Landscape and Urban Planning 108 (2012) 103–111

Contents lists available at SciVerse ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research paper

Spatiotemporal heterogeneity of urban planning implementation effectiveness: Evidence from five urban master plans of Beijing

Ying Long[a], Yizhen Gu[b], Haoying Han[c,*]

[a] Beijing Institute of City Planning, Beijing 100045, PR China
[b] Department of City and Regional Planning, University of California, Berkeley 94720, USA
[c] Department of Land Management, College of Public Administration, Zhejiang University, 268 Kaixuan Road, Hangzhou 310029, PR China

HIGHLIGHTS

- We identified spatiotemporally heterogeneities of UPI effectiveness.
- We made our analysis using concrete data of five urban master plans of Beijing.
- The effectiveness of UPI was visualized by an urban expansion simulation model.

ARTICLE INFO

Article history:
Received 18 August 2011
Received in revised form 19 July 2012
Accepted 20 August 2012
Available online 14 September 2012

Keywords:
Urban expansion
Urban planning implementation
Conformity
Spatiotemporal heterogeneity
Beijing

ABSTRACT

Evaluation of urban planning implementation (UPI) has attracted extensive attention from urban planners and researchers in recent years. Existing literature, however, mainly focuses on the conformity approach and does not take the spatial and temporal heterogeneity of UPI into account. In addition, previous research failed to distinguish the effects of urban planning from other institutional forces, as well as market incentives on urban expansion. To bridge this gap, we proposed a spatiotemporal approach to evaluate the effectiveness of UPI based on logistic regression and geographical information system (GIS) by identifying the spatiotemporal heterogeneous effects of urban planning on urban expansion. An empirical research was conducted in the Beijing Metropolitan Area (BMA) by analyzing five urban master plans drafted in 1958, 1973, 1982, 1992 and 2004. Five periods from 1947 to 2008 were examined to evaluate the dynamic effects of each master plan and other related factors. The effects of the 2004 Urban Master Plan on 16 districts in Beijing were estimated to identify the spatial variations of UPI. Within the context of China's booming economy, the results indicate that the effects of urban planning during the urban expansion increase over time, and are significantly stronger in exurban areas than in central cities and suburban areas. In addition, based on logistic regression results, we adopted an existing urban expansion simulation model to geographically visualize the impact of urban planning on future urban expansion, namely urban planning implementation effectiveness.

1. Introduction

Urban planning is an important tool for local governments to regulate urban development pattern. To achieve the goals set by urban planning, it is required that the urban planning implementation (UPI) be evaluated across countries. For instance, the evaluation of UPI is included in the regional planning guidance of the UK and the US (Lv & Wu, 2006). In China, the 2007 City Planning Law requires that local governments regularly evaluate the implementation of urban system plans, urban master plans and town master plans (Article 46), and the UPI evaluation is indispensable for any modification of urban planning (Article 47).

According to the review of Talen (1996a), the planning evaluation includes the evaluation prior to plan implementation, the evaluation of planning practice, the policy implementation analysis, and the evaluation of planning implementation, on which this paper basically focuses. The UPI evaluation can also be classified by the type of planning, and the main focus of this paper is on the spatial control. Until now, there are very limited studies on the UPI evaluation, because (1) the process of the UPI is intertwined with many factors, making it difficult to identify the effect of urban planning; (2) the comprehensive outcomes of the UPI are hard to evaluate; (3) to identify a uniform standard for the evaluation of the UPI is difficult (Sun & Zhou, 2003).

* Corresponding author. Tel.: +86 571 8697 1317; fax: +86 571 8697 1277.
E-mail addresses: hanhaoying@zju.edu.cn, hanhaoying@gmail.com (H. Han).

0169-2046/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.landurbplan.2012.08.005

The effects of the UPI can be identified using several approaches. According to the PPIP (Policy-Plan/Programme-Implementation-Process) plan evaluation model proposed by Alexander and Faludi (1989), the UPI can be evaluated by five criteria: conformity, rational process, optimality ex ante, optimality ex post and utilization, among which the conformity criterion is most commonly used (Berke et al., 2006; Brody & Highfield, 2005; Brody, Highfield, & Thornton, 2006; Laurian et al., 2004, 2010; Talen, 1996b, 1997). Wildavsky (1973) argues that a plan/policy should be implemented and realized within a fixed time, and that the higher the conformity between the final result and the original urban plan is, the more successful is the UPI, ignoring or excluding uncertainties. The conformity approach is suitable for evaluating the implementation of a traditional blueprint-style plan. For example, Tian and Shen (2011) and Han, Lai, Dang, Tan, and Wu (2009) evaluate the implementation of urban master plans of Guangzhou and Beijing, respectively, and find that the actual urban development pattern in both cities greatly deviated from the original master plans. Such inconformity between plans and their actual implementation has been proved to be common in Chinese cities.

However, the conformity approach is limited in that it only considers the final layout of cities, rather than the factors that work in the UPI process, especially for evaluating the implementation of spatial control plans. The conformity approach ignores the uncertainty caused by market forces during the process of plan implementation (Mastop & Faludi, 1997). Therefore, the UPI evaluation approach can be significantly improved by differentiating the effects of institutional factors (e.g. urban planning) on urban expansion from those of market forces.

Scholars in urban economics and urban geography have analyzed the driving forces of urban expansion (land use/cover change, LUCC) (see Agarwal, Green, Grove, Evans, & Schweik, 2002; Brueckner, 2001; McGuire & Sjoquist, 2002). Most empirical studies in urban economics focus on the influence of market factors, e.g. population, income, commuting cost and agricultural land rent according to the monocentric model, using the regression method and the cross-city dataset (Brueckner & Fansler, 1983; McGrath, 2005). The spatial distribution of urban expansion, however, is omitted in these studies. One exception is the study by Burchfield, Overman, Puga, and Turner (2006), which designs an index measuring the extent of sprawl of a metropolitan area and examines factors that drive or restrain sprawl, but their work is still based on a cross-city dataset.

