Land use pattern scenario analysis using **Planner Agents**: A preliminary study

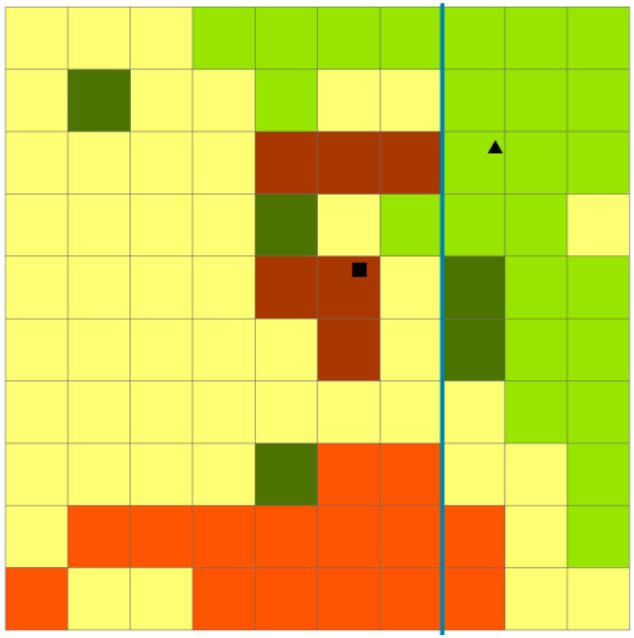
Yongping ZHANG, Peking University

Ying LONG, Beijing Institute of City Planning

1 INTRODUCTION

Land use pattern,

- or land use layout, is a key part of physical plan (master or detailed)
  - Spatial distribution of land use and density
  - Hard to predict by a planning support system (PSS)
- Land use pattern scenario analysis (LUPSA) – most are parcel-based
  - CUF (Landis 1994)
  - What if? (Klosterman 1999)
  - INDEX (Allen 2001)
  - iCity (Stevens et al. 2007)
  - Other papers regarding land use layout optimization



Planners in LUPSA tools

- Less attention was paid on the behavior of urban planners
- Our research question: How do planners compile land use pattern?
  - What are rules (*preferences*)?
  - How to identify these rules?
  - Are these rules varying among planners?
  - Could we develop a PSS for "simulating" land use patterns using the identified rules?

Building city in a vitro

Hatner and Benenson, 2007, EPB

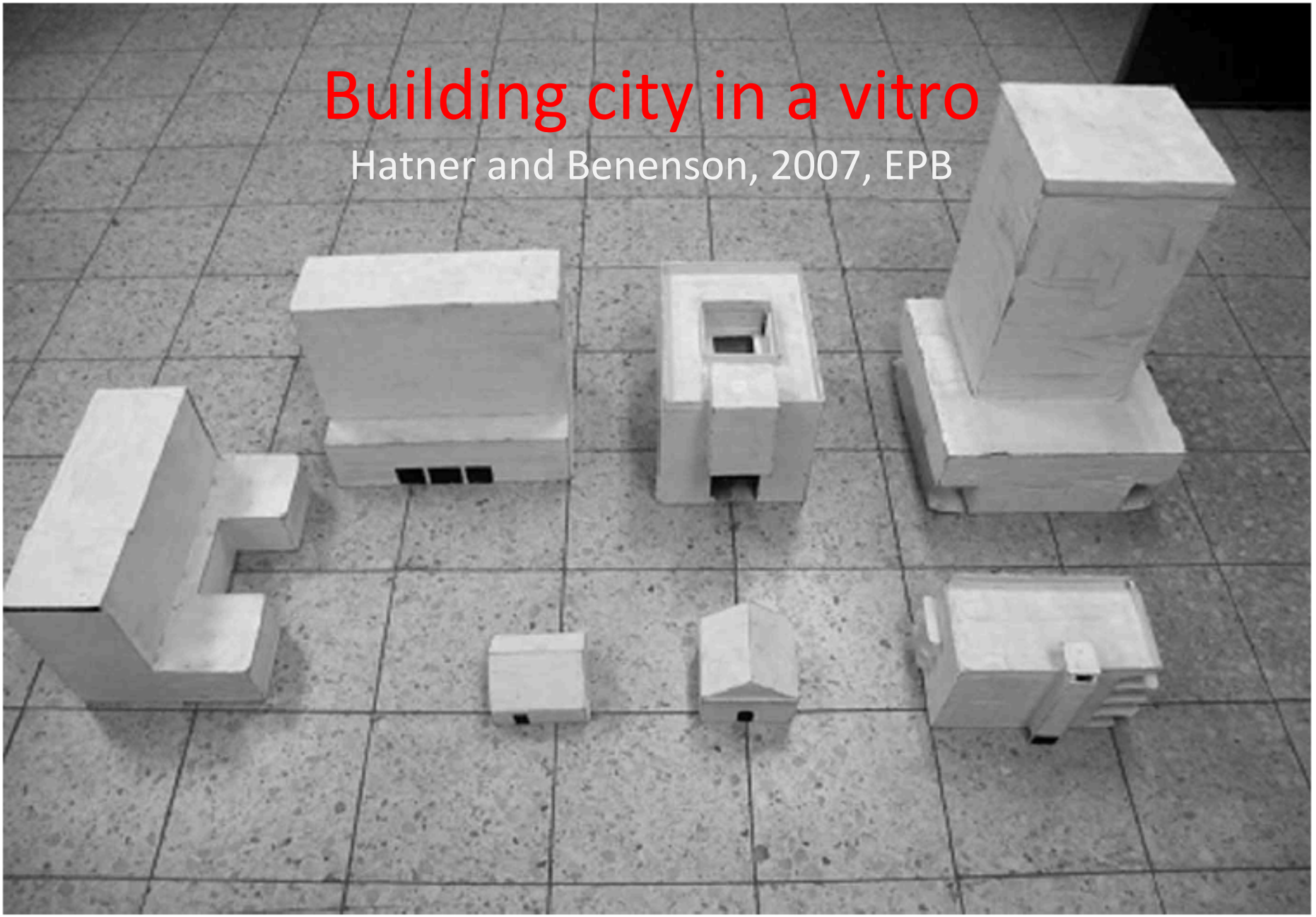


Figure 1. Seven of the fifty-two mock-ups used in the experiments (the floor tiles are of 20 cm × 20 cm size).

