Research on System Dynamics Model and Computer Simulation of Smart City System

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Abstract: This paper starts from the current social hot issues, carries out social survey around the smart city system, and puts forward a series of very sensitive social issues as relevant indicators. On this basis, the data of these indicators in recent years are analyzed, which lays a solid foundation for simulation. The operation of smart city is simulated by system dynamics model. System dynamics model is known as “government policy laboratory”. The system dynamics model is used to simulate the problems existing in the construction, and the causal relationship and quantitative relationship between these social phenomena are studied, so as to provide a “realization platform” for normal decision-making. The possible problems in the development of smart city and the measures that should be taken after the problems occur are simulated with the system dynamics model, and the problems in the further development and operation of smart city are further discussed.

1. Introduction

In recent years, science and technology drive the rapid development of major industries, and then promote the optimization of the national economic system, the development of the city is more intelligent. At present, the construction of smart city is still in exploration and practice, especially in the research of smart city evaluation, the evaluation dimension is not comprehensive, scientific and practical is not strong. Therefore, it is urgent to establish a reasonable evaluation index system of sustainable urban development.

2. One System Dynamics Model of Urban Development

For n index, m year. Form the original data matrix $X = \left(X_{ij}\right)_{m*n}$, For an indicator x_j, If the index valuex_{ij}, The larger the gap, the greater the role of the index in the comprehensive evaluation; On the contrary, the smaller. If the index values of a certain index are all equal, the index will not play a role in the comprehensive evaluation. Therefore, we use information entropy to determine the weight of indicators according to the degree of dispersion between indicators, which provides a scientific basis for the evaluation of regional sustainable development capacity.

Step 1: quantify each index in the same degree and calculate the proportion p_{ij} of index value in year i under index j.

$$p_{ij} = x_{ij} / \sum x_{ij} \qquad (1)$$

Step 2: calculate the entropy e_j of index j, $e_j = -k\sum p_{ij} Inp_{ij}$,let $k = 1/Inm$,so

$$e_j = -(1/Inm)\sum p_{ij} Inp_{ij} \qquad (2)$$

Step 3:calculate the difference coefficient a_j of index j, The smaller the entropy value is, the greater the difference between the indexes is, and the more important the indexes are

$$g_j = 1 - e_j \qquad (3)$$

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Step 4: define the weight a_j of the indicator j.

$a_j = g_j / \sum g_j$ (4)

Step 5: calculate the dynamic model of regional urban sustainable development system $RSDS_i$ of year i.

$RSDS_i = \sum a_{ij} p_{ij}$ (5)

In the process of entropy calculation, the concepts of logarithm and entropy are applied. Therefore, the corresponding rules must be followed, that is, negative values cannot be directly involved in calculation, and the extreme value should be changed accordingly. The data of such indicators should be transformed.

2.1 Selection of Evaluation System Index

To achieve smart growth of a city, the measure of its success must include a city's demographic, growth needs and geographical conditions, and strictly abide by the three e goals. Through the analysis of the above three criteria and the combination of the objectives of the three e's, we can get the following map:

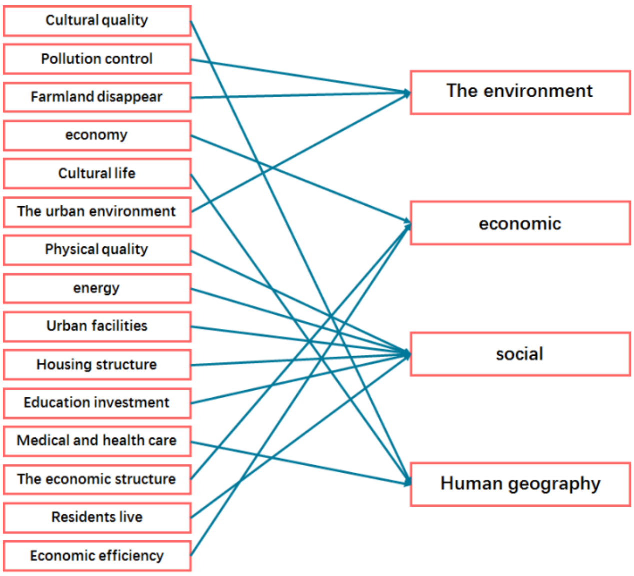

Fig.1 Index Map

Because the evaluation index system of this study chooses the parallel module structure, and through the analysis of the connotation of smart growth city, the system is divided into three subsystems: environment, economy and society, so the selection of index is based on the subsystem.