In the geography discipline, the driving forces of LUCC, including institutional factors, are quantitatively identified by various approaches, such as Markov-chain analysis (Muller & Middleton, 1994), artificial neural networks (ANNs) (Li & Yeh, 2002; Pajanowski, Brown, Shellito, & Manik, 2002), cellular automata (CA) (Batty, Couclelis, & Eichen, 1997; Dietzel & Clarke, 2006; White & Engelen, 1997; Yeh & Li, 2001), and multi-agent systems (MAS) (Brown, Page, Riolo, Zellner, & Rand, 2005; Sanders, Pumain, Mathian, Guerin-Pace, & Bura, 1997). In addition, the logistic regression has been widely applied to identify the driving forces of LUCC/urban growth/urban expansion. For instances, Wu (2002) applies this method for identifying the driving forces of rural-urban land conversions; Verburg et al. (2002) develop a land-use change model CLUE-S based on logistic regression; Cheng and Masser (2003) use the logistic regression to identify the impacts of various driving forces of urban expansion in Wuhan City; Fang, Gertner, Sun, and Anderson (2005) use the logistic regression to weigh the scores of the driving factors for an urban sprawl model; Hu and Lo (2007) model the urban growth for Alaska using the parameters of driving forces calibrated by logistic regression. Comparing with other approaches, the logistic regression is simple and straightforward in theory, easy to apply in data analysis and modeling. Due to this, our paper adopts the classical logistic regression to identify the effect of urban planning in the urban expansion process (transition from rural to urban).

Several studies have further investigated the spatial and temporal heterogeneities in the effects of the driving forces of urban expansion. Li, Yang, and Liu (2008) consider the spatial heterogeneity of state transition rules in their CA urban model and find that the influences of driving forces vary across sub-regions. The land-use change model by Liu, Wang, Liu, and Meng (2005) also proves the spatial heterogeneity of driving forces. Studies on submarkets in urban economics are to some extent similar to the above spatial heterogeneity studies. Such studies aim to validate the existence of housing submarkets (namely, the effects of various market factors differ significantly across subareas) (see Bourassa, Cantoni, & Hoesh, 2007; Jones, Leishman, & Watkins, 2004; Stevenson, 2004; Watkins, 2001), and to identify the boundaries of submarkets (see Goodman & Thibodeau, 1998). There are more studies on the temporal heterogeneity. One common way is to analyze the driving forces of urban expansion in various periods using data on urban forms derived from remote sensing images. However, few studies take into account the spatial and temporal heterogeneities in UPI evaluation. More policy implications can be derived by identifying the spatial-temporal dynamic effect of urban planning as well as other factors on urban expansion, which is missing in the studies that use the conformity approach mentioned above.

In this paper, a logistic approach using the GIS (geographical information system) data is used to identify the driving forces in urban expansion, and to explore the spatiotemporal heterogeneities of urban planning's effects on urban expansion. The Beijing Metropolitan Area (BMA) is taken as an example to evaluate the implementation of five master plans in different periods. Section 2 introduces the approach to evaluate the spatiotemporal heterogeneity of the UPI. Section 3 describes the study area and data. Section 4 uses a conventional conformity approach to evaluate master plans for comparison. Section 5 presents the empirical results, as well as the geographically visualized, predicted future urban expansion in Beijing. Section 6 discusses the results and Section 7 concludes.

2. Research approach

The UPI evaluation aims to measure the influence of urban planning on urban land use state, featured with land use type (including development status, i.e. urban land or non-urban land), floor-area-ratio (FAR) as well as building density. A change in urban state may be driven by both market incentives and institutional factors, which can be expressed as $y = f(a_1, a_2, \ldots, a_p, \ldots, a_m, x_1, x_2, \ldots, x_p, \ldots, x_m)$, where, y is an urban state change, m is the number of influencing factors, x is an influencing factor, a is the coefficient of an influencing factor, x_p represents the urban planning factor, and a_p is the coefficient of urban planning factor. The focus here is on the coefficient of urban planning factor a_p, which can be compared across periods or regions.

Here y represents the change in urban land use state (1 if there is a transition from rural to urban, otherwise 0). A binary logistic regression is estimated to obtain the coefficient vector A as shown in Eq. (1) (Wu, 2002):

$$P = \frac{1}{1 + e^{-z}}$$
$$z = a_0 + \sum_k (a_k * x_k) \quad (1)$$

where a_0 is constant, a_k is the regression coefficient, x_k is the influencing factor, and P is the transformation probability (from non-urban to urban, namely developed). In the following sections, we will use this method to empirically evaluate the effects of urban

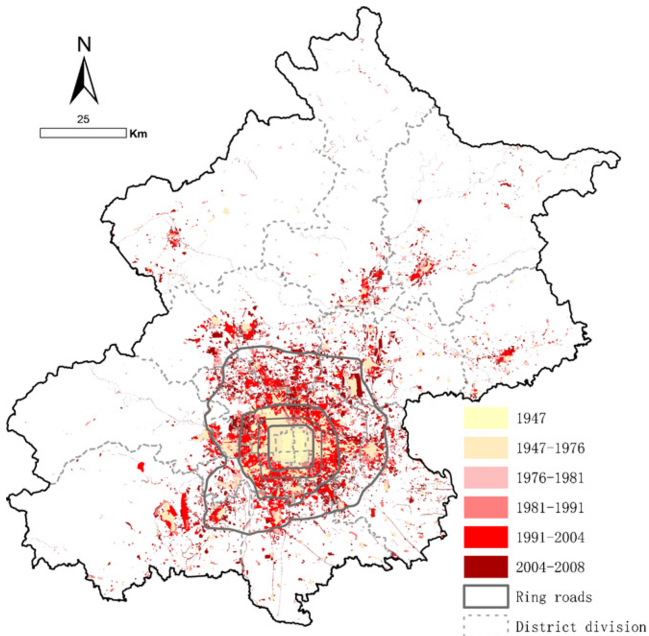

Fig. 1. The study area and its urban expansion process in 1947–2008.

master plans of Beijing, in which the change in urban state to be evaluated is whether a cell converts from rural to urban or not.

3. Study area and data

This paper uses the Beijing Metropolitan Area (BMA) as the study area. The BMA, located in northern China, has an area of 16,410 km^2 (see Fig. 1), with the mountainous area accounting for 61% of the whole. Beijing has experienced rapid urbanization in terms of population and urban construction land (see Fig. 1) since the market reform initiated in 1978 by the central government. Such an expansion is also expected to continue in the near future. Therefore, urban planning was and will be facing great challenges during this process.

Four types of factors influencing urban expansion are selected following related studies in urban economics, especially those using the Hedonic approach (Rosen, 1974). These factors include the location variables (market incentives) such as the proximity to town centers, rivers and roads, and the neighborhood variable, namely the development ratio within the neighborhood. The institutional variables include the construction restriction, the agricultural land suitability, the planned urban construction, as well as the inherent variable regarding whether it is the rural construction land.