The entropy of LEGO

Crompton, 2012, EPB

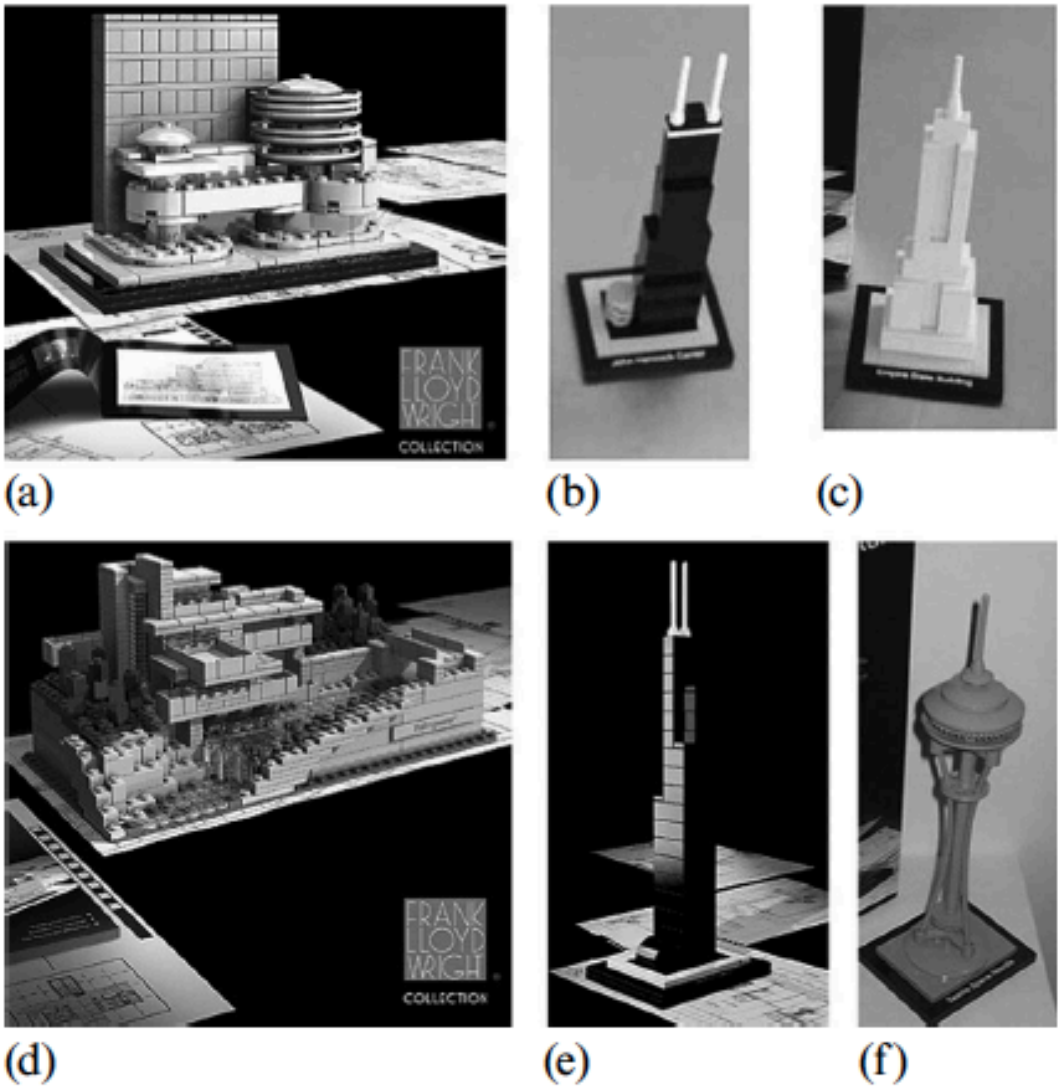


Figure 4. LEGO® models: (a) Guggenheim Museum, (b) Hancock Tower, (c) Empire State, (d) Falling Water, (e) Sears Tower, (f) Seattle Needle.

In this research, we will identify planner rules by

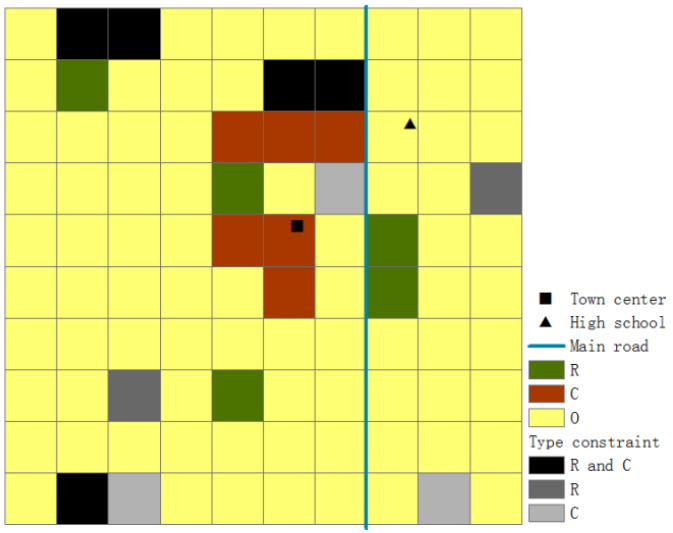
- Questionnaire
  - What one planner will do
- Mining plan drawings
  - What one planner has done

关于用地布局规划的问卷调查

您好，非常感谢您抽出宝贵的时间参与我们的问卷调查。本调查目的在于了解不同因素对不同土地使用类型布局（总规和控规尺度）的影响程度，进而了解规划师进行城市用地布局方案制定时的规划规则与偏好。请您根据自己的真实想法作答，所填写的资料仅供学术研究使用，不作个别披露或其他用途。非常感谢您对我们的支持！

