Research on Performance Evaluation about Investment and Financing Pattern of Urban Infrastructure

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Abstract Starting from the analysis of characteristics of urban infrastructure, this paper analyzes the selection factors of its investment and financing pattern. From the perspective of the whole city, the paper establishes synthesis performance appraisal model of the pattern with Analytical Hierarchy Process (AHP). The empirical study is then done on Shanghai, Tianjin, and Kunming in China and the paper takes these three cities to measure the rationality and profitability of the pattern selection. Therefore, by the comprehensive performance evaluation system of its investment and financing mode with a city as a unit can help the urban managers to find the most suitable pattern for the development of urbanization.
Key words Urban infrastructure; Investment and financing pattern; Performance appraisal; Analytical Hierarchy Process

1 Introduction

The situation of urban infrastructure is an important support of urban development and civilization level. What’s more, it is also the material conditions of the city’s economic and social development. Since the 80s of the 20th century, the urbanization trend is accelerating and urban infrastructure features and supply is increasingly inadequate with the country’s rapid economic development. Governments have increased investment in urban infrastructure construction. However, the urban infrastructure facility is a complex systematic project, which in certain ways directly or indirectly involved in the city’s production process. Compared with general products and services, it has some special economic characteristics such as natural monopoly, non-competition and exclusive in consumption, and the high concentration in cost, making the project difficult to attract a large number of private capitals. It is difficult to complete even in developed countries with only government finance.

To deal with the problem of funds insufficient, governments have introduced competitive mechanism to make the composition of investment and Financing colorful. At the same time, they have broadened the investment and financing channels and optimized the capital structure. The innovation of urban infrastructure’s investment and financing pattern has also been realized by diversifying the modes of investment and financing and improving the efficiency of capital allocation and operation etc.. In all these patterns, BOT, TOT, PPP, and ABS are the most widely used. However, the innovation is a dynamic and diversified progress of choosing which affected not only by the external factors such as financing environment and the area’s general economic environment, but also by the micro factors as technical level and management capacity. For urban managers, only complete grasp the influence effects of mode selection which affected by various factors and have comprehensive performance evaluation on the existing model, they can find the most suitable pattern for the development of urbanization.

To this end, many scholars at home and abroad also carried out the corresponding research. Charnes, Cooper and Hodes (1978) carried on evaluation and measurement on supply efficiency of public goods by using data envelopment analysis (DEA). It expands the theory of production frontier. Domestic researches are more focused on the economic effect evaluation of the application of a single project‘s investment and financing models. Fewer researches are done from the prospective of the whole city with consideration of rationality and profitability of the pattern chosen. In china, the city’s infrastructure construction is often one of the major tasks for local governments, whose investment and financing mode needs to be unified arranged and selected by the government. Therefore, it is necessary to establish a comprehensive Performance Evaluation System of its investment and financing mode with a city as a unit.

2 Model Construction

2.1 Ideology of performance rating index system

The performance of Urban Infrastructure Investment and Financing Patterns are ultimately reflected in the contribution level of investment and financing on urban development. Therefore, the performance evaluation model build in this paper includes two levels. First, a comprehensive and well-bedded evaluation system of urban infrastructure development level is established according to the characteristics of urbanization development in China on the basis of AHP and fuzzy comprehensive evaluation method. Then, per capita urban infrastructure investment situation and changes in development level of the urban infrastructure within a period of time are investigated to make judgment on the performance of the mode by using longitudinal evaluation mode.

2.2 System design of evaluation indexes on urban infrastructure development level

2.2.1 Classification and composition

Divide the assessment system of urban infrastructure development into hardware environment and software environment those two categories according to the requirements which urban development has on infrastructure environment. The main concern and analysis of hardware environment is the indicators which can direct reflect the quality life of residents and urban infrastructure development. It is used to determine the supply capacity of the city's infrastructure including the indicators of urban road traffic urban energy, urban communications and urban water supply and drainage those four categories. The soft environment paid more attention on the factors such as the external environment affecting urban infrastructure construction, comfort level of residential living environment, and the sustainable level of urban development. It can be divided into two categories which are the indicators of urban external environment and urban sanitation. On this basis of above, we selected 19 three-level indicators to form the development level indicator system of the investment and financing pattern combining the characteristics of urban infrastructure development. (See Table 1)

What's sure is that many indicators can be used to measure the development level of urban infrastructure and different stages of development and different regions can be adjusted according to actual situation.