The spatial unit of data is uniformly GRID, with a cell size of 100 m * 100 m, and there are a total of 1,640,496 cells in the whole study area. Data are described in Table 1. Urban forms are shown in Fig. 1, and other spatial factors are shown in Fig. 2. Location variables represent the attractiveness of various levels of town centers, rivers and roads. For comparison among location variables as well as with institutional variables or the neighborhood variable, all location variables are standardized to the range from 0 to 1, with 1 denoting the greatest location advantage, and 0 the least. The standardization process is for comparing the impacts of different variables on urban development. Suppose that we do not standardize variables and use distance as variables, it would be very hard to compare the effect of plan with that of a spatial variable, e.g. roads. In this paper, a location variable x_k, using the corresponding spatial feature class as the data source, is calculated as $x_k = e^{-\beta * dist}$, where $dist_k$ is obtained using the "Distance/Straight Line" toolbox of the Spatial Analyst module in the ESRI ArcGIS package and $\beta = 0.0001$. Note that β is used to represent the distance decay effect, and this is widely applied in the context of Geosimulation. We used the same β value for all logistic regressions for various historical phases in this paper, which would alleviate the influence of β on the identified planning effectiveness. For institutional variables, 1 represents the construction-forbidden areas (g_conf), the highest agricultural land suitability (g_agri), and the planned urban areas (g_pln). The neighborhood variable nei represents the development density within the cell's neighborhood, a circle with a radius of five cells. Because we will evaluate the UPI for master plans in different periods, these variables, e.g. the road, urban planning, and neighborhood and urban form, are calculated correspondingly. Since there are no road data for 1947 and 2004, we use data on planned roads in 1958 and existing roads in 2001, respectively. Similarly, urban form data for 1958 are replaced with the 1947 data.

4. Static evaluation of UPI

Since the latest administrative boundary adjustment of Beijing in 1958, fiver urban master plans in the BMA have been drafted in 1958, 1973, 1982, 1992 and 2004, respectively (Beijing Municipal Planning Committee, 2006). A planned land use map is provided in each master plan. In each map, each parcel is assigned with a land use type-urban (residential, commercial, industrial, public green land and mixed-use land) and non-urban (farmland, forestland and wetland). The variable g_pln is calculated from the re-classified binary land use map (1 for urban and 0 for non-urban). These plans are summarized as follows:

(1) The 1958 master plan, which designated Beijing as the political, cultural and educational center of China, required that it be rapidly converted into a modernized industrial city as well as a science and technology center so that it could lead the technological revolution and the institutional revolution in China. According to that plan, the urban and total population of BMA would be 3.5 million and 10 million respectively and several urban clusters would form around the central city at the end of the planning horizon (note that the central city area is similar with the area within the fifth ring road in Fig. 1). In 1957, the population was 4.15 million and the building floor area was 2.23 million m^2.
(2) The 1973 plan aimed to efficiently, rapidly and economically turn Beijing into a clean socialist capital with the modernized industry, the modernized agriculture, the modernized science and culture, and modernized urban facilities. The planned population in the central city was 3.70–3.80 million.
(3) The 1982 plan defined Beijing as the capital of socialist China and the political and cultural center of China. The planned population was 10 million, with 4 million in urban areas. In 1980, the population was 9.04 million, and the building floor area was 95 million m^2. In general, the planned development of this plan was similar to the status quo in 1980.
(4) The 1992 plan described Beijing as the capital of socialist China, the political and cultural center of China, a famous ancient capital and a modern world city. The planned population was 12.5 million, with 6.50 million in urban areas. In 1989, the population was 10.86 million, the urban area was 904 km^2 and the building floor area was 179 million m^2 in 1989.
(5) The 2004 plan described Beijing in the same way as the 1992 plan. The planned population was 18 million, with 8.5 million in urban areas, forming a spatial pattern featuring two axes, two development zones, and multi-centers. In 2003, the

Table 1
List of variables.

Type	Name	Min	Max	Mean	Std. Dev.	Description	Data source
Locational variables	l_tam	0.000	1	0.037	0.091	Proximity to Tian'anmen (main urban center)	
	l_cty	0.000	1	0.214	0.198	Proximity to new urban centers	Beijing Municipal Planning Committee (2006)
	l_twn	0.026	1	0.531	0.198	Proximity to town centers	
	l_rvr	0.238	1	0.789	0.162	Proximity to rivers	
	l_bdtwn	0.450	1	0.884	0.097	Proximity to town-level boundaries	
	l_r						
	l_r01	0.091	1	0.841	0.163	Proximity to roads in 2001	Interpreted from the same remote sensing images with those of *fm*
	l_r91	0.050	1	0.819	0.187	Proximity to roads in 1991	
	l_r81	0.050	1	0.797	0.202	Proximity to roads in 1981	
	l_r76	0.050	1	0.785	0.203	Proximity to roads in 1976	
	l_r58p	0.077	1	0.797	0.184	Proximity to planned roads in 1958	Beijing Municipal Planning Committee (2006)
Institutional variables	g_conf	0	1	0.593	0.491	Construction forbidden policy	He (2008)
	g_agri	0	1	0.418	0.237	Agricultural land suitability	Beijing Planning Commission (1988)
	g_pln						
	g_pln04			0.146	0.353		Beijing Municipal Planning Committee (2006)
	g_pln92	0	1	0.066	0.248	Urban planning	
	g_pln82			0.028	0.164		
	g_pln73			0.050	0.218		
	g_pln58			0.043	0.203		
Neighborhood variable	**nei**						
	nei04			0.077	0.231		Calculated based on *fm*
	nei91			0.049	0.175	Development intensity within the neighborhood	
	nei81	0	1	0.038	0.160		
	nei76			0.030	0.144		
	nei47			0.003	0.041		
Inherent variable	**s_rrl**						
	s_rrl04			0.025	0.156		Calculated based on *fm*
	s_rrl91			0.022	0.148	Whether a cell is rural construction land	
	s_rrl81	0	1	0.023	0.151		
	s_rrl76			0.025	0.156		
	s_rrl47			0.025	0.156		
Urban form	**fm**						
	fm08			0.082	0.274	Urban construction land in 2008	Landsat TM (Thematic Mapper) images on 12/06/2008
	fm04	0	1	0.077	0.266	Urban construction land in 2004	Landsat TM images on 01/04/2004
	fm91			0.049	0.216	Urban construction land in 1991	Landsat Tm images on 16/05/1991
	fm81			0.038	0.192	Urban construction land in 1981	Landsat MSS images on 23/06/1981 and 21/04/1981
	fm76			0.030	0.170	Urban construction land in 1976	Landsat MSS images on 05/06/1976 and 20/09/1976
	fm47			0.003	0.057	Urban construction land in 1947, this map can't cover the whole urban area of Beijing	Peking Municipal Engineering Bureau (2007)

Note: We use the value of s_rrl76 to represent s_rrl47 since there is no rural land information in the historical map in 1947.

population was 14.56 million, the urban area was 1150 km^2 and the building floor area was 430 million m^2.

