A grey relational analysis based study on green degree evaluation of urban logistics

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Abstract: According to the urban logistics green degree's evaluation, a weighted grey correlation analysis method based on the analytic hierarchy process is proposed to determine the weight of each index in the urban logistics green degree evaluation system, and then figure out the optimal relative degree, realizing the green degree of each urban logistics. Finally, an example was given for proving the evaluation methods' intuitive and high efficient.

Keywords: Grey Relational Analysis, Urban Logistics, Green Degree, Evaluation

1. Introduction

The world economy has brought serious damage to the environment. As part of the economic activity, urban logistics system is also facing environmental problems, such as polluted gas emissions, traffic congestion and improper waste disposal. Thus, countries have to develop green logistics as a key way to protect the environment and improve efficiency. Green degree of urban logistics industry has gradually become an important indicator of the standard of social development, urban construction and of living of the society. Therefore, the assessment of urban logistics green degree will not only help to identify bottlenecks in its development, but also provide theoretical guidance for the scientific development of circular economy.

2. Determining the City Logistics Green Degree Evaluation Index System

Green logistics refers to the reduction of environmental harm, while making the best use of logistics resources to achieve economic, social and environmental benefits. It follows four principles: 1) reduction principle, 2) reuse principle, 3) recirculation principle, 4) coexistence principles [1].

Green city logistics include green logistics operation and green logistics management [2]. Therefore, the evaluation of city logistics green degree should be considered mainly for the following indicators:

1) Intensification of resources. It's the dominant ideology of the logistics industry development. Through integrating the existing capacity resources and optimizing resource allocation and other means, logistics companies can improve resource utilization, reduce waste.

2) Green transport. Firstly, to achieve green logistics, transport routes must be optimized in order that we can shorten the transport distance, Secondly, the rational organization of the supply flow and stowage, can avoid unreasonable transport; In addition, focusing on the transport vehicle maintenance and using cleaner fuels, would be beneficial to reduce energy consumption and emissions.

3) Green warehousing. Green Warehousing needs three requirements: First, the warehouse's location should be reasonable so as to save transportation costs easily, Second, the layout of the warehouse should be scientific for realizing maximize storage volume utilization and reducing costs of inventory unit, third, the warehouse should be equipped with reasonable hardware and software facilities to improve

management efficiency.

4) Reverse logistics. Primarily by means of reuse of waste materials, recycling and waste disposal, we could achieve minimized environmental impact [3].

3. Multi-Level Gray Evaluation Model System

City logistics green degree evaluation system is a gray system. Firstly, because the factors that affect the city logistics' green degree are too numerous and complex, we generally select limited key indicators to analyze while conducting the evaluation. Secondly, the link between the factors are not fully known and difficult to be quantified accurately, it is difficult to make a reasonable, accurate judgment relying solely on qualitative methods and mathematical evaluation methods in general [4]. Therefore, it is suitable for using of gray correlation analysis method combined with AHP to "whiten" the not fully ascertain relationship between the evaluation factors [5]. It can also be achieved on multiple city logistics systems to queue in line according to the quality of being friendly to the environment.

The basic idea of the evaluation: All the index value of idealized city logistics x_{0k} composing the reference sequence X_0, all measured index value of a certain city logistics x_{ik} composing compared sequence X_i, we should find the correlation between X_0 and X_i. The larger the correlation, the more environmental the city logistics is. Therefore, we could judge city logistics systems based on finding the size of the correlation.

Evaluation procedure is as follows:

3.1. To Select the Reference Sequence

Set: i is the number of the ith object (city) for evaluation, $i = 1, 2, \cdots, m$; k is the number of the k th index for evaluation, $k = 1, 2, \cdots, n$; v_{ik} indicates the score of the k th index for the i th object. Take the ideal value v_{0k} for each indicator as entity of the reference sequence V_0, so we get,

$$V_0 = (v_{01}, v_{02}, \cdots, v_{0n})$$

In the formula, v_{0k} =Optimum (v_{ik}), $i = 1, 2, \cdots, m$; $k = 1, 2, \cdots, n$

For a system of evaluation object of m, evaluation indexes of n, we have the following matrix:

$$V = (V_{ik})_{m \times n} = \begin{bmatrix} V_{11} & V_{12} & \cdots & V_{1n} \\ V_{21} & V_{22} & \cdots & V_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ V_{m1} & V_{m2} & \cdots & V_{mn} \end{bmatrix}$$

Reference sequence to be selected is,

$$V_0 = (v_{01}, v_{02}, \cdots, v_{0n})$$

3.2. To Normalized Index Value

In order to compare between the various indexes, each index value needs to be normalized, normalized formula is as follows:

$$X_{ik} = \frac{V_{ik} - \min_i V_{ik}}{\max_i V_{ik} - \min_i V_{ik}}$$

After the normalization process, we get:

$$X = (X_{ik})_{m \times n} = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & \cdots & X_{mn} \end{bmatrix}$$