2.2.2 Weight assignment of evaluation indexes

Table 1 Evaluation Indexes System of Urban Infrastructure Development Level

First-level indexes	Second-level indexes	Third-level indexes
Indicator	Indicator	Indicator
Urban hard environ-mental system	Evaluation indexes of urban road traffic system	Road area per citizen
		The number of cars owned by citizen
		Rail transportation conditions
	Evaluation indexes of urban energy resources	Urban gas popularization rate
		The ability of urban distribution network to change electricity
		Energy consumption per unit of GDP
	Evaluation indexes of urban communication system	Telephone penetration rate
		Internet penetration rate
	Evaluation indexes of urban water drainage system	Per capita water quantity
		Water supply capacity
		Urban water penetration rate
		Drain pipe density
Urban soft environ-mental system	Evaluation indexes of external environment	Urban economic development level
		Financial ecological environment
	Evaluation indexes of environmental health system	City green coverage rate
		Urban sewage treatment
		MSW processing ability
		Waste harmless treatment rate
		The number of public toilets people have

(1) Determine factor set of assessment

According to the established assessment system, we further determined the factor set of assessment, which is $V=\{f_1, f_2 \cdots f_n\}$ = (Urban Hard Environment Indicators, Urban Soft Environment Indicators).

The primary estimation index f_i representing the affected factors, and $f_i = \{f_{i1}, f_{i2}, \cdots f_{ij}\}$, , where i = 1,2 ... n, n is the number of primary index. j is the number of secondary index included in primary index $f_{i,j}$ = 1,2 ... m. We then get m factors' matrix eigen value of n evaluation index.

$$F = \begin{bmatrix} F_1 \\ \vdots \\ F_n \end{bmatrix} = \begin{pmatrix} f_{11} & \cdots & f_{im} \\ \vdots & \ddots & \vdots \\ f_{n1} & \cdots & f_{nm} \end{pmatrix} \quad (1)$$

(2) Determine weights set of index

Use the basic principles of AHP, combine with the structure of evaluation index system and judge the relatively important degree of all indicators using expert scoring method, we assessed the weight of all indicators according to the range of relative importance values provided in the table. F is target value, f_i is assessment factor, $f_i \in F(i=1,2,\ldots n)$. w_{ij} is the weight between observation f_i and f_j. And the numeric areas of w_{ij} shown in table 2.

Table 2 Numerical Value of the Relative Importance Index

	f_i and f_j are equally important	f_i slightly important than f_j	f_i important than f_j
w_{ij}	1	3	5

2、4 represented the median of 1～3，3～5，If f_i and f_j comparability w_{ij}, the comparison of f_j and f_i have $1/w_{ij}$

In order to ensure the typicality and rationality of the data, we did dispersion degree measurement on each of the weight indicators to determine the need for a second round investigation and get the hierarchical matrix of evaluation index system.

Then underway normalized processing and consistency checking on the matrix W gotten above using AHP methods, to generate the weights of all levels, where

$$W = \begin{bmatrix} W_{11} & \cdots & W_{1m} \\ \vdots & \ddots & \vdots \\ W_{n1} & \cdots & W_{nm} \end{bmatrix} \quad (2)$$

The judgment matrix meets:

$$0 \le w_{ij} \le 5 \; i \ne j$$

$$w_{ij} = 1 \quad i = j$$

$$w_{ij} + w_{ji} = 1 \quad i \ne j$$

Here the unit eigenvector corresponding to the biggest eigenvalue of the judgment matrix can be obtained by integration method. That is , add each line of Matrix firstly and we get:

$$\overline{\omega} = \sum_{i=1}^{n} \omega_{ij} (i = 1, 2 \cdots n) \quad (3)$$

Then underway normalized processing on vector $\overline{\omega_j} = (\overline{\omega_1} \cdots \overline{\omega_n})$：

$$P_j = \frac{\overline{\omega_j}}{\sum_{i=1}^{n} \overline{\omega_i}} \qquad (i = 1, 2, \cdots n) \quad (4)$$

Where P（$P_1, P_2, \ldots P_n$）are the weight sets desired.