These master plans are illustrated in Table 2. The area of the planned construction land in these plans is measured using GIS techniques. Generally, it has been increasing over time. In addition, the planned urban form has continuously changed from concentration to decentralization.

The planned urban forms are compared with the actual urban forms at the end of each planning period (namely current urban forms) using the conformity approach. In this way, four types of areas are defined: a_{00} denotes that both the current urban form (*fm*) and the planned urban form (g_plan) are non-urban, a_{11} denotes that both of them are urban, a_{01} denotes that the current urban form is urban and the planned urban form is non-urban, and a_{10} denotes that the current urban form is non-urban and the planned urban form is urban. Then, the following three indices are calculated to evaluate the degree of conformity.

(1) Planning implementation rate: $r_P = (a_{11})/(a_{10} + a_{11}) * 100\%$, representing the ratio of the developed area conforming to the plan to the total planned area.
(2) Legal development rate: $r_L = (a_{11})/(a_{01} + a_{11}) * 100\%$, representing the ratio of the developed area conforming to the plan to the total actually developed area. An assumption here is that the development beyond the planned area is illegal.
(3) Overall accuracy: $r_O = (a_{00} + a_{11})/(a_{00} + a_{01} + a_{10} + a_{11}) * 100\%$, representing the ratio of the area conforming to the plan to the total area.

The calculated planning implementation rate, legal development rate and overall accuracy for all master plans are shown in Table 2.

(1) The planning implementation rate is low across periods, since usually the master plan was revised earlier before the end of the originally set planning period, which resulted in some planned areas that had not been developed. This rate is highest for the 1992 master plan. The planning period of this master plan is till 2010; but a new master plan was issued in 2004. This rate is also comparatively lower for the 2004 master plan because the evaluation is based on the 2008 data, while the planning period of this master plan is till 2020.

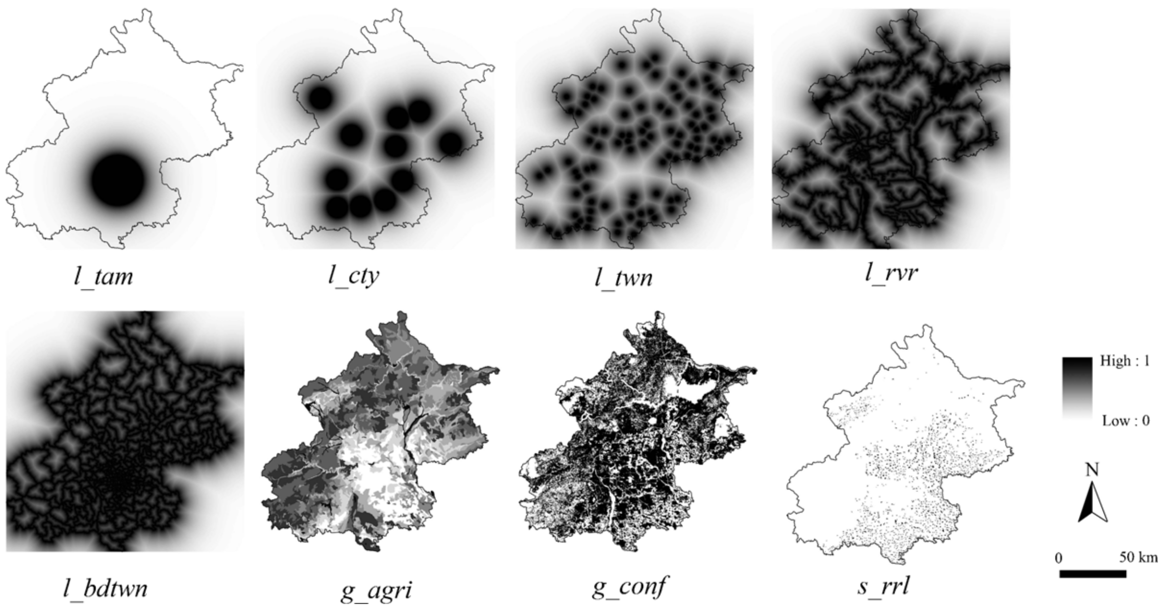

Fig. 2. Spatial distribution of spatial variables.

(2) The legal development rate is highest (76.3%) for the 2004 master plan, which possibly suggests that urban development has been strongly restricted by urban planning since 2004. However, this is also because the 2004 master plan has been implemented for only four years, much lower than that of the other master plans (at least eight years).

(3) The overall accuracy index is very high across periods because of the small proportion of planned construction land in urban areas. This indicates that such an index, widely used in the conformity studies, cannot well represent the actual urban development in a large region.

Generally, the conformity evaluation results for master plans in Beijing indicate that there are significant differences between the master plans and the actual urban developments. This might arise from the failure in taking into account markets incentives during the plan-making process, usually dominated by planners who major in architecture. A well-known fact in China is that the master plan is not grounded on sound scientific analysis, especially quantitative analysis.

As mentioned above, the conformity approach for UPI can only evaluate the planning implementation results and provide little insights into the factors that work in the implementation process.

5. Dynamic evaluation of UPI

5.1. Temporal evaluation

To evaluate the effect of five master plans in Beijing on urban expansion process, historical data are analyzed using the approach described in Section 2. According to the data availability and the implementation period of each master plan, this paper focuses on five historical periods: 1947–1976, 1976–1981, 1981–1991, 1991–2004 and 2004–2008, corresponding to the five master plans. It is assumed that variables l_tam, l_cty, l_twn, l_rvr, l_bdtwn, g_agri, g_conf and s_rrl do not change over time, while l_r, g_pln, nei and dependent variables remain fixed only within each period (see Table 3). The variables used in different periods are shown in Table 3. The average annual increase of urban construction land in different periods is also listed in Table 3. Logistic regressions are conducted in SPSS using the FORWARD:LR method.