3.3. To Calculate the Correlation Coefficient

Take the normalized sequence $X_0 = (x_{01}, x_{02}, \cdots, x_{0n})$ as a reference sequence and $X_i = (x_{i1}, x_{i2}, \cdots, x_{in})$, ($i = 1, 2, \cdots, m$) as a compared sequence, Correlation coefficient is calculated as follows:

$$\xi_{ik} = \frac{\min_i \min_k |X_{0k} - X_{ik}| + \rho \max_i \max_k |X_{0k} - X_{ik}|}{|X_{0k} - X_{ik}| + \rho \max_i \max_k |X_{0k} - X_{ik}|}$$

Where, $i = 1, 2, \cdots, m$; $k = 1, 2, \cdots, n$; $\rho \in [0,1]$, which is the distinguished factor.

Calculating the correlation coefficient $\xi_{ik} (i = 1, 2, \cdots, m; k = 1, 2, \cdots, n)$, we could obtain the correlation coefficient matrix:

$$E = (\xi_{ik})_{m \times n} = \begin{bmatrix} \xi_{11} & \xi_{12} & \cdots & \xi_{1n} \\ \xi_{21} & \xi_{22} & \cdots & \xi_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \xi_{m1} & \xi_{m2} & \cdots & \xi_{mn} \end{bmatrix}$$

Where, ξ_{ik} is the correlation coefficient between X_{ik} and X_{ok}.

3.4. To Calculate the Single-Level Correlation

Taking into account the importance of the indicators are not the same, the correlation calculating method of taking the weight multiplied by the correlation coefficient should be preferred. The priority weight of each index relative to the upper floor target can be calculated based on the Analytic Hierarchy Process,

$$W = (w_1, w_2, \cdots, w_n)$$

In the formula, $\sum_{k=1}^{t} w_k = 1$, t represents the number of indicators in the layer. Correlation is calculated as follows:

$$R = (r_i)_{1 \times m} = (r_1, r_2, \cdots, r_m) = WE^T$$

3.5. To Calculate the Ultimate Correlation of Multilayer Evaluation System

By a multilayer evaluation system, the final correlation calculation method is as follows: Synthesize correlation coefficient of each index in k layer, we could respectively obtain correlation of each index which belongs to $k-1$ layer. Then put the obtained correlation of each index in $k-1$ layer as raw data, continue to synthesize and get correlation of each index in $k-2$ layer. And so on, until we find the correlation of the highest layer so far.

3.6. To Judge the Urban Logistics System

According to the correlation $r_i (i = 1, 2, \cdots, m)$, judge pros and cons of each object for evaluation and sort it.

4. Empirical Analysis

Taking the status quo of four cities' (named City1, City2, City3, City4) logistics systems being carried out as an example to illustrate its application.

4.1. To Establish Urban Logistics Green Degree Evaluation System

Urban logistics green degree evaluation system is as shown in Table1. The system is composed by three lays of indicators. The first layer is called target layer, which means urban logistics green degree and is represented by A. The second layer is called elements layer, which consists of intensive resources (B_1), green transport (B_2), green warehousing (B_3), reverse logistics (B_4). The third layer is called index layer, which is composed of a total of 12 indicators ($C_1, C_2, \cdots, C_{12}$).

Note: The reference values in the table refer to the maximum value of each indicator in each city logistics score.

4.2. To Calculate the Single-Level Correlation

Taking the status quo of City1, City2, City3, City4 (V_1, V_2, V_3, V_4) four cities' logistics systems being carried out as evaluation object, organize 10 experts to rate each factor of index layer. Each evaluation scores between 0-10, the higher the score, the higher the degree of satisfaction. Using the sub-average method, we could obtain the overall score of 12 factors $v_{ik} (i = 1, 2, 3, 4; k = 1, 2, 3, \cdots, 12)$ for each system and the reference scores v_{ok} for the all the factors, see table 2.

Reference sequence can be derived from Table 2,

$$V_0 = (8, 8, 8, 8, 8, 7, 8, 8, 7, 8, 8, 7)$$

After each index value being normalized, take distinguished coefficient $\rho = 0.5$, we will have the correlation coefficients of each indicator to each optimum value in the reference sequence,

$$\xi_1(k) = \{1, 0.67, 1, 0.67, 0.5, 1, 1, 0.4, 0.67, 0.67, 0.5, 0.67\}$$
$$\xi_2(k) = \{0.5, 0.67, 1, 0.67, 0.67, 0.67, 0.4, 0.5, 1, 0.5, 1, 1\}$$
$$\xi_3(k) = \{0.67, 1, 0.5, 1, 1, 0.67, 1, 0.5, 1, 0.5, 1, 1\}$$
$$\xi_4(k) = \{0.33, 0.5, 0.5, 1, 1, 0.4, 0.4, 1, 1, 1, 0.4, 0.67\}$$

4.3. Correlation Synthesis for Multilayer Structure

Using AHP, through comparing the relative importance of every two indicators, we could get the appropriate proportion of weights to build judgment matrix for upper certain elements related elements of the underlying [6,7,8]. Using Yaahp software to calculate the maximum Eigen values of the judgment matrix and the corresponding eigenvectors, derived single sorting weight vector and total weight vector and get through the consistency test [9,10]. The results are shown in Table 3.

