

## Seeking the Smartest Growth

Kaiyuan Yu<sup>1,a</sup>

<sup>1</sup>North China Electric Power University, Beijing, 102206

<sup>a</sup>alanncepu@foxmail.com

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**Abstract.** Taking the cities of Karamay in Xinjiang and Arlington in the United States as examples, based on the complexity theory, we used the improved analytic hierarchy process (AHP) to determine the three indicators of economic development, social equity and environmental sustainability, the three indicators are positively correlated with the overall index.

We use the gray relational analysis theory to evaluate the relationship between the urban development plan and the ideal scheme index. We have established economic growth models for economic development and discussed the relationship between GDP and labor force, investment and regional cooperation through linear programming. We established the multi-agent model and the cellular automata model to simulate the dynamic urban expansion. By comparing the time and space, we got the conclusion that different stages of urban development, spatial location of the same impact factors may occur in different roles. We did these all to seek the best regional planning for the city in line with the principle of intelligent growth when population increases and demand grows.

### Introduction

We have established economic growth models for economic development. Then we established the multi-agent model and the cellular automata model to simulate the dynamic urban expansion, also we have considered the impact of multiple factors on the land using dynamics of cities and towns. By comparing the time and space, we got the conclusion that different stages of urban development, spatial location of the same impact factors may occur in different roles. We did these all to seek the best regional planning for the city in line with the principle of intelligent growth when population increases and demand grows.

### Assumptions

From now to 2050, there will be no war and natural disasters in the world; Assuming that the indicators do not affect each other; Assume that the data obtained are accurate, reliable and consistent with world trends and reflect the real situation; The same region will not have large scientific and technological innovation, the per capita labor output unchanged; Assuming that the residential agent has little influence on housing prices and other factors, it is assumed that the behavior prediction of government agents is in line with expectations.

### Model One: Construction of evaluation system

**Introduction.** Intelligent growth principle is a comprehensive, qualitative concept, involving different levels of urban systems, the use of improved analytical hierarchy method to determine the weight of each level, and entropy technology to optimize the weight.

**Indicator division.** Indicator division is shown in Fig 1:



Figure 1. Intelligent growth evaluation system

**Analytic Hierarchy Process.** The traditional nine-scale decision-making scale subjective in AHP is too strong to be exact given by existing data. Therefore, we use the three-scale judgment criterion which is shown in Table 1, to reduce the impact of the analyst’s subjective factors on the results.

Table 1. Judgment scale

Judgement scale	Evaluation rule
$C_{ij}=0$	The j element is more important than the I element
$C_{ij}=1$	The j element is as important as the I element
$C_{ij}=2$	The j element is less important than the I element

Then we calculate the importance ranking index:

$$r_i = \sum_{j=1}^n c_j \tag{1}$$

By consulting industry experts, we made significance comparison between the criteria layer and the indicator level, then calculated the judgment matrix elements, constructed the comparison matrix and transformed it into a judgment matrix A:

$$\begin{matrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{matrix} \tag{2}$$

In this matrix, if  $r_i < r_j$ , namely  $a_{ij} = r_i - r_j$ ;

if  $r_i = r_j$ , namely  $a_{ij} = 1$ ;

if  $r_i > r_j$ , namely  $a_{ij} = (r_i - r_j)^{-1}$

And in this equation,  $r_i, r_j$  are importance index,  $n$  is matrix order,  $a_{ij}$  is the corresponding judgement element in the matrix.

**Weight Adjustment by Entropy Technique.** We do the normalized processing of the constructed  $n$ th-order judgment matrix A according to the formula

$$\bar{a}_{ij} = a_{ij} * \sum_{k=1}^n a_{ik} \tag{3}$$

After which we will get the standard matrix A', so the entropy of the  $j^{\text{th}}$  element is

$$\bar{E}_j = -( \ln^{-1} ) * \sum_{i=1}^n \bar{a}_{ij} * \bar{\ln}_i \tag{4}$$

Then we began to find the deviation of the  $j^{\text{th}}$  index  $d_j=1-E_j$ , next we determined the information weights of the  $j$ th index

$$u_j = d_j * \sum_{j=1}^n d_j \quad (5)$$

Finally, the information weights are used to modify the weight coefficients obtained by AHP, we got the formula from  $w=(w_1, w_2, \dots, w_n)$  to .

