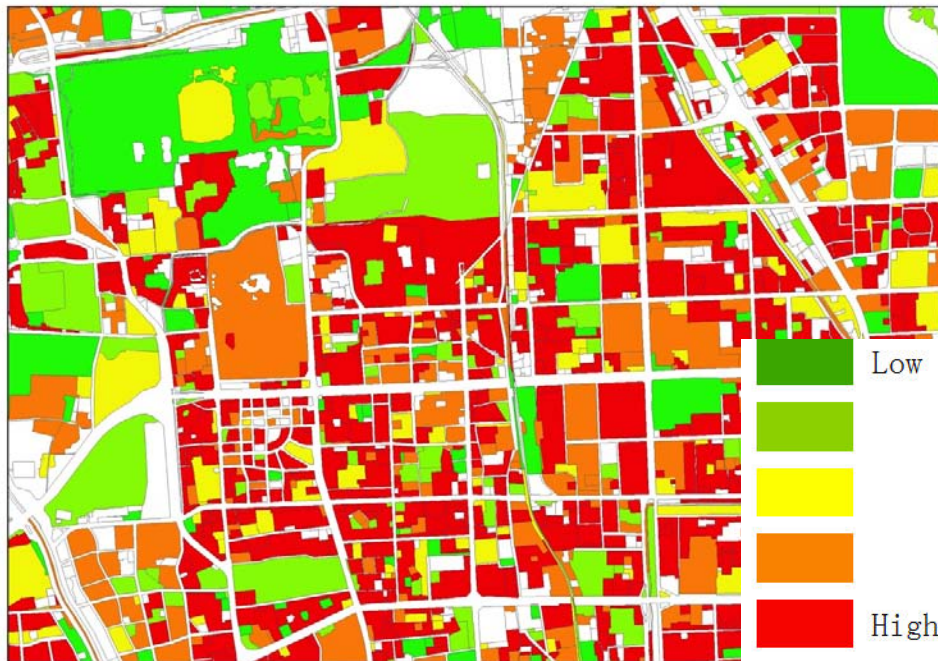
Feedback and decision by individuals



Macro behavior and spatial heterogeneities

**What
could
the
plan
response?**

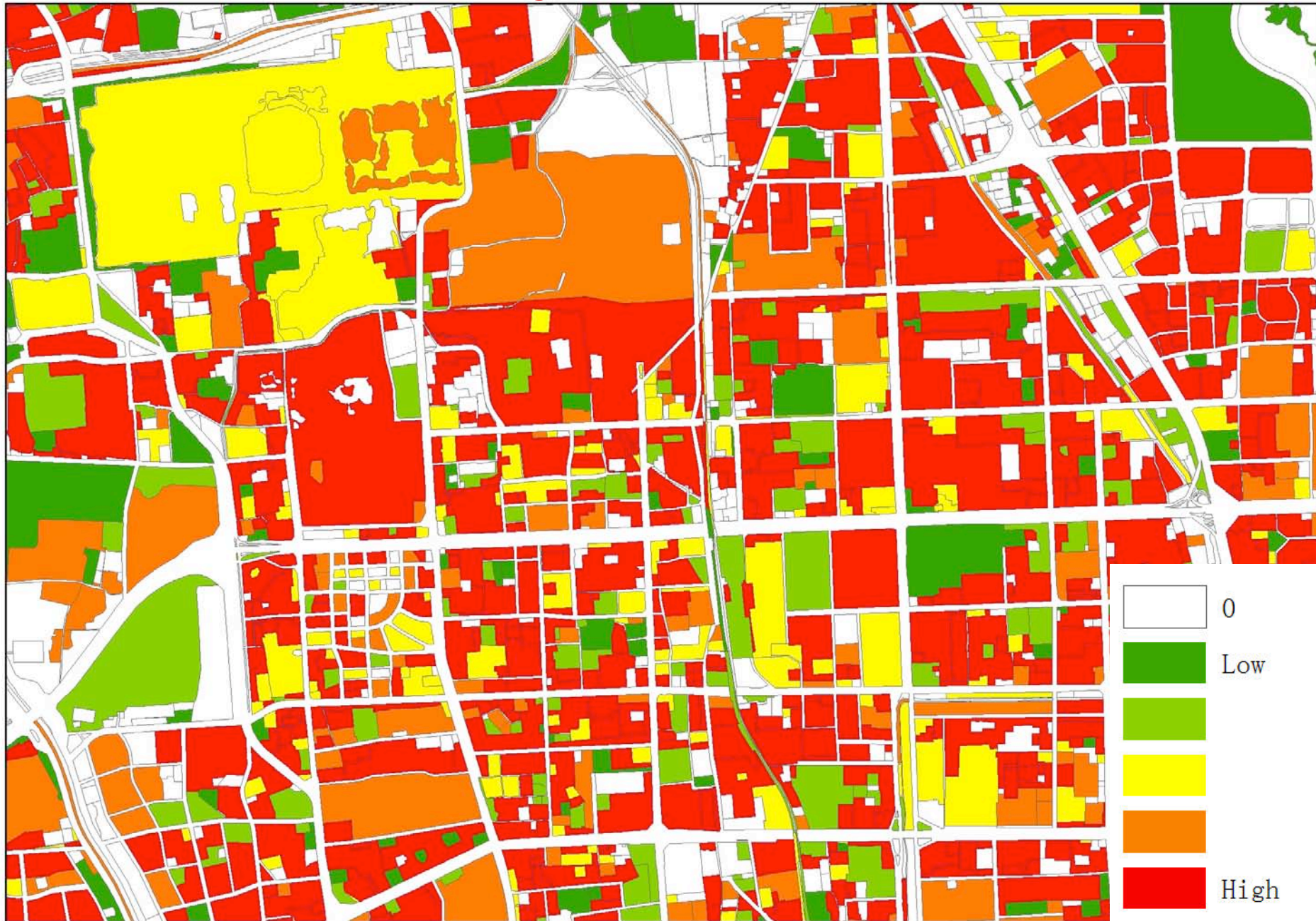
Case 1: Environmental evaluation