Table 2
Inventory of five master plans of the BMA.

Index	g_pln58	g_pln73	g_pln82	g_pln92	g_pln04
Compilation time	1958	1973	1982	1992	2004
Implemented period	1958–2000	1973–2000	1982–2000	1991–2010	2004–2020
Spatial distribution					
Developed area (km^2)	611	465	454	1079	2389
Planned population (million)	10.0	3.70–3.80 (central city)	10.0	12.5	18.0
Urban form at the end of plan	fm76	fm81	fm91	fm04	fm08
Planning implementation rate (%)	38.5	45.6	60.9	69.2	42.9
Legal development rate (%)	55.3	59.4	34.4	59.1	76.3
Overall accuracy (%)	96.0	95.7	95.7	94.8	89.8

Table 3
Logistic regression settings for all periods.

Period (Time span, year)	1947–1976 (29)	1976–1981 (5)	1981–1991 (10)	1991–2004 (13)	2004–2008 (4)	
Dependent variables (annual urban expansion, km^2/a)	fm76 !=fm47 (15)	fm81 !=fm76 (28)	fm91 !=fm81 (17)	fm04 !=fm91 (35)	fm08 !=fm04 (21)	
Independent variables (changed)	l_r g_pln nei s_rrl	l_r58p g_pln58 nei47 s_rrl47	l_r76 g_pln73 nei76 s_rrl76	l_r81 g_pln82 nei81 s_rrl81	l_r91 g_pln92 nei91 s_rrl91	l_r01 g_pln04 nei04 s_rrl04

Note: In row "dependent variables", the sign "!=" stands for the GRID operator "Not Equal" in ESRI ArcGIS. The result of this operator is 0 for equal or 1 for not equal. In Beijing, a region in rapid urban expansion, there was no observed land transition from urban to non-urban according to our study, and therefore a value of "1" could represent urban expansion process.

The estimated coefficients for various periods are shown in Fig. 3. The effects of market and government differ greatly across periods. In each period, city main centers, new urban centers and roads all had significant influence on urban expansion. In all the five periods, construction forbidden areas were not well protected, in contrast with farmlands. The influence of urban planning, an institutional factor, on urban development is weaker than that of market forces, such as the expansion centering city main centers and the development along roads. In other words, urban expansion has been dominated by market factors in all periods, not considering the potential endogeneity issues (e.g. the construction of roads).

The effects of urban planning remain positive in all periods, indicating that urban planning has played a role in the urban development. In addition, the coefficients of urban planning increase over time, except for a slight reduction from 1981 to 1991, when most of Chinese cities including Beijing experienced rapid urban growth due to the famous *Reform and Opening Up* policy implemented after 1978. This reduction might result from over development beyond the limited available land quota in the old urban master plans. However, the overall trend is that the implementation of urban planning has been gradually strengthened over time.

Note: All coefficients in this figure are significant at 0.01 level. The variable l_twn was removed in the logistic regression for the phase 2004–2008 due to its insignificance.

5.2. Spatial evaluation

The effect of urban planning varies across regions. For the period of 2004–2008, the whole BMA is divided into 11 sub-regions mainly by district/county-level administrative boundaries. Factors driving urban expansion in different sub-regions are identified using the same approach in Section 5.1. The regression results illustrated in Fig. 4 demonstrate that the effect of the 2004 plan differs significantly across sub-regions, from 0.464 (Shunyi) to 1.612 (Yanqing). Overall, the effectiveness of urban planning in exurban districts is greater than that in suburban districts and central districts.

5.3. Visualizing future urban development using a cellular automata model

The coefficients from logistic regressions in Sections 5.1 and 5.2 can be used to initiate the urban expansion simulation model we developed, BUDEM (for more detail see Long, Mao, & Dang, 2009), thus enabling us visualizing future urban development in Beijing. BUDEM was established for analyzing historical urban growth and simulating future urban growth in the BMA using cellular automata. In BUDEM, the logistic regression is applied for deriving the transition rule from historical datasets, similar with those in this paper. The precision of BUDEM is 82.5% in terms of Kappa using datasets in

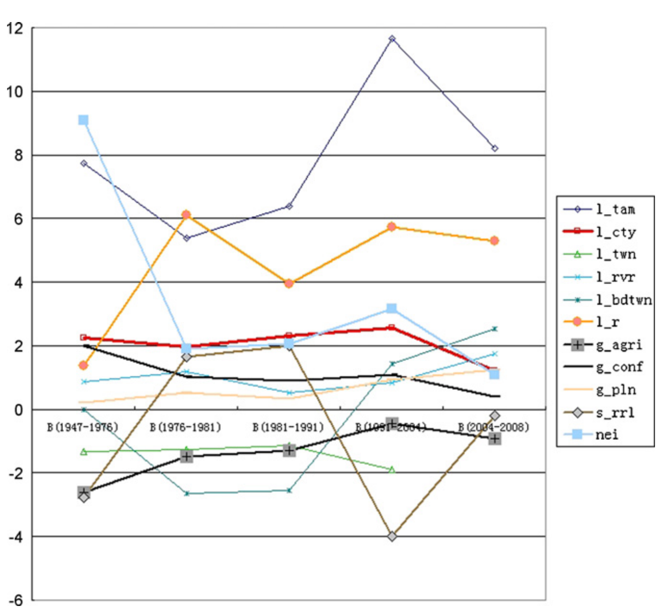

Fig. 3. Coefficients of all factors in various periods.