$$\overline{w}_j = u_j * w_j * \sum_{j=1}^n u_j * w \quad (6)$$

3.5 Gray Relational Ideal Model Based on the index determined by the analytic hierarchy process, we first compare the numerical values of the evaluation index of the development plan, then find the correlation coefficient for each comparison series to the reference sequence, and find the expression of the correlation degree as follows:

$$r_i = \sum_{j=1}^m w_j * \sigma_i(j) \quad (7)$$

$r_i$  is the correlation,  $w_j$  is the indicator weight,  $\sigma_i(j)$  is the correlation coefficient of the reference sequence on the index is compared. We defined the formula as:

$$\xi_i(j) = \frac{\min i \min j |x_0(j) - x_i(j)| + \rho \max i \max j |x_0(j) - x_i(j)|}{|x_0(j) - x_i(j)| + \rho \max i \max j |x_0(j) - x_i(j)|} \quad (8)$$

We evaluate the development of Karamay and Arlington by gray relational analysis. The results show that the development of both meet the principle of intelligent growth.

### **Model One: Cellular Automata**

**Introduction.** Cellular automata is a dynamic model with discrete time, space and state. It has powerful spatial modeling and computing ability, and can simulate complex dynamic systems with temporal and spatial features. It is based on the idea that if the computer repeatedly computes extremely simple algorithms, it can be developed into an unusually complex model that can explain all the phenomena in the nature.”

**The Basic Principle of Urban Cellular Automata.** The simulation results show that the urban development pattern can be modeled by embedding the planning target in the conversion rules of CA. We use Matlab as the development platform to build the model of urban development. The results showed that the cellular automata greatly shorten the time to acquire spatial variables and obtain higher precision, which can simulate the urban development process more accurately and provide more accurate forecast for future urban development, which can provide the basis for urban planning. However, in real life, the city is a complex system, and its internal land use dynamic evolution system simulation involves natural, social and economic parameters, far more than we assume. Karamay City is located in the northwest margin of the Junggar Basin, located between 84 44’- 86 1’ east longitude and 44 7’- 46 8’ north latitude. Central and eastern open flat terrain to the Junggar Basin center tilt. Karamay City, the widest point of 110 km east-west, north-south longest 240 km, has a total area of 7733 square kilometers, the urban area of about 16 square kilometers. Altitude of Karamay is 270 to 500 meters. Arlington and Washington DC are on the opposite sides of the Potomac River, and Arlington belongs to Washington community. In recent years, the rapid economic development of the two cities, is the ideal places for city simulation. Therefore, we apply the model to them, simulate the development process of the city, and make a reasonable prediction, at the same time test the validity and versatility of the model for the city’s development planning to provide reasonable and effective recommendations.

**The Combination of Multi - Agent and Cellular Automata.** Cellular automata: The cellular automaton model can be expressed as follows:  $S_{t+1}=f(S_t, N)$ . In this equation, S is the collection of all possible states in CA model, f is the conversion rules, N is the neighborhood of a cell. The core of the model is the transformation rules to determine the cell state changes, that is, a cell's state in t +1 time is decided by its t time's state and the neighborhood state.

For cellular automata model operation, the cells in space have only two states, one is urban land, one is not converted into urban land. The rule adopts the Binary Logistic regression method to get the weights of each influencing factor from the empirical data, so as to form the reliable transformation principle and obtain the probability of each raster P c to urban land conversion. According to the literature and experts' comments, we selected influence factors as follows:

