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Establishment and Application of Evaluation Index System (EIS) for Recycling Economy Development of Highway Transport (REDHT) in China

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Abstract. Highway transport is a resource-occupied and energy-consumed industry. Establishing a scientific, effective, overall and systematic evaluation index system (EIS) will steadily push forward the recycling economy development of highway transport (REDHT) in China. Based on the 3R theory of recycling economy as well as the connotation, present situation characteristics of REDHT in China, we used the latest research results for reference and proposed an EIS framework for REDHT. The evaluation indexes were selected by the fuzzy mathematical evaluation method and divided into evaluation indexes and condition indexes. The evaluation indexes comprise 16 indexes, separating into four systems of resource utilization, service ability, environmental protection and social participation. The condition indexes involve 2 artificial indexes. Benchmarking establishment of the EIS can work as orientative tools for the decision-makers, managers, practitioner and consumers to implement recycling economy concept into the construction, operation, management and consumption of highway transport. The EIS had been applied to evaluate the REDHT for 31 provinces in China. Affected by the impact of regional per capita GDP and population density, the REDHT of 31 provinces are different with 15 provinces higher than the average while the other 16 provinces lower than the average. The suggestions from the evaluation results have great significance in guiding REDHT and improving the EIS.

Keywords: recycling economy, highway transport, fuzzy mathematical evaluation, principal component analysis, cluster analysis

1. Introduction

Highway transport is not only the key foundation for modern social economy, but also the core part of the comprehensive transport system. In recent years, highway transport in China has shown a remarkable trend of intensive land use [1] and had faced the problems of a rising trend in tremendous unit energy loss [2], enormous consumption of construction materials, low recycling rate of discarded materials, severe ecological impact and serious pollution [3]. As a resource occupying and energy consuming industry, the development of highway transport is increasingly restricted by the factors of land supply and demand, energy saving, emissions reduction and ecological environment. Therefore, it is urgent to promote the recycling economy development in highway transport to decrease the resource and energy consumption, transfer the use patterns of resource and energy, increase the effect of energy saving and emissions reduction and quicken the sustainable development process. The establishment of a scientific EIS is critical for the assessment on REDHT.

Lack of comprehensive and systematic research on REDHT has restricted the establishment of the EIS and EIS is still on the exploration stage. Based on the latest research results on transport sustainable development around the world, we construct an EIS for REDHT in China and establish the benchmarking for

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the EIS. We also use the EIS to comprehensively evaluate the recycling economy development level of highway transport of 31 provinces in China. The evaluation results may provide supports for the strategic decisions on REDHT.

2. Research Advances on Transport Sustainable Development

Researchers around the world have done some prior work on transport sustainable development [4-5] other than transport recycling economy. They have put forward the concept of sustainable transport [6] and four principles to change the unsustainable transport development trend [7-9]. In order to evaluate effects and problems of the transport system and promote the sustainable transport, many city engineers have tried to establish some management and environment evaluation indexes, for example, the index pyramid [10], sustainable transport evaluation system [11], Transport and Environment Reporting Mechanism (TERM) index system [12] and Canadian Sustainable Transport Performance Indicators (STPI) [13].

The researchers in China have focused on establishing the index system on sustainable transport and have proposed some comprehensive evaluation methods, for instance, principal component analytical method based on the multivariate statistical analysis, coordination degree function, fuzzy mathematics and analytic hierarchy process (AHP) [14-19]. The available index systems have significant impact on the application effects. The indexes with large coverage, especially the ones with background factors, may weaken the sustainable development themes in practical application. On the contrary, the indexes with small coverage cannot reflect the transport sustainable development level to some extent. The design deficiency of the indexes representing the important connotation of sustainable transport may lead to insufficient evaluation. In addition, the data is not available for every index system and this affects the application effects.

Taking a wide view of the research on the EIS of sustainable transport around the world, although different researchers have various classification methods, the index system has basically covered four fields of transport service, resource, energy and environment, representing the industry characteristics of transport development. Nevertheless, the establishment of EIS for REDHT based on the 3R (Reduce, Reuse and Recycle) principles of the recycling economy and their core ideas still remains blank. In spite of this shortage, the ideas, methods and practical experience of the index system available from the research results work as reference for the establishment of EIS for REDHT in China.

3. Establishment of EIS for REDHT

Based on the 3R theory of recycling economy, the connotation of recycling economy development as well as the materials metabolism characteristics of highway transport in China[20-21], we construct an initial EIS for REDHT by combining the statistics situation of highway transport in China, reviewing the literatures, conducting the field investigation and applying expert estimation. The initial EIS is comprised of 18 evaluation indexes and 2 condition indexes. The former ones are separated into 4 subsystems of resource utilization, service ability, environmental protection and social participation.