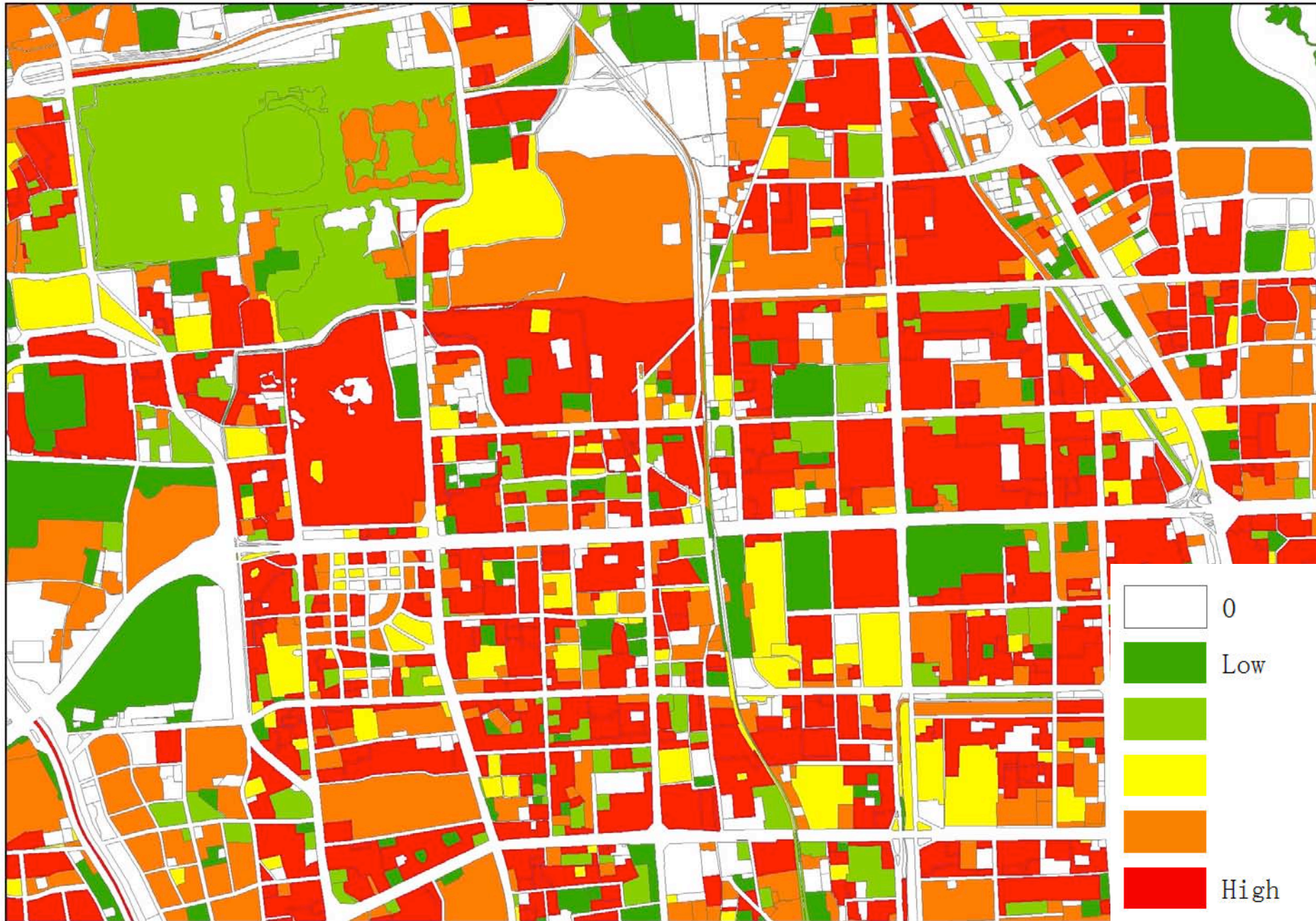
Energy consumption per sqkm

- Totals for all inventories from census report
- Allocating totals into parcels
 - Firms
 - Population
 - Human mobility
- Available for evaluating CO₂ emission in the parcel level