Then calculate the biggest eigenvalue λ_{max} of the judgment matrix, we get the consistency index C.I.（C.I.= $\lambda_{max}{}^{-n}$)/(n-1). According to the average random index R.I. of judgment matrixes with different order, we calculate the consistency ratio C.R.（C.R.=C.I./R.I.）and at last realize the consistency test of the matrixes. When C.R.≤0.10, the judgment matrix meet the consistency and when C.R.>0.10, the relatively important value need to be amended till it meets the consistency demand.

2.2.3 Establish criteria of data evaluation and grade classification

First of all, the way of non-dimensional points is used to divide the sub-system development level of urban infrastructure into four grades—good, fair, general and poor. Here, 80 to 100 points indicates that the urban infrastructure development which represents by the index is good. It can fully meet community needs and provide quality services for residents. 50 to 80 points says that the urban infrastructure development can fully meet the needs of production and residents' life well, but it has further optimized space in relation to urban development needs. 20 to 50 points indicates that the urban infrastructure development lags behind, which would constrain urbanization if not to transform. 0 to 20 points means that the level of urban infrastructure development lagged far behind, which has already caused great damage to people's daily lives and need to be improved immediately.

Secondly, we determine the critical value of grading index. To determine and measure the critical value of urban infrastructure's development level, the paper compiled the original data of 19 relevant indicators from 1990 to 2008. Based on the reference of average level and target value of international cities whose related indicators developed, and combined with the China's current urbanization development level and regional differences with consideration of the research results which has done by other experts and scholars, this paper at last determined the evaluation criteria and classification threshold of the measurement indicators in current empirical evaluation system.

Then, we get the comprehensive weight and the evaluation criteria of the 19 indicators in the urban infrastructure development listed in Table 3.

Combined with the indicators weight given above, we can get the comprehensive evaluation value of a city's infrastructure development level *V* as follows:

$$V = \sum_{i=1}^{n} \omega_i \times f_i (i = 1, 2 \dots n) \quad (5)$$

Where V is the comprehensive value of urban infrastructure development, ω_i and f_i are the comprehensive weight and the evaluation value of the indicator i respectively. Obviously, a higher comprehensive value indicates a better urban infrastructure development.

Table 3 Evaluation Index System Weight and Index Critical Value of Urban Infrastructure Construction

First-level indexes		Second-level indexes		Third-level indexes		Grade value and critical value			
Indicator	Weight	Indicator	Weight	Indicator	Weight	80～100	50～80	20～50	0～20
Urban physic environment system	0.7	Urban road traffic	0.423	Road area per citizen	0.199	＞15	10～15	5～10	＜5
				The number of cars owned by citizen	0.455	⩾20	15～20	10～15	<10
				Rail transportation conditions	0.346	⩾8	6～8	4～6	＜4
		Urban energy resources	0.227	Urban gas popularization rate	0.297	95%	85～95	70～85	＜70
				The ability of urban distribution network to change electricity	0.540	2.2-1.8	1.8-1.6	1.6-1.3	＜1.3
				Energy consumption per unit of GDP	0.163	⩽0.65	0.65-0.85	0.85-1	＞1
		Urban communication system	0.123	Telephone penetration rate	0.500	＞1350	1100-1350	500-1100	＜500
				Internet penetration rate	0.500	＞400	200-400	100-200	＜100
		Urban water drainage system	0.227	Per capita water quantity	0.423	⩾250	200-250	150-200	＜150
				Water supply capacity	0.227	1.8～2	1.5～1.8	1.2～1.5	＜1.2
				Urban water penetration rate	0.123	95～100	90～95	80～90	＜80
				Drain pipe density	0.227	⩾10	8-10	6-8	＜6
Urban soft environment system	0.3	External environment	0.3	Urban economic development level	0.5	⩾3	1.8～3	1～1.8	＜1
				Financial ecological environment	0.5	⩾0.8	0.5～0.8	0.2～50	＜0.2
		Environmental health system	0.7	City green coverage rate	0.317	⩾60%	40%～60%	20%～40%	⩽20%
				Urban sewage treatment	0.317	⩾80%	65%～80%	50%～65%	⩽50%
				MSW processing ability	0.189	⩾85%	70%～85%	55%～70%	⩽ 55%
				Waste harmless treatment rate	0.103	⩾0.2	0.15～0.2	0.10～0.15	＜0.10
				The number of public toilets people have	0.074	⩾4.3	3.8～4.3	3.3～3.8	＜3.3