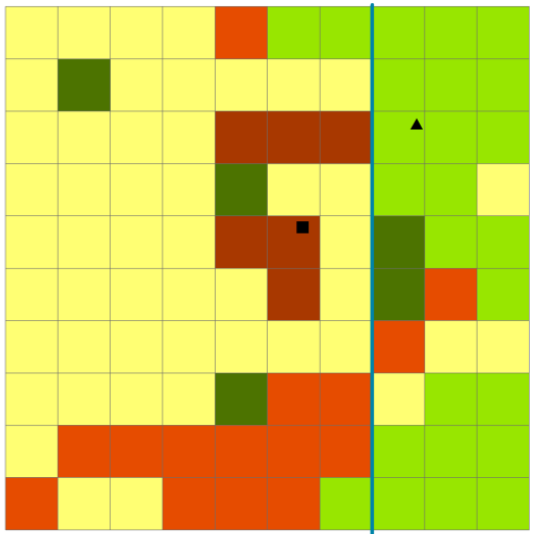
问卷中将土地使用类型分为四类：居住用地、商业用地、工业用地和其他用地。通过分值大小（0-9）反映各因素对规划师制定方案的影响程度，如对于工业用地布局，如果需要特别考虑邻近城市主干道，则打分为9，如果不需要考虑城市主干道，则用0表示。

影响用地布局的因素		评分（0-9分：没有影响-影响很大）		
因素类别	因素名称	居住（R）	商业（C）	工业（M）
1．基础地形	高程	4	4	4
	坡度	6	6	4
2.可达性 2.1交通设施	飞机场	2	2	2
	火车站	4	7	6
	高速公路	1	1	7
	城市主干道	6	4	7
	地铁站	9	9	3
	公交车站	9	9	7
2.2公共服务设施	政府机关	6	3	6
	体育娱乐设施	9	9	1
	生活便利设施（商场、超市等）	9	9	1
	医疗卫生机构	9	3	3
	教育设施（学校、科研机构等）	9	5	6
	银行、保险机构	7	9	5
	公园、景点	9	7	1
2.3区位	CBD	5	8	3
	城镇中心	8	8	3
	开发区（如优惠产业政策区）	4	4	9
	河流、湿地	9	3	9
3.地块属性	现状土地使用类型	6	6	6
	地块面积	3	3	7
	土地价格	6	6	6
4.社会经济特征	人口密度	5	9	3
	就业率	4	7	3
5.环境因素	空气质量	9	8	3
	交通噪音	9	8	3
	植被覆盖率	9	8	3
	邻避设施（高压站、垃圾场等）	9	9	3

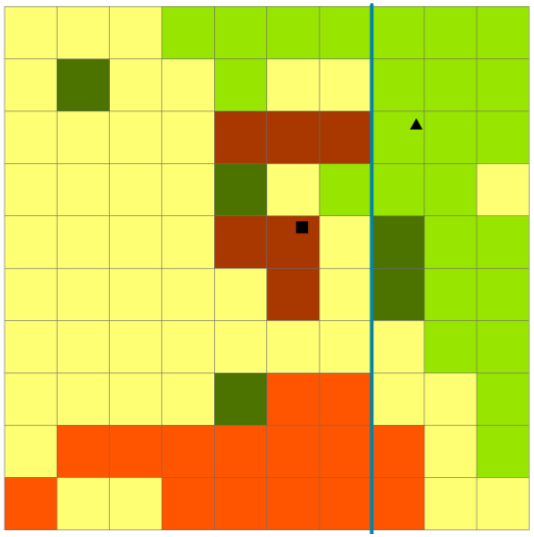


Then we will
develop a PSS (Planner Agents),
and simulate land use pattern using identified rules.

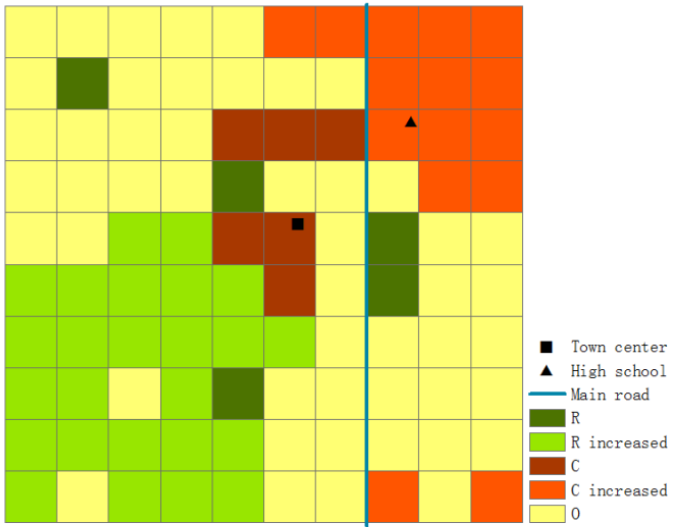
Planner A



Planner B



Planner C



Ideally and hopefully to

- save planner's time and promote plan compilation efficiency.
- E.g.
  - A plan area
  - Identified rules of 20 planners
  - Generate 20 patterns in one minute by using Planner Agent
  - The principal investigator chooses a perfect one
  - All 20 planners focus on it and propose the final drawing

2 PLANNER AGENTS

Planner types

- Non-spatial planners
  - Infrastructure, transportation
  - Not directly with land use pattern
- Spatial planners
  - Responsible for preparing land use pattern
- Chief planner
  - Confirm the final plan scheme

Spatial planner: the general process

1. Totals in area
   - For each type of land use (e.g. residential, commercial and industrial)
   - From decision makers or forecasted by macro models
2. Constraints
   - Geographical context: *slope, eco space*
   - Institutional constraints: *development restrictions*
3. Negotiating with non-spatial planners (factors)
   - Assume planned facilities, roads, city centers, CBD, etc., are ready prior to plan a land use pattern
   - Weight factors
4. Negotiating with citizens (public participation process)
   - Not accounted in our current research

Spatial planner: simplified rules

- The taste (*weight*) of each land use on factors is different.
- The weight could be calibrated using questionnaire or data mining on existing plan archives (land use with the highest probability would be selected for a parcel).
  - E.g., industrial parcels tend to be located along main transportation network, commercial parcels around amenities.