Although the initial index system can be used to comprehensively evaluate the multiple connotations of the REDHT, some indexes have not been involved in the statistic scale and the effective data is not available [22]. In order to apply the index system in the practical evaluation in the near future, it is necessary to examine, evaluate and test the rationality and feasibility of the initial indexes one by one. These processes can identify the indexes without availability or comparability and select the competent indexes to compose the EIS for REDHT that adapts with the statistics situation of highway transport in China. A questionnaire is carried out among 49 experts in the fields of recycling economy and transport. The questionnaire data is used to evaluate the initial indexes by using the fuzzy mathematical evaluation method.

According to the maximum membership degree principle, the indexes with high, middle and low feasibility are 8, 8 and 2, respectively. R-1-1, R-4-1, R-5-1, R-6-1, E-2, E-3 and E-4 show high feasibility while R-2-1, R-3-1, S-1, S-2, S-3, E-1, M-1 and M-2 have middle feasibility. The index R-7-1 (mileage rate of first-class highway) and index R-8-1 (per capita of highway mileage) show low feasibility and they are deleted from the initial EIS. The EIS for REDHT is shown in Table 1.

Table 1. EIS for REDHT

Index Type	System Level	Control Level	Index Level			
			Recommendation Index		Unit	Representative of Index
Evaluation Indexes	Resource Utilization System (R)	Resource Consumption	R-1	Land consumption of per traffic capacity	ha./vehicle	To measure the occupation situation and consumption efficiency of land, bitumen and cement, energy utilization efficiency during highway operation, representing the development direction of reducing the resource and energy investment
			R-2	Bitumen consumption of per traffic capacity	t/ vehicle	
			R-3	Cement consumption of per traffic capacity	t/ vehicle	
			R-4	Energy consumption of per traffic turnover of commercial vehicles	kl./ ten thousand ton•km	
		Resource Recovery Utilization	R-5	Recovery utilization rate of waste bitumen	%	To measure the reuse and recycle level of the highway infrastructure and conveyance, representing the development direction of resource recycling
			R-6	Recovery utilization rate of waste tyre	%	
	Service Ability System (S)	Transport Service	S-1	Freight volume of per highway mileage	ten thousand ton/km	To measure the level of highway utilization and transport service, representing the development direction of using the resource effectively
			S-2	Passenger volume of per highway mileage	ten thousand ton/km	
		Highway Maintenance	S-3	Proportion of highway maintenance mileage in total mileage	%	To measure the maintenance level of highway, representing the principles of effective utilization and reuse
			S-4	Comprehensive value of highway maintenance quality	—	
	Environmental Protection System (E)	Ecology Impact	E-1	Proportion of highway greening mileage in total mileage	%	To measure the ecology impact of highway construction and the recovery level of vegetation and land, representing the principle of reducing the resource investment
		Pollution Control	E-2	Over standard rate of vehicle exhaust emission	%	To measure the emission level of solid waste, air pollutant and sewage during highway operation, representing the development direction of pollution control level and low emission
			E-3	Pollutant emission of per traffic volume	kg/t	
			E-4	Recovery utilization rate of sewage during highway operation	%	
	Social Participation System (M)	Public Participation	M-1	Cognition rate of highway transport green consumption by the public	%	To measure the attention degree on REDHT by the public
		Industry Management	M-2	Proportion of environmental investment in the total investment for the highway construction projects	%	To measure the support on the recycling economy development by highway construction
Condition Indexes						
Condition Indexes	Artificial Condition		1	Per Capita GDP of the Evaluation Region (RMB/ person)		To measure the regional economic development status and indirectly reflect the support ability of the social and economic resources for REDHT
			2	Population Density (person /km^2)		To measure the population gathering status, reflect the demand of the regional highway infrastructure construction and the harmonious degree among regional highway network, people and economy

4. Evaluation on Recycling Economy Development Level of Highway Transport in China

4.1. Principal Component Analysis

We use the principal component analytical method to calculate the general score of recycling economy development level of highway transport for 31 provinces in China with the support of transport statistical annual data, statistical data of transport environment investment and the regional statistical annual data in 2005. The calculation results can reflect the relative recycling economy development level of highway transport. The general score calculation model for the system or subsystem of REDHT is designed as follow:

$$F = \sum_{i=1}^{m} \omega_i f_i$$

Where fi is the score of a province on No.i principal component and ω_i is the relevant weight.