2.2 Selection and Description of Environmental Dimension Indicators

Environmental indicators can be divided into two categories: one represents the current situation of urban environment; The other is the pollution control index for the current situation of urban environment. The relationship between various indicators and environmental dimensions is shown in Figure 2.

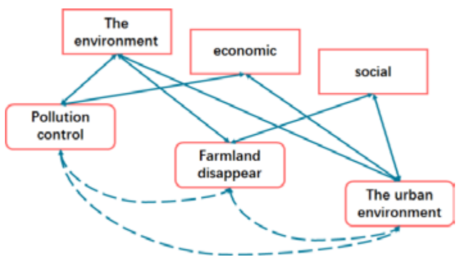

Fig.2 Environment Dimension Relationship Diagram

(1) Per capita public green space area: $\alpha = \frac{Ga}{P}$

(2) Annual PM2.5 average value: $\varepsilon = \frac{PM}{365}$

(3) Domestic sewage discharge per capita: $pTds = \frac{Tds}{P}$

(4)Treatment rate of urban domestic sewage: $\eta = \frac{Ts}{Tst}$

(5) Loss area of Farmland: $Fla = Ofa - Efa$

2.3 Economic Dimension Index Selection and Explanation

The index of economic urbanization should include economic gross, industrial structure and economic efficiency. The relationship between each aspect and economic dimension is as follows:

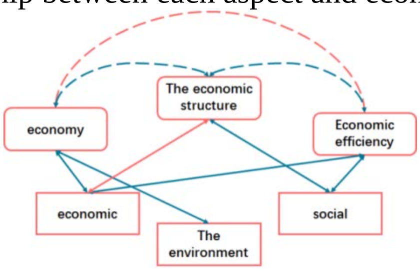

Fig.3 Economic Dimension Diagram

(6) GDP is a national concept, which refers to the market value of the final products produced by all the production factors owned by a national in a certain period of time.

(7) The proportion of service industry to industry and agriculture $Rsi = \frac{Ser}{Tio}$

(8) Energy consumption per 10000 yuan GDP reflects the degree of urbanization development $Ec = \frac{Tec}{10000}$

(9) Per capita production value can reflect the advantages and disadvantages of a city $Pc = \frac{Gp}{Aae}$

2.4 The Selection and Explanation of the Dimension Index of Social Culture and Human Geography

In order to realize sustainable urbanization, it is necessary to make urban facilities coordinate with regional geographical conditions, economic, social and environmental development not only in scale, but also in structure and function

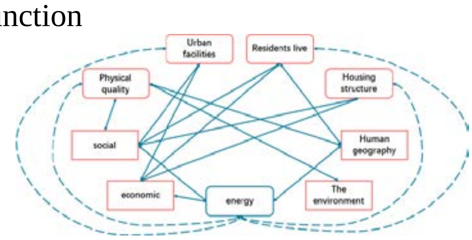

Fig.4 Social Dimension Diagram

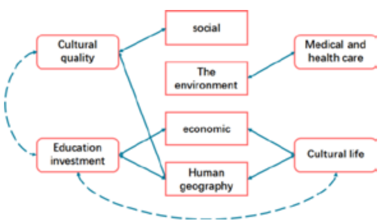

Fig.5 The Dimension Relationship of Human Geography

(10) The average regional life span of population reflects the level of medical treatment and the development level of science and technology