$$T = \{t_k | k = 1,2,3, \dots K\} \quad (1)$$

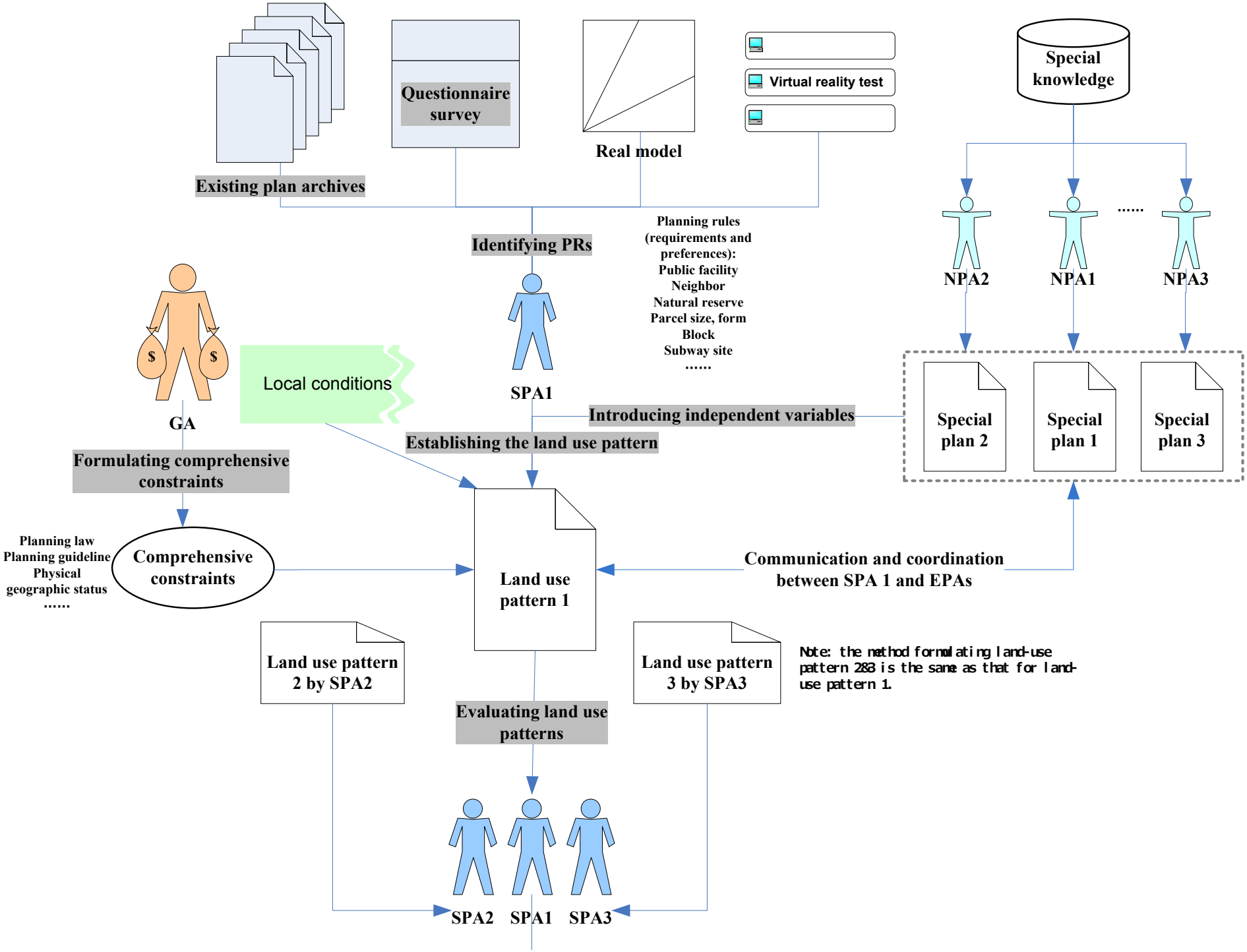
$$F = \{f_i | i = 1,2,3, \dots I\} \quad (2)$$

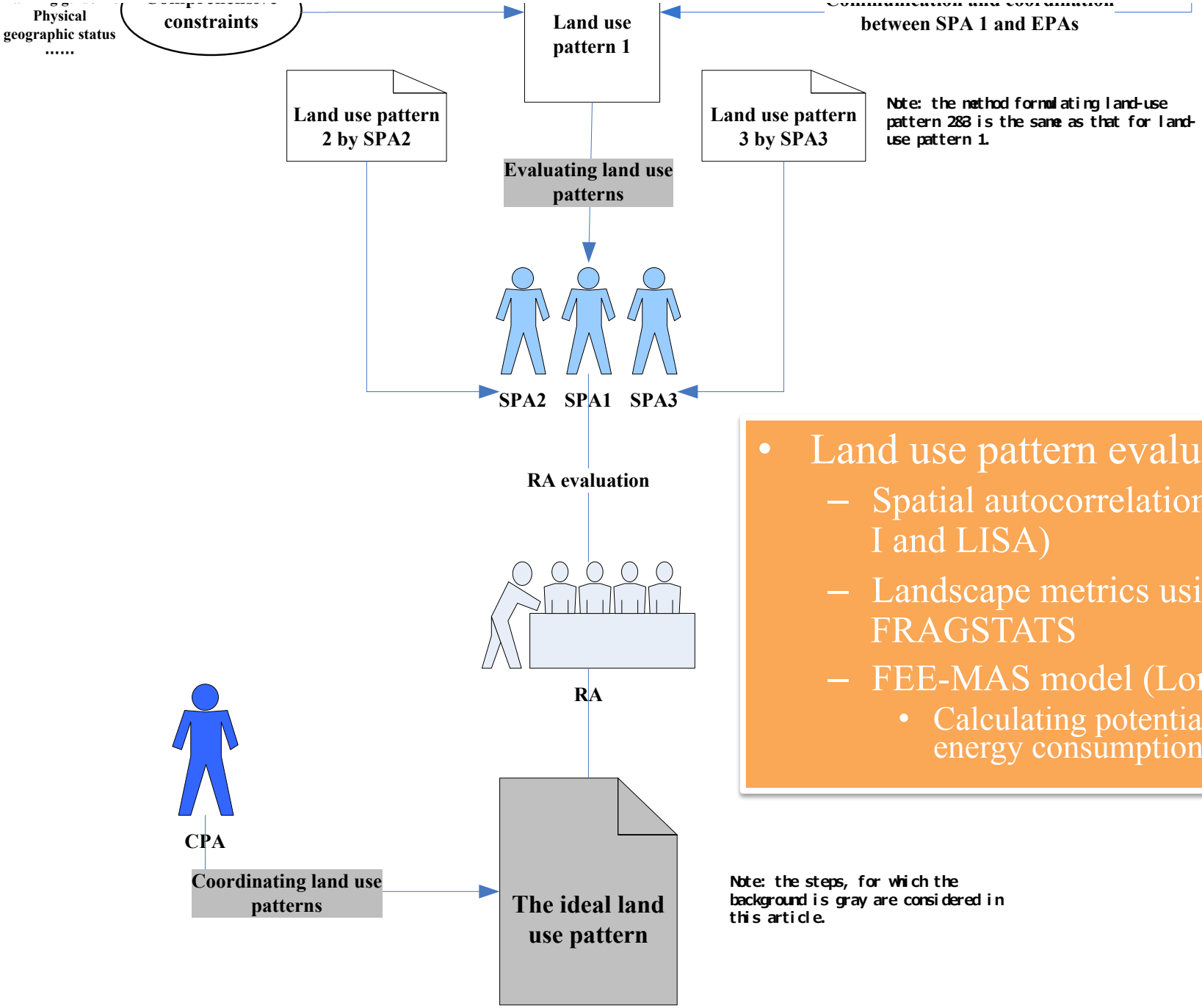
$$P = \{p_n | n = 1,2,3, \dots N\} \quad (3)$$