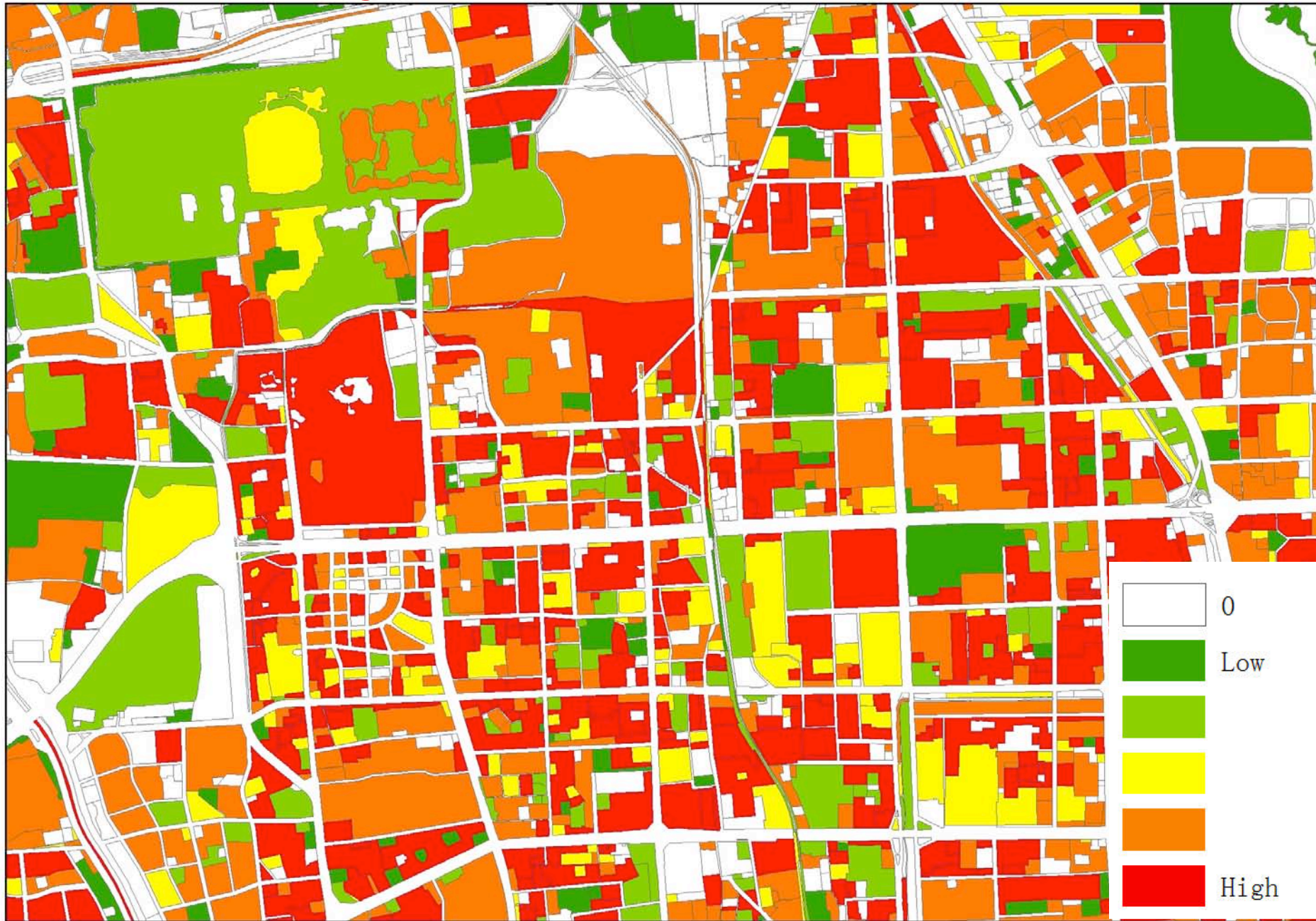
Wastewater discharge per sqkm



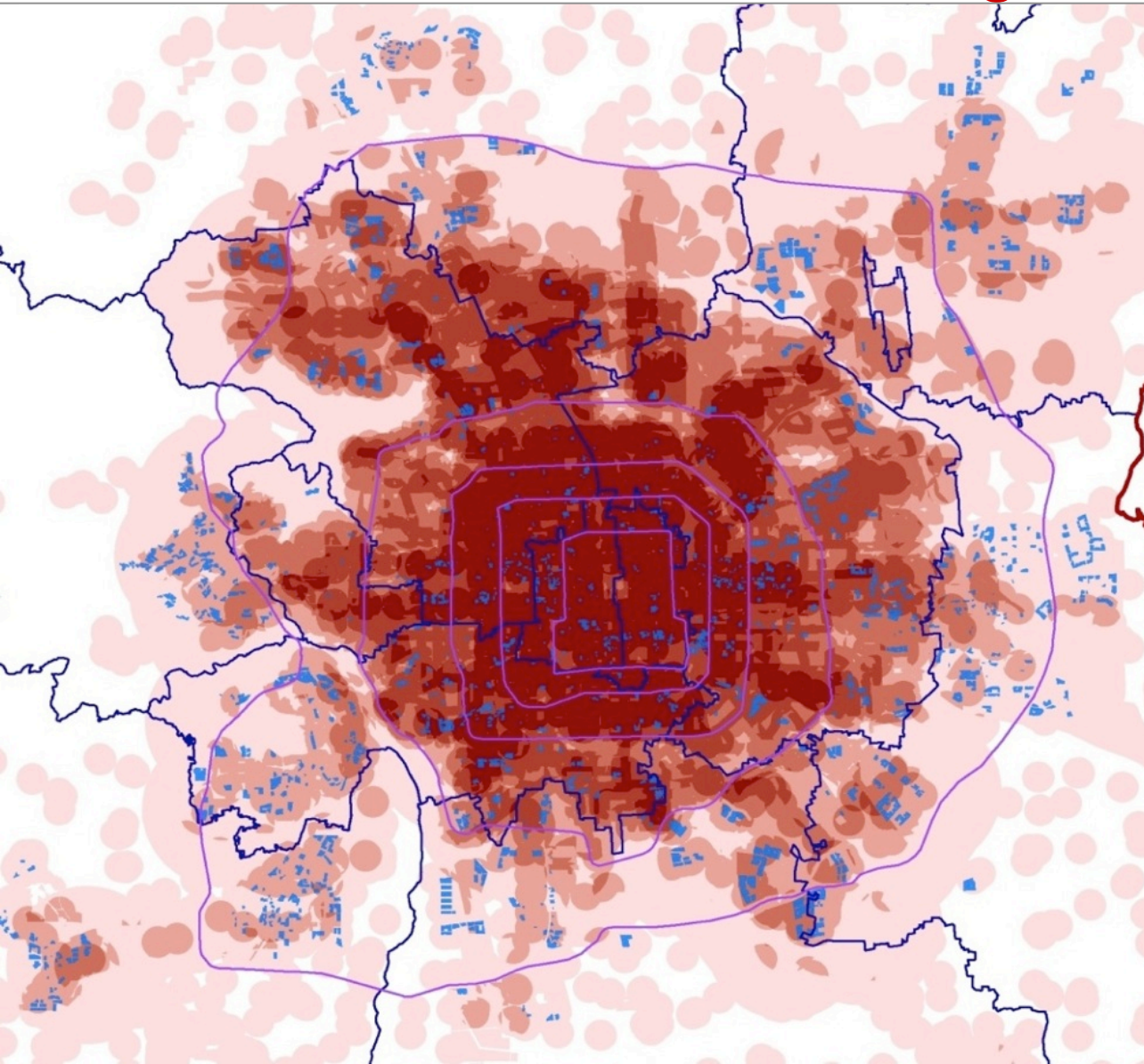
Solid waste discharge per sqkm



SO2 discharge per sqkm



Case 2: Affordable housing location choice



Supply side

- Multi-criteria decision making using AHP
 - Market oriented factors
 - Institutional factors
- 110 sqkm available
- In the parcel scale

Demand side

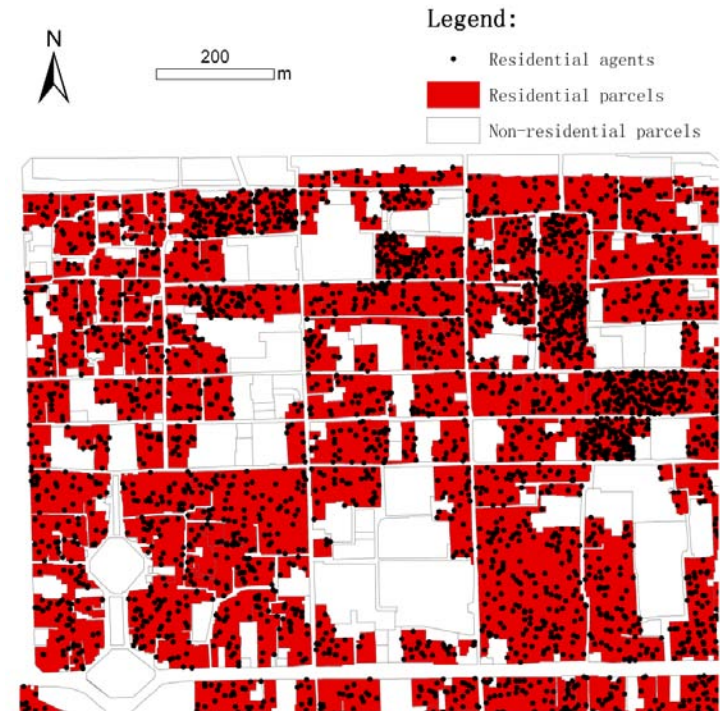
- Synthetic population
- Quantified policy housing policies
- Contingency survey

Combining supply and demand sides

- Suggested locations, scales and construction order
- Policy evaluation □

Other potential applications using BEIJING100%

- Small-scale urban redevelopment in the downtown area
- Metro line location choice
- Congestion zone setting
