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Study on the Application of a New Evaluation Method to Urban Ecosystem

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Abstract: Since, a certain degree of subjectivity exists in determining of weights in gray relational analysis and the DEA analysis can only evaluate whether the unit is efficient, but the effective unit cannot be ordered, data envelopment analysis (DEA) and weighted grey correlation have been combined to achieve fairness and objectivity of the evaluation results. An evaluation system from the perspective of input and output for the coordination of urban ecosystem has been established and an empirical application of urban ecosystem in Shanghai has been carried out to verify the validity of this method.

Key words: Urban ecosystem, data envelopment analysi, grey correlation analysis, empirical application

INTRODUCTION

Urban ecosystem has been defined as the complex human ecosystem as a new term. A precise evaluation of urban ecosystem is of great importance to decide the direction of urban development and support the realization of sustainable urban development strategies. There are many studies on eco-efficiency and ecosystem health at home and abroad (Chen *et al*., 2010; Li *et al*., 2006; Zhang *et al*., 2007), but the research methods are mainly confined to the DEA and Analytical Hierarchy Process (referred to as AHP) in these studies. For example, Yang (2009) and Wang *et al*. (2010) has analyzed the regional eco-efficiency with the use of DEA, Ke and Li (2005) has studied the relationship among the resources, environment and economic development in various regions of China. However the research method applied in these studies are still relatively monotonous and lack of innovation. For that reason, a better method-weighted gray correlation analysis based on DEA has been introduced in this study to study Shanghai urban ecosystem coordination. This method has two advantages over DEA and AHP separately. It not only has a simpler evaluation process than AHP but also can overcome the ordering problem of DEA when the decision-making units are all efficient. Shanghai urban ecosystem development of coordination from 2003-2010 can been analyzed by using this study method in order to find out the problems that exist in Shanghai urban ecosystem development process and propose rational and effective policy measures to provide the basis for construction of Shanghai ecological city.

NEW EVALUATION METHOD MODEL

A certain degree of subjectivity exists in determining of weights in gray relational analysis and once the weights are determined they will be applied to the correlation calculations of all the factors, namely correlation calculation of each factor will use the same set of weights with subjectivity every time, so this weights belong to the "homogenization" weighting. At the same time, the DEA analysis can only evaluate whether the unit is efficient, but the effective unit cannot be ordered. Based on that, weighted gray relational analysis based on DEA has been adopted in this study to synthesize advantages and avoid disadvantages of the two methods mentioned above. The integration of gray correlation analysis and DEA can overcome the problem of subjectivity existing in the gray relational analysis when determine the weight coefficients to enhance the accuracy of the calculation of the correlation and can also order effective units in order to achieve fairness and objectivity of the analyzing results.

Gray correlation analysis and DEA are integrated again in this study to shape a framework of weighted gray correlation analysis method based on DEA for urban ecosystem. There are aspects of work to be done to apply this method smoothly. First, the correlation coefficient e_{ik} should be calculated to measure the correlation between the optimal index and each index. The specific steps are as follows: the optimal value of each index must be selected to determine the optimal index set Y_0; Dimensionless processing should be carried out for every index values. If the index value is all objective value, it is better to select the mean dimensionless for comprehensive evaluation (Ye, 2003). According to this regulation, this study apply the formula $X_i = Y_i \div \overline{Y}(i = 1, 2, \cdots, n)$ ($\overline{Y}$ represents the average of all the indicators for each year) to carry on dimensionless processing; The differencing sequence should be calculated. In accordance with the formula $|X_0 - X_i|\,(i = 1, 2, \cdots, n)$, differencing sequence can be solved out, respectively, then the minimum and maximum values must be found out among all the

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differencing sequence and can be expressed as Δ and Δmax; Correlation coefficient can be calculated by using the formula:

$$e_{ik} = \frac{\Delta\min + \rho\Delta\max}{|X_{0k} - X_{ik}| + \rho\Delta\max} (\rho=0.5)$$

e_{ik} represents the correlation coefficient between index k of sub-factor i and the index k of optimal index set. Secondly, the correlation coefficient between sub-factor i and the optimal index set should be calculated with the use of linear programming derived from DEA model, in which the weights should be regarded as a decision variable to avoid homogenization weighting. Specific models are as follows:

$$\max \theta = \sum_{k=1}^{m} w_k e_{ik}$$

$$\text{s.t.} \begin{cases} \sum_{k=1}^{m} w_k e_{ik} \le 1 (i = 1, 2, \ldots, n) \\ \sum_{k=1}^{m} w_k = 1 \end{cases}$$

where, θ represents the optimal connection degree between index i and optimal index set which w_k represents the weight of index k, m represents the number of index and n represents the number of units to be evaluated. The greater the θ is, the greater the correlation between the sub-factors and the optimal index set is in this article and the greater correlation means that the input is less while the output is larger, in other word, the urban ecosystem development at this time is more coordinate according to the selection criteria of optimal index set. Therefore, the optimal correlation coefficient can be defined as the coordination degree of urban ecosystem development.