$$W = \{w_{ik} | i \in [1, I], k \in [1, K]\} \quad (4)$$

$$P_{nk} = \frac{e^{r_k + \sum_{i=1}^{I} w_{ik} \times f_i}}{1 + \sum_{k=1}^{K-1} e^{r_k + \sum_{i=1}^{I} w_{ik} \times f_i}}, \quad (5)$$

re t_k is the planned land use type, K is its number, f_i is the PIF, I is its number, parcel, N is its total amount, w_{ik} is the weight of f_i for t_k, P_{nk} is the probability o t_k, and r_k is the corresponding constant term.

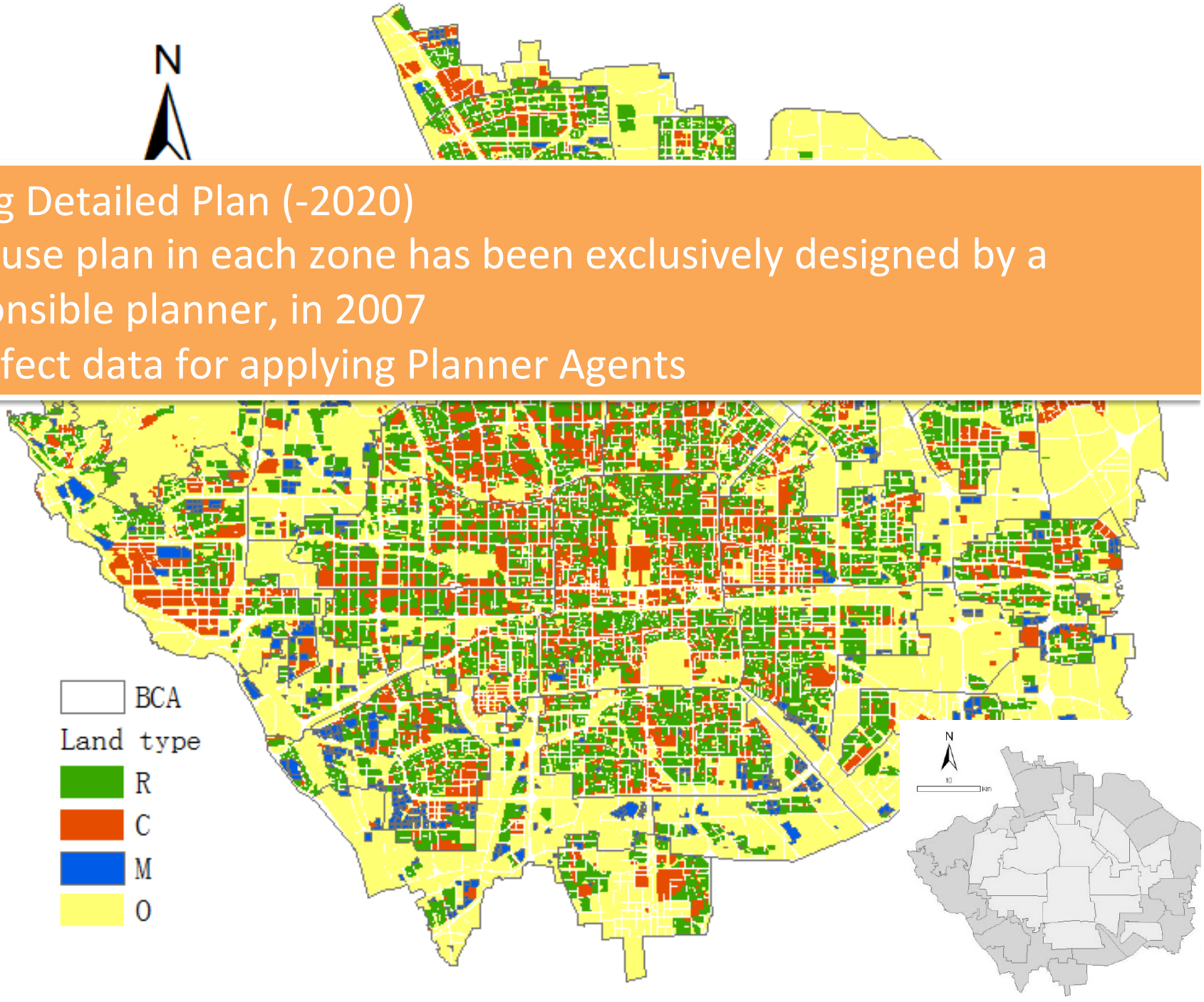

Existing plan archives
Questionnaire survey
Real model
Virtual reality test
Special knowledge
Identifying PRs
Planning rules (requirements and preferences):
Public facility
Neighbor
Natural reserve
Parcel size, form
Block
Subway site
.....
NPA2
NPA1
NPA3
.....
$
$
GA
Local conditions