2.3 Model establishment of performance evaluation on urban infrastructure investment and financing

Construction of urban infrastructure is a long process. In order to scientifically evaluate the performance of the urban infrastructure investment and financing mode, we have to investigate that whether level of urban infrastructure development matches the increase value of investment and financing scale of the city within a period of time. If in a certain period of time the growth rate of urban infrastructure development is higher than the growth rate of investment for urban infrastructure, then the choice of investment and financing mode is more suitable for the development of the city with a higher performance level. Shall use the formula said:

$$P_{t,t+k} = \frac{(V_{t+k} - V_t)/V_t}{\left(\frac{I_{t+k}}{R_{t+k}} = \frac{I_t}{R_t}\right)/\left(\frac{I_t}{R_t}\right)} \qquad (6)$$

Where $P_{t,t+k}$ indicates the investment and financing pattern performance of a city's urban infrastructure from year t to $t+k$; V_{t+k}、 V_t represents the composite scores of this city 's infrastructure development level at year $t+k$ and t respectively ; I_{t+k}, I_t indicates the amount of investment put into urban infrastructure at year $t+k$ and t respectively; R_{t+k}, R_t states the Average population of urban resident at the year $t+k$ and t respectively.

3 Empirical Analyses

China's vast territory and distinguish between big cities makes the role of the same kind of investment and financing modes in different urban infrastructure construction different. Obviously, it is not scientific and objectively if only uses the data of one city to reflect the performance problems. Therefore, this paper chose Shanghai, Tianjin and Kunming, these three typical cities to make an empirical analysis. Among these three cities, Shanghai is an international metropolis, whose economic strength, financial resources are rich, and has a rapid development of urbanization. Tianjin city is one of the traditional industrialization whose urbanization development is rapid in recent years, while Kunming is located in southwestern China whose geographical environment is complex and economic strength is relatively backward. It is on behalf of the western underdeveloped region of the city. In terms of time, the years from 2004 to 2008 in China is the peak of urbanization development, and at that time the urban infrastructure investment and financing mode innovations are emerge in an endless stream. This paper will select the related data about urban infrastructure development and performance in 2004 and 2008 respectively in Shanghai, Tianjin and Kunming, and evaluate the investment and financing mode in this period, in order to find the existing problems in Chinese urban infrastructure construction and the way to innovation.

This original data comes from "China statistical yearbook", "China urban statistical yearbook" "Shanghai statistical yearbook", "Tianjin statistical yearbook" and "Kunming statistical yearbook" respectively in 2005 and 2009 etc. Due to the reasons of statistical data of individual phenomenon inevitably default, this study will use the calculation of sample the default value as the "imaginary value". Through calculation we can get the urban infrastructure development synthetically score in Shanghai, Tianjin, and Kunming city, seen in Table4.

According to the formula of 5 calculated the performance of urban infrastructure investment and financing mode in 2004-2008 in Shanghai Tianjin and Kunming, the result came out that Shanghai is 0.065, while Tianjin and Kunming are 0.2714 and 0.070 respectively.