The general score of recycling economy development level of highway transport is a relative concept and it can use for the comparison among different provinces. The score reflects the relative progress of the REDHT. A province shows high development level with high score and vice versa. The positive score indicates that the relative progress of the REDHT for this province is above the national average (the national average is 0) and the negative score demonstrates the relative progress is under the national average. Conditional indexes are used as the cluster analysis basis for classified discussion. The general principal component score of recycling economy development level of highway transport of 31 provinces in China is illustrated in Figure 1.

As we can see from Figure 1, the general principal component score rises with the increase of regional per capita GDP and population density. The developed areas get higher scores. REDHT in eastern coastal areas is more advanced than that in the western areas. The general principal component score of 16 provinces is above 0, indicating that recycling economy development level of highway transport in these areas is above the national average.

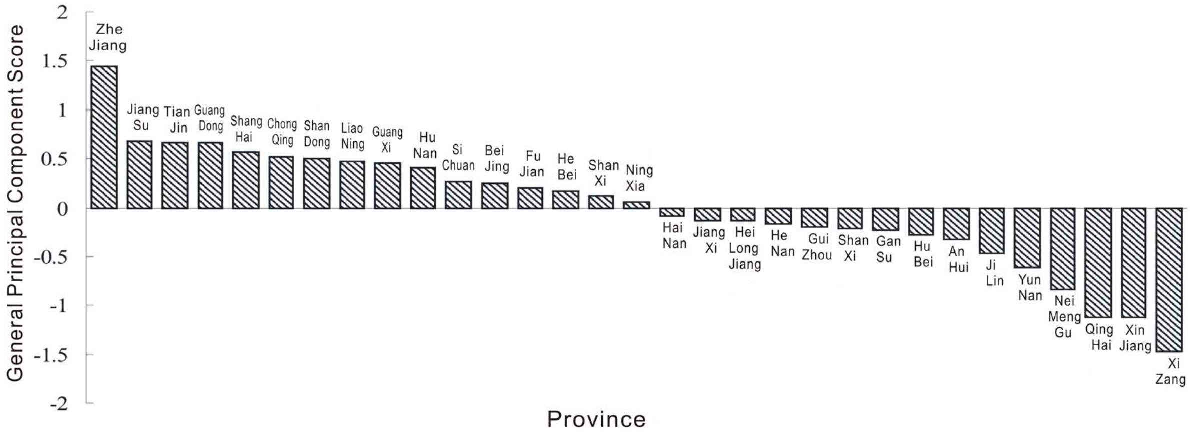
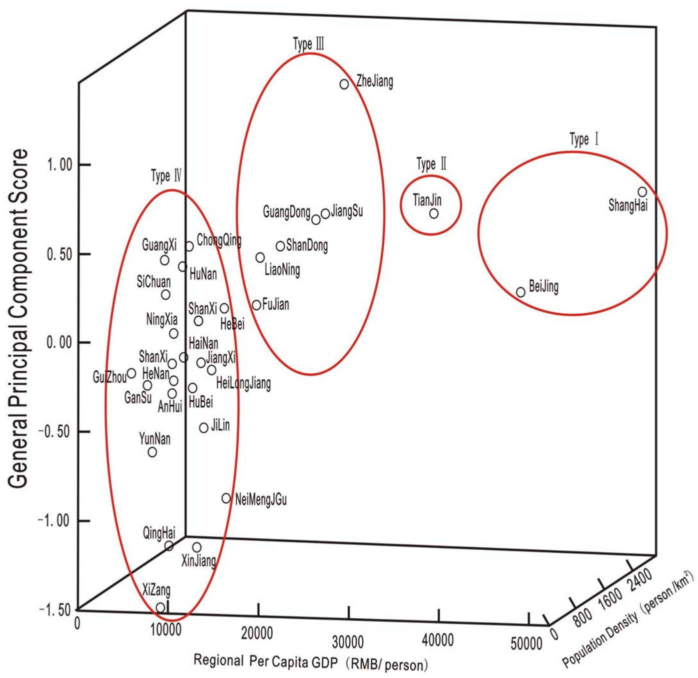


Fig. 1: General Principal Component Score of REDHT's Level of Highway Transport of 31 Provinces in China

4.2. Cluster Analysis

Two artificial condition indexes of regional per capita GDP and population density are used to classify 31 provinces into four groups. The results of cluster analysis are illustrated in Figure 2 and Figure 3.