SPA1
Introducing independent variables
Special plan 2
Special plan 1
Special plan 3
Establishing the land use pattern
Formulating comprehensive constraints
Planning law
Planning guideline
Physical geographic status
.....
Comprehensive constraints
Land use pattern 1
Communication and coordination between SPA 1 and EPAs
Land use pattern 2 by SPA2
Land use pattern 3 by SPA3
Note: the method formulating land-use pattern 2&3 is the same as that for land-use pattern 1.
Evaluating land use patterns
SPA2
SPA1
SPA3



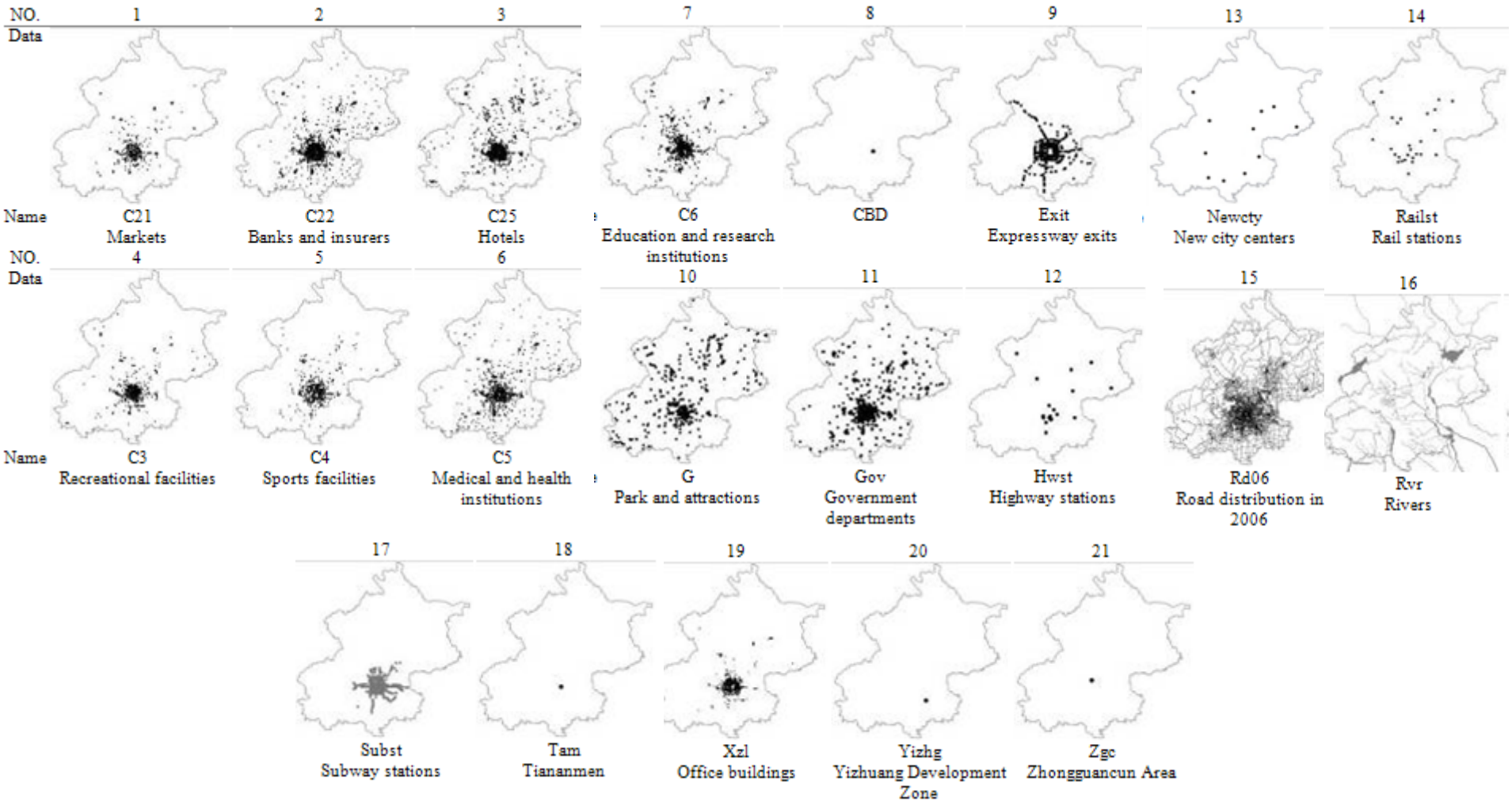
- Land use pattern evaluation
  - Spatial autocorrelation (Moran's I and LISA)
  - Landscape metrics using FRAGSTATS
  - FEE-MAS model (Long 2011)
    - Calculating potential transport energy consumption