4 Results Analysis

Underway empirical analysis on urban infrastructure investment and financing patterns of Shanghai, Tianjin and Kunming these three cities, which has different scale and are in three different stages of economic growth using performance evaluation model we found Shanghai is best developed. It is due to the substantial wealth, economic power and financial ecological environment (inside it its urban financial ecological environment index scores is 100 points) which Shanghai have. However, the level of performance in Shanghai is not high as concerns to the 5 years from 2004 to 2008 because of the soaring population. The indicators such as number of private owned cars, City power substation capacity and Per capita water consumption for residential use don't have obviously improvement. Increasing in investment fund scale failed to make great improvement in urban infrastructure construction also indicates that there exist problem of wasting fund in the process of construction.

Although the overall development level of urban infrastructure construction of Tianjin is slightly lower than that of Shanghai, its performance of urban infrastructure investment and financing pattern is the best in these three cities. Its contribution reached 27.14%, which shows that Tianjin choice a suitable investment and financing mode for their urban infrastructure.

Comparatively speaking, the development level of Kunming is the lowest, which is only 48.20 % in year 2008. It is closely related to its external economic environment. Kunming is located in the southwest of China, whose traffic is relatively isolated and financial ecological environment comparatively lag behind. It is difficult to obtain other social capital input for its urban infrastructure construction program except the government financial support. Therefore, the performance level of current financing mode in Kunming is difficult to meet the development needs, which need further mercerization reform and attract non-governmental funds into the market, so as to supplement the shortage of financial capital.

Table 4 Qscore of the Evaluation Index System on Urban Infrastructure Development Level in City Shanghai, Tianjin and Kunming from2004 to 2008

City	Shanghai		Tianjin		Kunming	
Year	2004	2008	2004	2008	2004	2008
Urban infrastructure development index	62.06	67.63	39.73	58.37	41.83	48.20
1.Urban hardware environment System index	52.89	60.56	35.28	56.74	37.70	45.31
(1)Urban road traffic system index	68.15	68.37	22.32	60.96	53.73	44.73
Urban road traffic system index	81.00	89.40	45.8	70.34	20.12	61.10
Number of private owned cars index	38.30	35.12	24.2	45.8	99.36	63.98
Rail transport situation index	100	100	6.35	75.5	13.05	10
(2)City energy and power Systems index	39.15	47.02	38.51	45.34	26.71	37.65
City gas penetration index	100	100	94	100	57.23	92.48
City power substation capacity index	12.31	11.24	15.38	15.38	17.08	14.46
Unit GDP energy consumption index	17.17	69	14	45	3	14.46
(3)Urban communication system index	87.68	100	51.45	70.38	23.73	81.84
Telephone penetration index	88.56	100	39.85	52.76	38.25	63.68
Internet penetration index	86.8	100	63.05	88	9.2	100
(4)Urban water supply and drainage system index	23.42	46.22	57.46	63.86	31.93	41.39
Per capita water consumption index	9.87	18.13	6	17.24	8.93	7.47
Water supply capacity index	19	62	91	95	74	100
Urban water coverage index	92	99	94	100	63.80	98
Drainage channels density index	15.93	54.2	100	100	15.47	15.30
2.Urban soft environment system index	83.47	84.12	50.10	62.17	51.46	54.94
(1)Urban external environment index	100	92.70	65.38	62.5	43.63	32.75
Urban development index	100	85.4	79.75	65	49.25	24.5
Urban financial ecological environment index	100	100	51	60	38	41
(2)Urban sanitation systems index	76.39	80.44	43.55	62.03	54.82	64.45
Urban green coverage index	44.05	50.93	44.53	46.25	27	43.9
Wastewater treatment rate index	96.3	93.8	23.6	64.8	58.24	69.28
Municipal solid waste ability index	100	100	98	86	89.78	90.14
Garbage disposal rate index	97.19	98	18.95	93.50	97.85	99.34
Number of Public toilets index	40.4	75.2	20	12.79	10.18	17.64

5 Conclusion

In short, this paper analyzed investment and financing pattern of China's urban infrastructure with the application of performance evaluation model and investigated the rationality and profitability of the model choice in this area from the overall prospective. It provides basis for improvement of profitability level and is efficient for manager in making a timely choice of the model to advance the construction of the urban infrastructure.

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