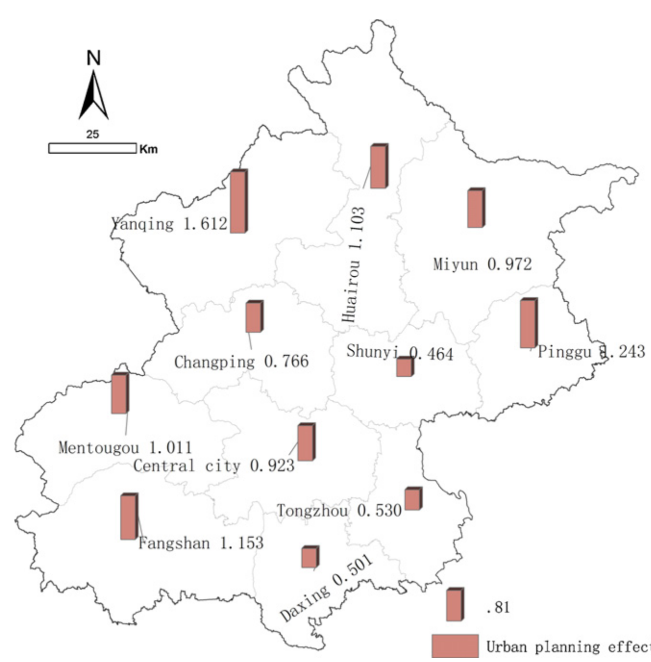

Fig. 4. Comparison of urban planning coefficients in various districts.

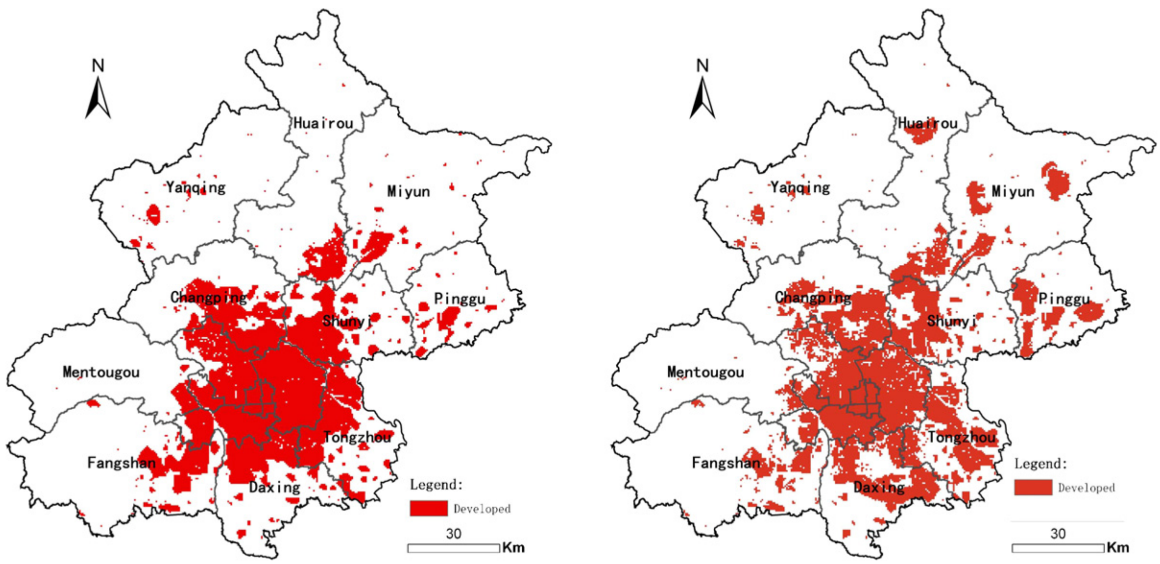

Fig. 5. Simulated urban forms by adjusting urban planning coefficient in BUDEM: the baseline scenario (left) and planning-strengthened scenario (right).

2001 and 2006, indicating that the model can well replicate urban growth from 2001 to 2006 in Beijing.

We aim to use the BUDEM to visualize the future urban form of the BMA in 2020, the end of the implementation period of the 2004 plan, by incorporating the effect of this plan. For this, we adopt the same neighborhood (the circle with a radius of five cells) and cell size (100 m * 100 m) in BUDEM. The transition rule of BUDEM is set as follows.

$$s_{ij}^t = w_0 + w_1 \cdot \text{l\_tam}_{ij} + w_2 \cdot \text{l\_cty}_{ij} + w_3 \cdot \text{l\_twn}_{ij} + w_4 \cdot \text{l\_rvr}_{ij} + w_5 \cdot \text{l\_bdtwn}_{ij} + w_6 \cdot \text{l\_r}_{ij} + w_7 \cdot \text{g\_conf}_{ij} + w_8 \cdot \text{g\_agri}_{ij} + w_9 \cdot p\ln_{ij} + w_{10} \cdot \text{nei}_{i,j}^t + w_{11} \cdot \text{s\_rrl}_{ij}$$

$$p_g^t = \frac{1}{1 + e^{-s_{ij}^t}} \quad (2)$$

$$p_{ij}^t = \exp\left[\alpha \cdot \left(\frac{p_g^t}{p_{g,\max}^t} - 1\right) \cdot \text{RI}_{ij}^t\right], \text{ where } \text{RI}_{ij}^t = 1 + (\gamma_{ij}^t - 0.5)/k$$

$$\text{if } p_{ij}^t > p_{\text{threshold}}, \text{ then } V_{ij}^{t+1} = 1$$

where, w is the estimated coefficient of logistic regression, p_g^t is the initial transition probability, $p_{g,\max}^t$ is the maximum p_g^t in iteration t, p_{ij}^t is the final transition probability, $p_{\text{threshold}}$ is the urban growth threshold, RI is the random item, γ is the random value varying from 0 to 1, k is the random index used to regulate RI, and α is the dispersion parameter ranging from 1 to 10, which indicates the rigid level of development.

We generate two urban expansion scenarios using the BUDEM, the baseline scenario and planning-strengthened scenario. Both scenarios have the same urban land area as that of the 2004 plan. The coefficients of the 2004–2008 period calculated in Section 5.1 are used as input weights of spatial factors for the baseline scenario in BUDEM. In this scenario, the weight of planning, namely the planning effectiveness, is 1.255. The planning-strengthened scenario is generated based on the baseline scenario, and the only difference lies in the weight of planning that is 3.000, much higher than 1.255, indicating the increasing planning effectiveness in future.

There are significant differences in the simulated urban form between these two scenarios (Fig. 5). In the baseline scenario, urban lands sprawl around the central city, and the new cities of Shunyi, Changping and Tongzhou expand significantly. In addition, the southern part expands slower than the northern part. Compared with baseline scenario, the planning-strengthened scenario generates a more scattered urban form and there is less natural resource encroached. The simulated urban forms are compared with the 2004 plan using KAPPA, a goodness-of-fit indicator for measuring the consistency. The planning-strengthened scenario is with a greater KAPPA value (78.7%) than the baseline scenario (65.2%), as expected. This visualization helps illustrate the impact of urban plan on urban expansion.