3 BEIJING APPLICATION

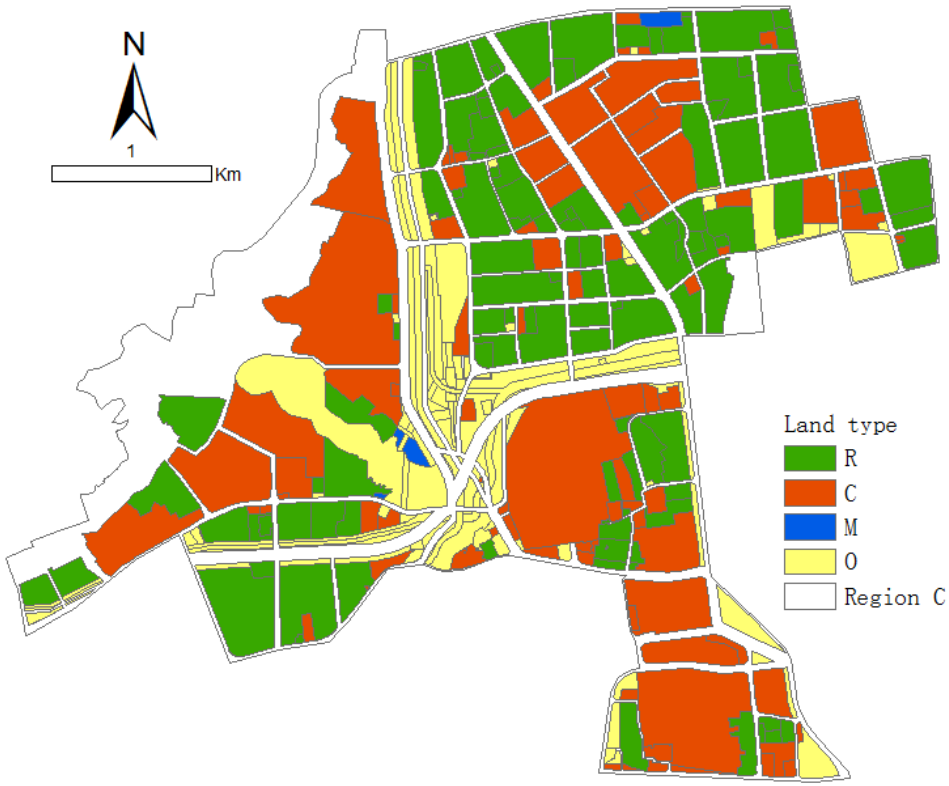
- Beiing Detailed Plan (-2020)
- Land use plan in each zone has been exclusively designed by a responsible planner, in 2007
- A perfect data for applying Planner Agents



21 factors

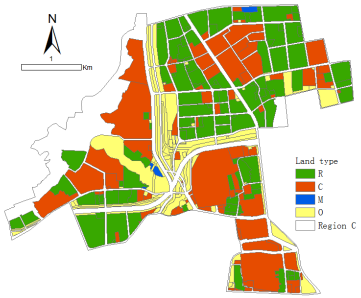

NO.
Data
Name
1
C21
Markets
2
C22
Banks and insurers
3
C25
Hotels
7
C6
Education and research institutions
8
CBD
9
Exit
Expressway exits
13
Newcty
New city centers
14
Railst
Rail stations
NO.
Data
Name
4
C3
Recreational facilities
5
C4
Sports facilities
6
C5
Medical and health institutions
10
G
Park and attractions
11
Gov
Government departments
12
Hwst
Highway stations
15
Rd06
Road distribution in 2006
16
Rvr
Rivers
17
Subst
Subway stations
18
Tam
Tiananmen
19
Xzl
Office buildings
20
Yizhg
Yizhuang Development Zone
21
Zgc
Zhongguancun Area

Zone 12 as an example



Land use type	Parcel distribution		
	Number	Area (km2)	Percentage
R	114	43.85	0.41
C	97	44.41	0.41
M	4	0.47	0.004
O	121	18.94	0.18
Total	336	107.67	1.00

Constraints



Extracted from Urban Containment Plan of Beijing
See Long et al 2011 for details

Identified rules using multinomial regression

Parameter	Weight		
	R	C	M
Intercept C21	−.70203*** .59824***	−2.24992*** .10866	−1.78990*** −1.50529***
C22	1.69092***	1.98993***	1.48453***
C25	.27165***	.63531***	−1.50131***
C3	.54465***	.53033***	.09401
C4	.19670**	.20072**	.34227
C5	1.01238***	.71570***	−.37010
C6	.59667***	.83476***	.57046***
CBD	−3.13736***	−.73107***	−7.74911***
Exit	−.77072***	−.81033***	.21059
G	.06680	.14353*	−.52322**
Gov	−.22590***	.11004	.78724***
Hwst	−.08708	−.28315**	−.95491*
Newcty	−8.33651**	−.01048	−1.21120
Railst	−.29179**	−.14296	.79214***
Rd06	−2.09906***	−1.19993***	−1.10308**
Rvr	−.26074***	−.71772***	−1.32691***
Subst	.36312***	.57882***	−.41520**
Tam	.52299	1.24361***	−39.32950***
Xzl	.31318***	.52759***	1.24840***
Yizhg	−91.77109***	−101.64079***	33.57548**
Zgc	−1.49658***	.16891	−23.24940***

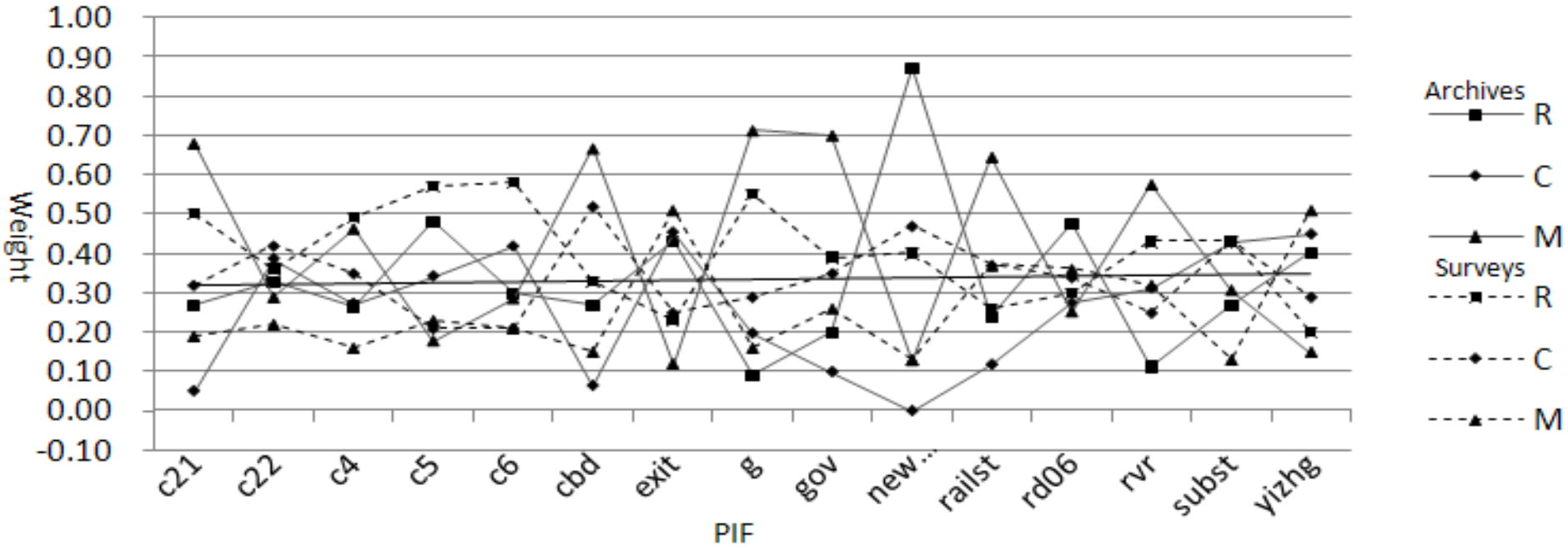
Rules of the same planner,
by questionnaire