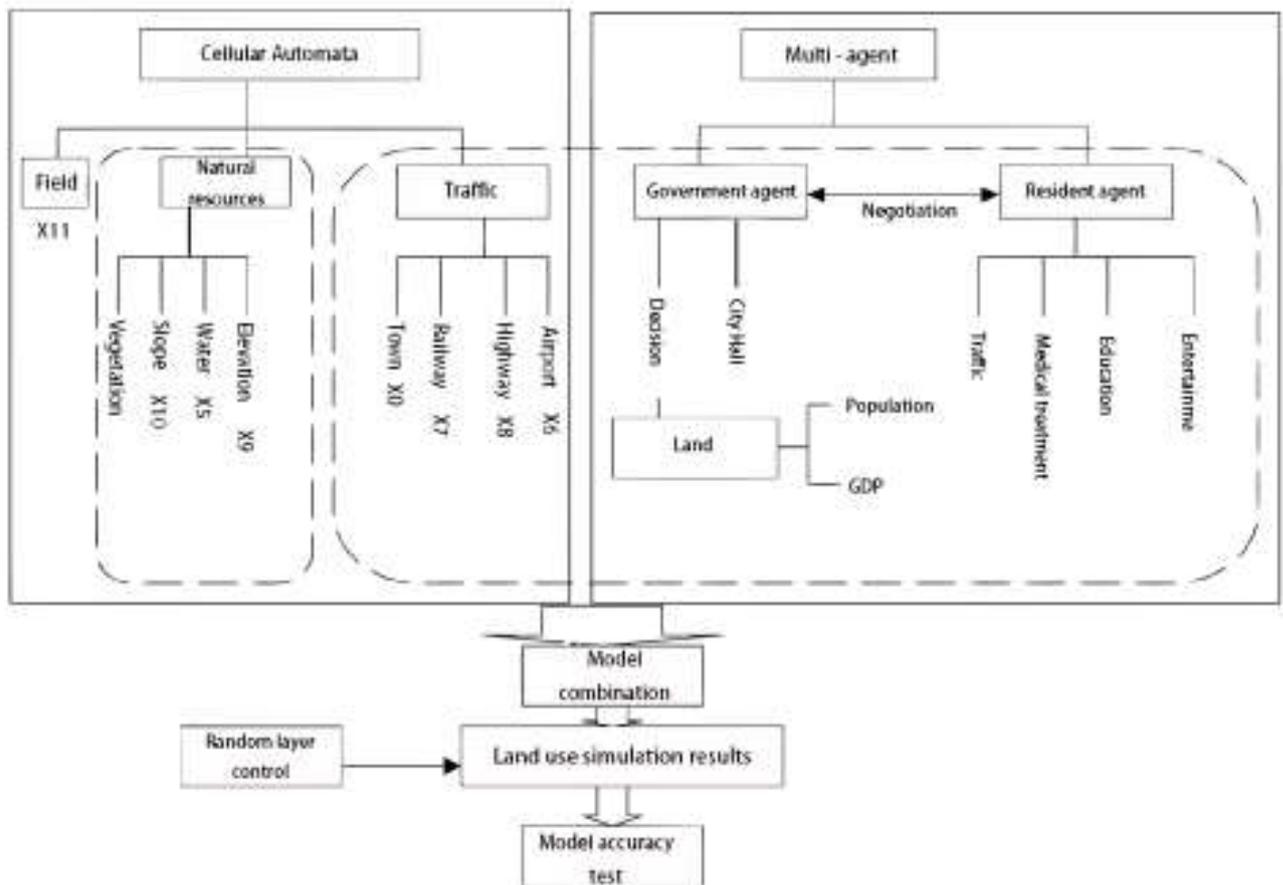


Figure 2. The urban land use simulation model based on ABM and CA

All influence factors are treated with fuzzy membership function, and the effect of dimension is eliminated.

**Multi - Agent and Cellular Automata:** We used the CreateRandomRaster commanding in Arcgis to generate a random raster dataset with boundaries between Karamay and Arlington, set the raster values 0-1, and each raster value is included in the model as Random, as a random factor to control the dynamic transformation of urban land. After the two models are calculated independently and combined with the control function of the random layer, the probability of finally converting the location ij into urban land is:  $P_{ij}=P_{abm} \times P_{ca} + P_{random}$ ,  $P_{abm}=P_{presidents} + P_{gov}$ . In these equations mentioned above,  $P_{presidents}$  are the probability of selection of resident agents,  $P_{gov}$  is the choice probability of government agents,  $P_{abm}$  is the final selection probability of the multi-agent system, and  $P_{ca}$  is the probability of cellular automaton raster ij conversion.  $P_{random}$  is the control probability of the random layer. By multiplying the above probabilities and adding the

adjustment of the random layer, we finally got the probability  $P_{ij}$  of the conversion of the spatial position  $ij$  to the urban land.

**Conclusion.** Through the combination of cellular automata and multi-agent model, through the application of GIS technology, we did the empirical research of two cities, and draw the conclusion that: By Binary Logistic regression analysis, the influence of  $n$  influence factors on land dynamic change was analyzed. By the comparison of time and space, the same influence factors of different urban development stages or the same city development spatial location might have different effects, should be an objective analysis of their internal links. It combines the cellular automata and the multi-agent model, which makes use of its' top-down 'self-organization development law to form the whole change, but also through the residential and government agents' macro-control behavior to the key decision-making role, taking into account the two aspects of decision-making.

## Conclusion

We have established evaluation indicators for the principles of urban intelligence development, and evaluated the development plans of the cities of Karamay and Arlington, Xinjiang, and formulated new growth plans based on this principle. Based on the complexity theory and using the improved AHP, we have identified three indicators: economic development, social equity and environmental sustainability. All three indicators are positively correlated with the total index. We seek the impact of labor and investment on the GDP by linear programming. We establish a multi-agent model and a cellular automaton model of urban dynamic simulation, considering the impact of multiple impact factors on urban land use dynamics, given when the population increases, demand growth in line with the principle of intelligent growth of the best urban areas Planning and planning.

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