(11) Per capita domestic water consumption $pDwc = \frac{Dwc}{P}$

(12) Per capita share of energy $Pces = \frac{Te}{P}$

(13) Urban population density $Upd = \frac{Ua}{P}$

(14) Per capita living area of urban residents $Ula = \frac{Tha}{P}$

(15) Urban Road area per capita $Ura = \frac{Tra}{P}$

(16) Water use penetration rate and gas penetration rate in cities and towns $Tgpr = \frac{Cgr}{P}$

(17) Urban per capita disposable income

(18) Urban unemployment rate $u = \frac{Tnu}{P}$

(19) Engel coefficient of urban residents: direct query

(20) Engel coefficient of urban residents: a direct query on the ratio of fiscal education expenditure to GDP $Eoep = \frac{Eoe}{GDP}$

(21) Number of doctors per 10000 people $Pdn = \frac{Dt}{P}$

(22) Radio and television and network penetration rate $Btnp = \frac{Bti}{Th}$

(23) Illiteracy as a proportion of the total population $Ir = \frac{Ni}{P}$

2.5 Criteria for the Evaluation of Success Rate

In this paper, the world average value is selected as the evaluation stand:

Table 1 Evaluation Index System

Index model	The index name	Evaluation standard		
The environment	Per capita public green area	I	II	III
economic	In the average PM2.5	16 ㎡	13 ㎡	10 ㎡
	Sewage emissions per capita	35μg/m³	50μg/m³	65μg/m³
	Town life sewage treatment	200m³	220m³	240m³
	Farmland area disappear	90.00%	80.00%	70.00%
	GDP	5.00%	7.00%	8.00%
social	Services and industry, the proportion of agriculture	¥90000	¥80000	¥70000
	Every ten thousand yuan GDP energy consumption	65.00%	60.00%	55.00%
	The per capita output	1.2 Ten thousand tons of standard coal	1.5 Ten thousand tons of standard coal	1.8 Ten thousand tons of standard coal
	The population average area of life	¥65000	¥55000	¥45000
Human geography	Water consumption per capita	75	70	65
	Per capita energy	180m³	210m³	240m³
	Urban population density	6.7 Ten thousand	6.2 Ten thousand	5.7 Ten thousand

		tons of standard coal	tons of standard coal	tons of standard coal
	Urban per capita road area	10000	9000	80000
	Urban water penetration, urban gas penetration	4.5 ㎡	4 ㎡	3.5 ㎡
	Urban per capita disposable income	90.00%	80.00%	70.00%
	Urban unemployment rate	¥30000	¥25000	¥20000
	Urban residents' engel coefficient	5.80%	6.00%	7.20%
	The proportion of bungalow with building	30.00%	35.00%	40.00%
	Financial education expenditure to GDP ratio	70.00%	55.00%	40.00%
Index model	The number of doctors per ten thousand people	5.00%	4.50%	4.00%
	Radio and TV penetration	20	15	10
	The proportion of illiteracy	90.00%	80.00%	70.00%
	The index name	3.00%	5.00%	8.00%

2.6 Smart Growth Success Rate Assessment

In order to realize the standard application of quantitative indicators and qualitative indicators (which can be quantified), eliminate the influence of different dimensions between indicators, and make each indicator have a standard to measure:

$$nd = (sd - miv)/(mav - miv) \qquad (6)$$

nd represents new data, sd represents original data, miv represents minimum value and mav maximum value. Through this method, four index model grading evaluation criteria are obtained. According to sustainability $RSDS_i$, a comprehensive evaluation PI standard can be combined.

Table 2 Comprehensive Grade Table

Index	Evaluation standard		
	I	II	III
environment $PI(C_1)$	0.247	0.189	0.139
Economics $PI(C_2)$	0.409	0.157	0.209
Sociology $PI(C_3)$	0.289	0.328	0.450
human geography $PI(C_4)$	0.345	0.289	0.275
PI	0.370	0.310	0.027

By comparing the actual standard with the comprehensive standard, we can measure the success rate of smart urban growth.