6. Discussion

The evaluation using the consistency indices has been used extensively in previous practices. Because such indices cannot distinguish the effect of planning from that of other factors, it is usually difficult to make comparisons across periods or regions. For example, Han et al. (2009) calculated three indices to examine the consistency between the actual urban development and plans based on the implementation of 1982 and 1992 BMA master plans. Although the results of both periods to some extent reflect the failure of the planning, it is difficult to compare the results of consistency in different periods due to different planning contexts. In our paper, the conformity evaluation also faces the same problem. By estimating three consistency indices – planning implementation rate, legal development rate and overall accuracy, the influence of planning is partially revealed. However, it is still difficult to interpret the spatiotemporal characteristics of planning implementation.

Spatiotemporal dynamic evaluation based on the logistic regression reveals that the effects of planning vary with time or region: (1) The effects of urban master plans in the recent period are stronger than those in the early periods. (2) The planning effect is weaker in the inner city districts than that in exurban districts. This may be because, in general, with the gradual improvement in technologies and regulating tools, the restrictions of urban planning on town development have been strengthened. In addition, the relatively high demand for development in the inner city districts could explain, at least partially, the smaller effects of planning in such districts.

The contributions of this paper lie in the following aspects. First, in methods for UPI evaluation, we extended the extensively used static “uniform evaluation”. We proposed an approach for evaluating UPI effectiveness in both temporal and spatial dimensions, and this approach helps overcome the limitations of the conventional conformity evaluation approach, which cannot distinguish the effect of planning control in the context of urban expansion. Second, we visualize UPI effectiveness over future urban expansion borrowing ideas from Geosimulation. This has not been conducted by existing literature regarding UPI evaluation. Third, the precise digital maps of the urban master plans in Beijing had been, for a long time, unavailable to researchers in urban planning. In planning practices, our work is conducted in the context of great socio-economic transition of China, using the digital maps of all the five urban master plans in Beijing since the foundation of People's Republic of China in 1949. To our knowledge, this is the first exercise in exploring such a data treasure.

7. Conclusions

The evaluation of the urban planning implementation (UPI) is only one component of planning evaluation. The conformity criterion is currently the most commonly used approach. Considering that many factors exist during urban expansion, the evaluation of the UPI using the conformity approach provides little insights because it lacks the analysis of the urban expansion process and its driving forces.

A spatiotemporal-dynamic evaluation approach is used in this paper to identify the effect of urban planning on urban expansion. Through the empirical research in the BMA using a logistic regression model, this study reveals that the restriction of urban planning on urban development in Beijing has been gradually strengthened since the founding of the People's Republic of China. In addition, the effects of urban planning on urban expansion differ significantly across regions in Beijing. The planning effect in the outer suburban area is significantly greater than that in the central city and inner suburban area. This suggests that the existing planning system still varies in its rigidity. We also simulate the future urban expansion in Beijing, by incorporating the effect of urban planning based on the estimation results in dynamic evaluation of the UPI.

Several issues are worth further exploration in future. First, this paper focuses on only whether land has been developed to urban use. There are still other indicators on whether a plan has been successfully implemented, such as the FAR and building height, which are specified in detailed plans. Second, we will use geographically weighted regression (GWR) for identifying spatial heterogeneity of urban planning implementation effectiveness in the near future. GWR allows assessment of the spatial heterogeneity in the estimated relationships between the independent and a set of dependent variables (Fotheringham, Brunsdon, & Charlton, 2002), thus enabling exploring more details of urban planning implementation effectiveness in contrast to the current approach adopted in this paper.

Acknowledgments

This research is funded by National Natural Science Foundation of China (Nos. 50908200 and 51078213), Qianjiang Talents Program (No. QJC1002007), and Key Laboratory of Regional Sustainable Development Modeling, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences (No. DP173163-2012). We also thank the anonymous reviewers for their in-depth comments on the earlier manuscript

References

Agarwal, C., Green, G. L., Grove, J. M., Evans, T., & Schweik, C. (2002). *A review and assessment of land use change modelsDynamics of space, time, and human choice TR NE-297*. Newton Square, PA: US Department of Agriculture, Forest Service Northeast Research Station.

Alexander, E. R., & Faludi, A. (1989). Planning and plan implementation – Notes on evaluation criteria. *Environment and Planning B: Planning & Design*, *16*, 127–140.

Batty, M., Couclelis, H., & Eichen, M. (1997). Urban systems as cellular automata. *Environment and Planning B: Planning & Design*, *24*, 159–164.

Beijing Municipal Planning Committee (2006). Beijing Institute of City Planning, Beijing Academy of Urban Planning. 2006 Beijing Urban Planning Atlas (1949–2005). Internal Publication of Beijing Academy of Urban Planning.

Beijing Planning Commission. (1988). *Beijing land resources*. Beijing: Beijing SciTech Press. (in Chinese).

Berke, P., Backhurst, M., Day, M., Ericksen, N., Laurian, L., Crawford, J., et al. (2006). What makes plan implementation successful? An evaluation of local plans and implementation practices in New Zealand. *Environment and Planning B: Planning & Design*, *33*, 581–600.

Bourassa, S. C., Cantoni, E., & Hoesh, M. (2007). Spatial dependence, housing submarkets, and house price prediction. *Journal of Real Estate Finance and Economics*, *35*, 143–160.

Brody, S. D., & Highfield, W. E. (2005). Does planning work? Testing the implementation of local environmental planning in Florida. *Journal of the American Planning Association*, *71*, 159–175.

Brody, S. D., Highfield, W. E., & Thornton, S. (2006). Planning at the urban fringe: An examination of the factors influencing nonconforming development patterns in southern Florida. *Environment and Planning B: Planning & Design*, *33*, 75–96.

Brown, D. G., Page, S., Riolo, R., Zellner, M., & Rand, W. (2005). Path dependence and the validation of agent-based spatial models of land use. *International Journal of Geographical Information Science*, *19*, 153–174.

Brueckner, J. K., & Fansler, D. A. (1983). The economics of urban sprawl: Theory and evidence on the spatial sizes of cities. *Review of Economics and Statistics*, *65*, 479–482.

Brueckner, J. K. (2001). Urban sprawl: Lessons from urban economics. In W. G. Gale, & J. R. Pack (Eds.), *Brookings-Wharton papers on urban affairs*. Washington, DC: The Brookings Institution.