According to the mentioned calculation steps, correlation coefficient between each index and the optimal index set will be calculated, then there will be total mn correlations produced. Then with the use of EXCEL software here, the linear programming consistent with the constraints in DEA model can be carried out to solve the optimal correlation which is a integrated value representing the best correlation between m indexes. Repeating this EXCEL calculation process for n times, the all optimal coordination coefficient can be calculated.

APPLICATION OF THE NEW METHOD

The recent rapid economic development has brought urban ecosystem a lot of pressure to most cities in China, therefore it is important to make a scientific evaluation of the development situation of these cities. While it is a prerequisite for complex integrated urban ecosystem assessment to establish an evaluation index system.

Establish research index system: Since, it is the inherent requirement for the construction of ecological city to achieve balanced development among the resources, environment and economics, the urban ecosystem indicators this article used are divided into three kinds: resource consumption, environmental pollution and economic growth indicators. Among these three kinds of index, the first two kinds measure the input situation and the third one is output indicators. There is a relationship of mutual interaction, restraint, interdependence existing in these three indexes, for example, resource consumption and environmental pollution index there can reflect investment efforts for economic development as well as the extent of the affected by economic development.

A evaluation system of urban ecosystem has been made up with the following seven indexes showing in Table 1.

Data sources: The data related to this evaluation can be easily collected from a serial of statistical Yearbooks in which the dada has authority and recognized by the public. In this study the collected data are as following figure.

Figure 1 has shown the different developpment trends of seven indexes that can impact the coordination during 2003-2010 periods.

Table 1: Index system of evaluation

Level one indicator	Level two indicator	Specific indicator's form
Input indicators	Categories of indicators of resource consumption	Total energy consumption (10,000 tons of standard coal)/index 1
		Total electricity consumption (100 million kW h)/index 2
		Total water (100 million cubic meters)/index 3
	Categories of indicators of environmental pollution	Industrial wastewater emissions (10,000 tons)/index 4
		Industrial waste gas emissions (100 million cubic meter)/index 5
		Industrial solid waste generation (10,000 tons)/index 6
Output indicators	Categories of indicators of economic growth	GDP (100 million yuan)/index 7

Table 2: Optimal correlation

Year	2003	2004	2005	2006	2007	2008	2009	2010
Correlation	0.997571	0.998804	0.999793	0.9994	0.999189	0.999583	0.99975	0.999932

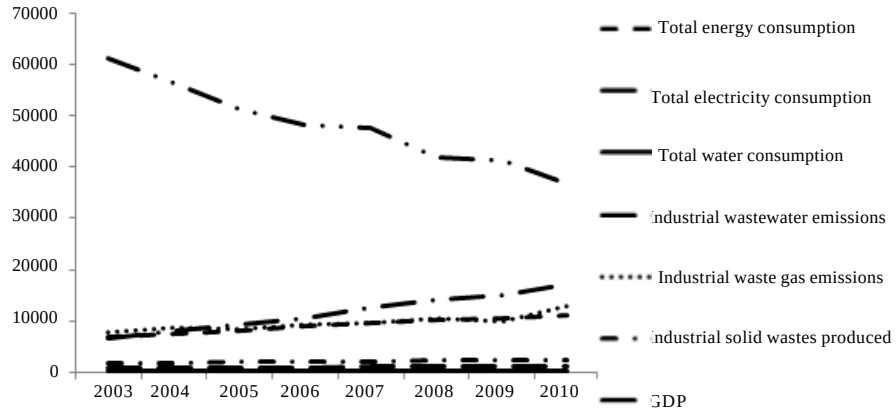

Fig. 1: Shanghai urban ecosystem trends of individual indicators

Evaluation results: The specific results are shown as Table 2.

According to the Table 2, two pieces of information can be deduced. First, Shanghai urban ecosystem coordination can be ordered in descending: 2010>2005> 2009>2008>2006>2007>2004>2003. The coordination reached the lowest level in 2003 and then hit the optimal degree in 2010. In general, the development of the urban ecosystem continues going better except a little slip from 2006 to 2008 in Shanghai. Second, the average level of Shanghai urban ecosystem coordination is 0.999246 and the coordination has been continually higher than the average of 8 years' level from 2005 except 2007 and the fluctuations of coordination are very small from then.

CONCLUTION

The method used in the article is good enough to overcome the disadvantages of DEA and grey correlation analysis to realize the fairness and effectiveness of comprehensive evaluation and compared with the DEA it has simpler calculation process. So, it will be very easy for us to use it. We have reason to believe and hope that the combination of the two methods can be applied to assessment study in other field in the future.

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