3. Computer Simulation of Urban Development System Dynamics Model

According to the index system, from the perspective of indicators, the paper makes a systematic evaluation of the current development of the city according to the current urban development status. The evaluation results are as follows.

Table 3 Summary of Evaluation

Index model The environment	The index name Per capita public green area	Venice · Xi'an	level
economic	In the average PM2.5	14.7 ㎡	II
	Sewage emissions per capita	47μg/m³	II
	Town life sewage treatment	235m³	III
	Farmland area disappear	81.70%	II
	GDP	2.29%	I
social	Services and industry, the proportion of agriculture	¥54804	III-

	Every ten thousand yuan GDP energy consumption	84.59%	I
	The per capita output	1.39 Ten thousand tons of standard	I
	The population average area of life	¥49861.1	II
Human geography	Water consumption per capita	76	I
	Per capita energy	225m³	III
	Urban population density	4.42 Ten thousand tons of standard	III-
	Urban per capita road area	11454	I
	Urban water penetration, urban gas penetration	4.18 ㎡	II
	Urban per capita disposable income	98.00%	I
	Urban unemployment rate	¥20145	III-
	Urban residents' engel coefficient	19.80%	III-
	The proportion of bungalow with building	45.64%	III-
	Financial education expenditure to GDP ratio	42.50%	III
Index model	The number of doctors per ten thousand people	3.68%	III-
	Radio and TV penetration	11	III
	The proportion of illiteracy	98.00%	I
	The index name	5.68%	III

According to the data in the table, the radar chart of Xi'an's current growth plan is made, and the results are as follows:

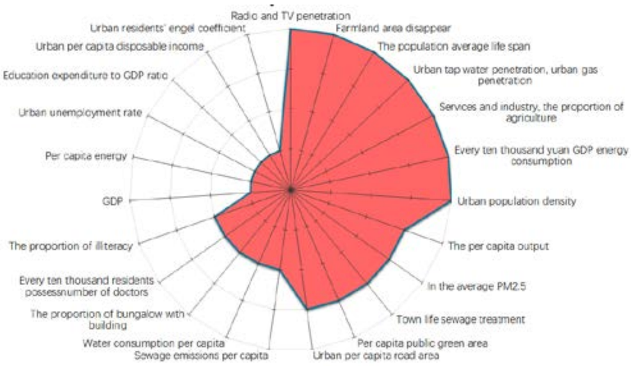

Fig.6 Radar Map of Xi'an City

It can be seen from the radar chart of Xi'an in Figure 7 that the city's economic growth plan is not perfect and needs to be improved. In terms of society, the city's growth plan is relatively perfect, but it is still lacking. In terms of environment, the environmental system in the urban growth plan is relatively formed, but there is still a big lack. In terms of human geography, the city's growth plan is relatively deficient.

According to the model , the smart growth success rates of the cities of Xi'an is 72%, PI =0.37, $RSDS_i$ =0.195

4. Summary

The intelligent city evaluation index system proposed in this paper is a comprehensive system evaluation problem, involving various kinds of multi factor indicators. The model established in the existing methods is practical and easy to be applied in real life. The model can evaluate the sustainable development ability of the city well, and clearly reflect the influence of 25 indexes on the sustainable development of the city. For the evaluation system of the development of smart city established in this paper, Xi'an City in Western China is selected for evaluation, and compared with the actual situation, it is proved that the evaluation index system constructed in this paper is feasible and can be used for the evaluation of the smart city in China.

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References

[1] Wang guangbin, Zhang Lei, Liu Honglei. Theoretical research and practical thinking of smart city at home and abroad [J]. Scientific and technological progress and countermeasures. 2013 (19)

[2] Guo Liqiao. Research on China's smart city standard system [M]. China Construction Industry Press, 2013

[3] Li Deren, Yao yuan, Shao Zhenfeng. Big data in smart city [J]. Journal of Wuhan University (Information Science Edition). 2014 (06)

[4] Shan Zhiguang. Challenges to the healthy development of smart cities in China [J]. National governance. 2015 (18)