Burchfield, M., Overman, H., Puga, D., & Turner, M. (2006). Causes of sprawl: A portrait from space. *Quarterly Journal of Economics*, *121*, 587–633.

Cheng, J., & Masser, I. (2003). Urban growth modeling: A case study of Wuhan City, PR China. *Landscape and Urban Planning*, *62*, 199–217.

Dietzel, C., & Clarke, K. (2006). The effect of disaggregating land use categories in cellular automata during model calibration and forecasting. *Computers, Environment and Urban Systems*, *30*, 78–101.

Fang, S., Gertner, G. Z., Sun, Z., & Anderson, A. A. (2005). The impact of interactions in spatial simulation of the dynamics of urban sprawl. *Landscape and Urban Planning*, *73*, 294–306.

Fotheringham, A. S., Brunsdon, C., & Charlton, M. (2002). *Geographically weighted regression: The analysis of spatially varying relationships*. Chichester: John Wiley & Sons Ltd.

Goodman, A. C., & Thibodeau, T. G. (1998). Housing market segmentation. *Journal of Housing Economics*, *7*, 121–143.

Han, H., Lai, S., Dang, A., Tan, Z., & Wu, C. (2009). Effectiveness of urban construction boundaries in Beijing: An assessment. *Journal of Zhejiang University Science A*, *10*, 1285–1295.

He, Y. (2008). Planning in restrictions for Beijing urban and rural development. In *Proceedings of 44th ISOCARP congress*. Available online at. http://www.isocarp.net/Data/case_studies/1185.pdf,. Accessed 02.04.12

Hu, Z., & Lo, C. P. (2007). Modeling urban growth in Atlanta using logistic regression. *Computers, Environment and Urban Systems*, *31*, 667–688.

Jones, C., Leishman, C., & Watkins, C. (2004). Intra-urban migration and housing submarkets: Theory and evidence. *Housing Studies*, *19*, 269–283.

Laurian, L., Day, M., Berke, P., Ericksen, N., Backhurst, M., Crawford, J., et al. (2004). Evaluating plan implementation – A conformance-based methodology. *Journal of the American Planning Association*, *70*, 471–480.

Laurian, L., Crawford, J., Day, M., Kouwenhoven, P., Mason, G., Ericksen, N., et al. (2010). Evaluating the outcomes of plans: Theory, practice, and methodology. *Environment and Planning B: Planning and Design*, *37*, 740–757.

Li, X., Yang, Q. S., & Liu, X. P. (2008). Discovering and evaluating urban signatures for simulating compact development using cellular automata. *Landscape and Urban Planning*, *86*, 177–186.

Li, X., & Yeh, A. G. (2002). Neural-network-based cellular automata for simulating multiple land use changes using GIS. *International Journal of Geographical Information Science*, *16*, 323–343.

Liu, X. H., Wang, J. F., Liu, M. L., & Meng, B. (2005). Spatial heterogeneity of the driving forces of cropland change in China. *Science in China Series D-Earth Sciences*, *48*, 2231–2240.

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

Lv, X., & Wu, W. (2006). On the evaluation of urban plan implementation. *City Planning Review*, *30*, 41–45 (in Chinese).

Mastop, H., & Faludi, A. (1997). Evaluation of strategic plans: The performance principle. *Environment and Planning B: Planning & Design*, *24*, 815–832.

McGrath, D. T. (2005). More evidence on the spatial scale of cities. *Journal of Urban Economics*, *58*, 1–10.

McGuire, T. J., & Sjoquist, D. L. (2002). Urban sprawl and the finances of state and local governments. In D. L. Sjoquist (Ed.), *State and local finances under pressure*. London: Edward Elgar.

Muller, M. R., & Middleton, J. (1994). A Markov model of land-use change dynamics in the Niagara region, Ontario, Canada. *Landscape Ecology*, *9*, 151–157.

Pajanowski, B. C., Brown, D. G., Shellito, B. A., & Manik, G. A. (2002). Using neural networks and GIS to forecast land use changes: A land transformation model. *Computers, Environment and Urban Systems*, *26*, 553–575.

Peking Municipal Engineering Bureau. (2007). *Peking Urban and Suburb Map*. Beijing: SinoMaps Press.
Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, *82*, 34–55.
Sanders, L., Pumain, D., Mathian, H., Guerin-Pace, F., & Bura, S. (1997). SIMPOP: A multiagent system for the study of urbanism. *Environment and Planning B: Planning and Design*, *24*, 287–305.
Stevenson, S. (2004). New empirical evidence on heteroscedasticity in hedonic housing models. *Journal of Housing Economics*, *13*, 136–153.
Sun, S., & Zhou, Y. (2003). Evaluation research on urban planning implementation. *Urban Planning Forum*, *2*, 15–20 (in Chinese).
Talen, E. (1996a). Do plans get implemented? A review of evaluation in planning. *Journal of Planning Literature*, *10*, 248–259.
Talen, E. (1996b). After the plans: Methods to evaluate the implementation success of plans. *Journal of Planning Education and Research*, *16*, 79–91.
Talen, E. (1997). Success, failure, and conformance: An alternative approach to planning evaluation. *Environment and Planning B: Planning & Design*, *24*, 573–587.
Tian, L., & Shen, T. (2011). Evaluation of plan implementation in the transitional China: A case of Guangzhou city master plan. *Cities*, *28*, 11–27.
Verburg, P. H., Soepboer, W., Veldkamp, A., Limpiada, R., Espaldon, V., & Mastura, S. (2002). Modeling the spatial dynamics of regional land use: The CLUE-S model. *Environmental Management*, *30*, 391–405.
Watkins, C. A. (2001). The definition and identification of housing submarkets. *Environment and Planning A*, *33*, 2235–2253.
Wildavsky, A. (1973). If planning is everything, maybe it's nothing. *Policy Sciences*, *4*, 127–153.
White, R., & Engelen, G. (1997). Cellular automata as the basis of integrated dynamic regional modeling. *Environment and Planning B: Planning & Design*, *24*, 235–246.
Wu, F. (2002). Calibration of stochastic cellular automata: The application to rural-urban land conversions. *International Journal of Geographical Information Science*, *16*, 795–818.
Yeh, A. G. O., & Li, X. (2001). A constrained CA model for the simulation and planning of sustainable urban forms by using GIS. *Environment and Planning B: Planning & Design*, *28*, 733–753.