By the formula $R = WE^T$, we could calculate each city's correlation for each index of B layer,

$$R_{B_1} = W_{B_{1C}} E^T_{B_{1C}} = (0.78, 0.613, 0.89, 0.443)$$

Namely the correlation on "intensive resource" in City1, City2, City3, City4 four urban logistics system is 0.78, 0.613, 0.89 and 0.443 respectively.

Also available,

$$R_{B_2} = W_{B_{2C}} E^T_{B_{2C}} = (0.731, 0.697, 0.849, 0.759)$$
$$R_{B_3} = W_{B_{3C}} E^T_{B_{3C}} = (0.851, 0.550, 0.939, 0.611)$$
$$R_{B_4} = W_{B_{4C}} E^T_{B_{4C}} = (0.595, 0.806, 0.806, 0.678)$$

Further, correlation of A at the highest level index can be obtained

$$R_A = (r_1, r_2, r_3, r_4) = W_{AB}[R_{B_1}, R_{B_2}, R_{B_3}, R_{B_4}]$$
$$= (0.748, 0.659, 0.872, 0.609)$$

4.4. Comprehensive Evaluation and Sorting for the Green Degree of Urban Logistics

In accordance with the size of the correlation available in R_A, the four urban logistics green degree integrated Sorting from low to high as follows: City4＜City2＜City1＜City3.

In addition, since the correlation of the city1 on "reverse logistics" is 0.595, and the correlation of city2 on "green storage" is 0.55, the correlation of city4 on "intensive resource" is 0.443, each correlation is at the lowest level compared with other cities in the same index which indicates it's a major bottleneck in the current development and the local government should take greater efforts to improve in the future.

5. Conclusions

1) Using the gray system theory evaluation of urban logistics green degree has several features of simple operation, high efficiency, less required data and clear

explanation of the problems etc., meanwhile, it can help to expand sources of information, improve evaluation analysis of the credibility and enhance the objectivity of the evaluation results in case of incomplete information and inaccurate conditions.

2) In calculating the correlation, using AHP to determine the weight of each index, to account for differences in the degree of importance of each indicator, makes the evaluation results more reasonable and with a strong persuasiveness.

Acknowledgements

***Table 1.** Green degree evaluation index system of urban logistics*

Target layer	Elements layer	Index layer
Unban logistics green degree A	Intensive resources B_1	Integrating resources C_1
		Optimizing allocation C_2
		Using cleaner fuels C_3
	Green transport B_2	Regular vehicles maintenance C_4
		Optimization of transport route C_5
		Reasonable cargo stowage C_6
		Correct warehouse location C_7
	Green warehousing B_3	Reasonable warehouse layout C_8
		Advanced facilities C_9
		Waste materials reusing C_{10}
	Reverse logistics B_4	Waste materials reprocessing C_{11}
		Waste materials recycling C_{12}

***Table 2.** Index scores of urban logistics and reference sequence*

Index layer	City1	City2	City3	City4	Reference
Integrating resources Optimizing allocation	8 7	6 7	7 8	4 6	8 8
Using cleaner fuels	8	8	6	6	8
Regular vehicles maintenance Optimization of transport route	7 6	7 7	8 8	8 8	8 8
Reasonable cargo stowage	7	6	6	4	7
Correct warehouse location	8	5	8	5	8
Reasonable warehouse layout	5	6	6	8	8
Advanced facilities	6	7	7	7	7
Waste materials reusing	7	6	6	8	8
Waste materials reprocessing Waste materials recycling	6 6	8 7	8 7	5 6	8 7

***Table 3.** Urban logistics green degree evaluation index weight summary*

Target layer	Elements layer	Weight	Index layer	Weight
Unban logistics green degree A	Intensive resources B_1	0.3618	Integrating resources C_1	0.3333
			Optimizing allocation C_2	0.6667
	Green transport B_2	0.3270	Using cleaner fuels C_3	0.129
			Regular vehicles maintenance C_4	0.0804
			Optimization of transport route C_5	0.1385
			Reasonable cargo stowage C_6	0.4468
	Green warehousing B_3	0.1635	Correct warehouse location C_7	0.3343
			Reasonable warehouse layout C_8	0.6483
			Advanced facilities C_9	0.1217
	Reverse logistics B_4	0.1477	Waste materials reusing C_{10}	0.2300
			Waste materials reprocessing C_{11}	0.3873
			Waste materials recycling C_{12}	0.4435
				0.1692

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