- Underground ring road
- Hazard influence evaluation
- Market-oriented applications
 - Shopping facility



Short-term forecast / scenario analysis

On going...

- ✦ Extend human behavior in BEIJING 100%
- ✦ Based on the macro/meso BUDEMs
- ✦ Parcel-scale UrbanSim
 - Land develop, residential location choice, firm location choice
- ✦ Activity-based travel model
 - Representative travel chains extracted from the 2010 survey

Conclusions

Three urban spatial development models in Beijing

☛ A family of BUDEMs

- Applicable urban models
- Ranging from macro, meso to micro levels

☛ Macro and meso BUDEMs

- Applications in strategic and master plans

☛ Micro BUDEM

- **BEIJING100%**
- Applications in the detailed plan scale, e.g. plan scheme evaluation, policy evaluation and EIA
- More frequent application in plan practices

☛ Demanding continuing efforts

Conclusions

Urban models in the era of “big data” □

🔦 “Big data”

- GSM, GPS trajectories, smart card swaps, credit card, SNS, etc.
- Individual based
- Increasing availability

🔦 Opportunities or challenges

- Population synthesis **v.s.**
- inferring urban activities from bus/metro smart card data

🔦 The second requiem for large-scale urban models?

- Too much data, rather than limited computation capacity, in contrast to the first requiem in 1970s (Lee, 1973)

🔦 Urban modelling using “big data”?

- Enriching data related with urban physical space, transportation, and human mobility/ activities □

Thanks for your attention!

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