Fig. 2: 3D Graph of Regional Per Capita GDP, Population Density



and General Principal Component Score of Four Regions

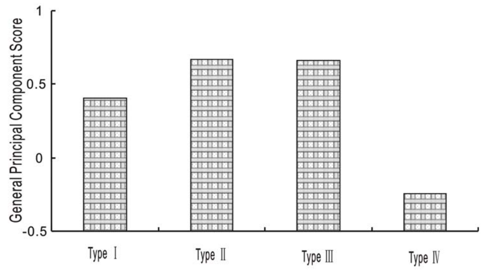


Fig. 3: General Principal Component Average Score of Four Regions

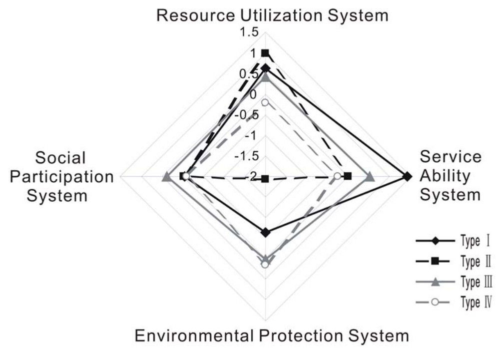


Fig. 4: Radar Chart of Four Evaluation Systems of Four Regions

As can be seen from Figure 1 and Figure 3, the recycling economy development level of highway transport in the type I、type II and type III regions are higher than national average. Some provinces of type IV show higher level than the national average while some provinces have lower score below the national average. The regional per capita GDP of Shanghai and Beijing (Type I) rank first and second, but their general principal component score is lower than that of Tianjin. Six provinces in type III locate in eastern coat and have developed economy. The high per capita GDP can provide a solid economic support for REDHT. The general principal component score of the type III provinces is higher than 0. Among the 22 provinces in type IV, 6 provinces get the general principal component score above 0 while 16 provinces have the score below 0. The per capita GDP of 22 provinces is relative low and the REDHT needs to be improved. It means that the regional per capita GDP is one of the important factors that may affect the REDHT.

4.3. Comprehensive Assessment and Suggestions

A radar chart (Figure 4) is formulated by using the general principal component score of resource utilization system, service ability system, environmental protection system and social participation system of the four regions (Table 2). Comparing the development balance degree of each system of four region, there are significant differences among them:

Table 2. General Principal Component Score of Four Evaluation Systems of Four Regions

Type	Resource Utilization System	Service Ability System	Environmental Protection System	Social Participation System
Type I	0.618	1.415	-0.645	-0.052
Type II	0.976	-0.005	-1.935	-0.038
Type III	0.417	0.506	0.011	0.381
Type IV	-0.214	-0.266	0.144	-0.097

(1) The four systems of type I provinces show imbalanced development. The development level of resource utilization system and service ability system is high while the development level of environmental protection system and social participation system is relative low. These provinces should pay more attention to the improvement of environmental protection and social participation.

(2) The resource utilization system of type II province gets high score while the service ability system, environmental protection system and social participation system get lower scores. Tianjin province should

improve the service ability of highway transport and social participation. It should promote the REDHT by attach more attention to environmental protection.

(3) Four systems of type III provinces show balanced development. These provinces should further consolidate and improve the regional REDHT.

(4) The score of environmental protection system of type IV provinces is above the national average while the scores of resource utilization system, service ability system and social participation system is under the national average. The recycling economy development level of highway transport and the regional per capita GDP are the lowest among the four-type provinces. As the less development provinces in the western areas, these provinces should improve the regional economy development and highway construction to promote the REDHT.

5. Conclusion

(1) Based on the 3R theory of recycling economy as well as the connotation, present situation characteristics of REDHT in China, we select 16 evaluation indexes separating into 4 systems of resource utilization, service ability, environmental protection and social participation and 2 artificial condition indexes to build the EIS and set benchmarking for each evaluation index.

(2) The evaluation results of 31 provinces in China indicate that affected by the impact of regional per capita GDP and population density, the recycling economy development level of highway transport is different. The general principal component scores of 15 provinces are higher than the national average (0) while the other 16 provinces are lower than 0. It is suggested that the 31 provinces should appropriately readjust the current development situation and promote the balanced development of four evaluation systems to enhance the recycling economy development level of highway transport.

(3) The establishment of EIS and benchmarking can be applied as three important tools:

- A descriptive tool: The EIS explains the concept of REDHT into clear indexes and operable content.
- A orientative tool: The EIS and benchmarking can affect the ideas and actions of construction, management, operation and consumption of highway transport industry by multiple policy guidance. Therefore, the EIS and benchmarking can be used as the effective means to supervise the REDHT.
- A performance evaluation tool: The evaluation results can not only assess whether the actions adopted by the highway transport administrative departments in different level and different region are effective, but also build up communication between the highway transport administrative departments and the public.

(4) The evaluation results can objectively reflect the actual situation and propose the operable suggestions for the recycling economy development level of highway transport in China. The EIS is scientific and reasonable, showing the excellent practice value and providing decision basis information and guidance of development trend for the industrial decision-makers and the public.

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