Category	PIF	Weight		
		R	C	M
1. Basic topography	1. Elevation	0.32	0.31	0.37
	2. Slope	0.30	0.32	0.39
2. Accessibilities				
2.1Transport facilities	3. Airports	0.26	0.31	0.43
	4. Rail stations	0.26	0.37	0.37
	5. Highways	0.23	0.25	0.51
	6. Main roads	0.30	0.34	0.36
	7. Subway stations	0.43	0.43	0.13
	8. Bus stops	0.42	0.40	0.19
2.2 Public facilities	9. Government departments	0.39	0.35	0.26
	10. Entertainment facilities	0.49	0.35	0.16
	11. Amenities (such as supermarkets)	0.50	0.32	0.19
	12. Medical and health institutions	0.57	0.21	0.23
	13. Educational and research institutions	0.58	0.21	0.21
	14. Banks and insurers	0.36	0.42	0.22
	15. Parks and attractions	0.55	0.29	0.16
2.3 Location	16. CBD	0.33	0.52	0.15
	22. Land price	0.33	0.32	0.35
4. Socioeconomic characteristics	23. Population density	0.36	0.41	0.23
	24. Employment rate	0.30	0.37	0.32
5. Environment	25. Air quality	0.46	0.34	0.21
	26. Traffic noise	0.56	0.28	0.17
	27. Vegetation coverage	0.49	0.28	0.23
	28. NIMBY facilities	0.46	0.36	0.18

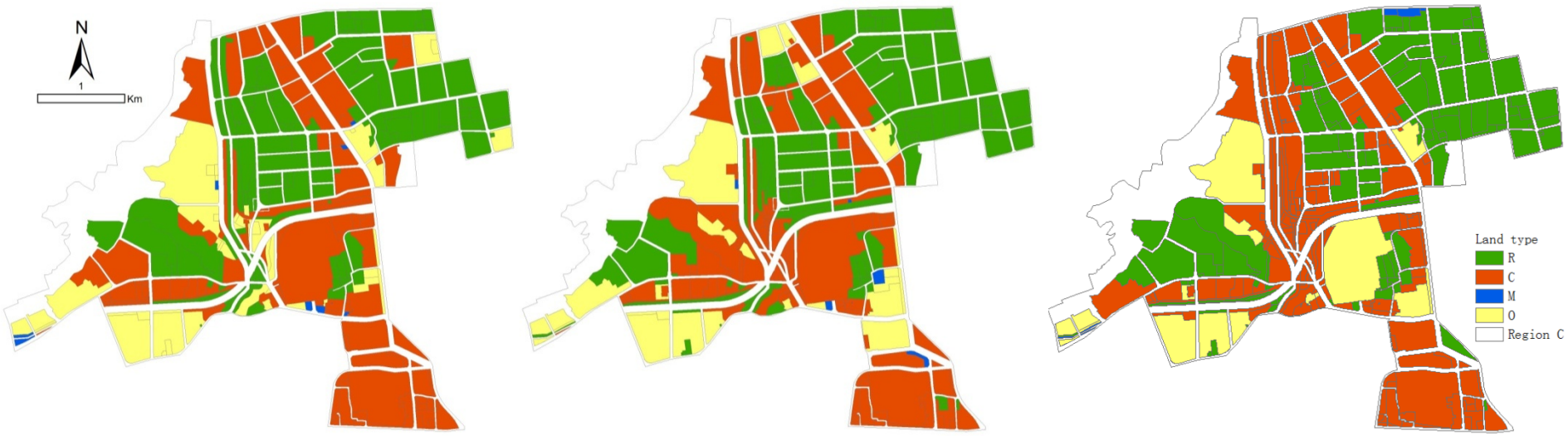
Total 20 planners surveyed in BICP (planners) and PKU (plan students)
Comparison to be conducted

Comparison of mined and surveyed rules

What has done and will do are generally different,
in terms of taste of each land use on various factors.



Three scenarios by different planners



A B C

Land use type	Parcel number (scenario A)	Parcel number (scenario B)	Parcel number (scenario C)
R	163	157	130
C	116	146	182
M	11	7	8
O	46	26	16
Total	336	336	336

4 CONCLUSIONS

Conclusions

- Planner Agents for supporting land use pattern scenario analysis (LUPSA)
  - Limited to land use plan in the master plan level
  - Identified rules by questionnaire and data mining
  - A very preliminary research in its first step
- Tested in the hypothetical space and applied in Beijing
  - Compile and evaluate land use plan quantitatively
- Promising in promoting working efficiency of planners
  - Jobless planners?

Next steps

- Polish existing work
- Include public participation
  - By introducing residential agents
- Evaluate simulated patterns
- Rules for density distribution

Limited spatial plan implementation effectiveness in China (around 50% outside planned urban growth boundaries).

See *Han et al, 2009; Long et al, 2012; Tian and Shen, 2011*

The value for promoting urban plan compilation efficiency?

longying1980@gmail.com

THANKS FOR YOUR ATTENTION!