Study on Standard Evaluation System for Environmental protection and Water Conservation of Railway Construction Projects

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Abstract: To conduct systematic evaluation on the whole process of the environmental protection and water conservation for railway construction projects, a scientific, rational and practical evaluation standard index system of environmental protection and water conservation for railway construction projects is established to realize the flexible evaluations of railway construction units in different stages of engineering design, construction and acceptance. By collecting the basic engineering data of relevant projects, the paper introduces the significant environmental impact factors and water and soil conservation measures of railway construction projects. Selection of indices in the evaluation system is determined and completed by analytic hierarchy process and expert consultation. The weight of indices is determined by the comprehensive evaluation index method. The evaluation model is further established and evaluation method determined.

Key words: green railway; environmental protection and water conservation; analytic hierarchy process; comprehensive evaluation index; evaluation system

(This paper is selected from *Chinese Railway*)

1 Introduction

With the high-speed development of railway construction and promotion of ecological and civilization construction in China, studies have been conducted in recent years by many scholars in the light of green-based assessment for railway projects. Yang Qing has introduced the gray system theory into the green railway constructions. Bao Xueying has built the grade-based evaluation system for green railway construction in the light of the northwest cold and dry areas. Ge Kaiguo et al have built the assessment system of environmental protection for the railway construction projects during their construction period by taking the newly-built Lhasa-Linzhi section of the Chengdu-Lhasa Railway as the example. Currently, the research on the green railway evaluation is concentrated on the project construction period and in the light of the integral evaluation of the railway construction projects without focusing the evaluation object on the detailed responsible unit. It is necessary to score all the selected indices and the evaluation system lacks the targeting and flexibility. A set of evaluation systems with operability is still lacking in the face of specific problems for implementing the responsibility in the actual management and statistics cannot be made for part of indices in the evaluation.

A standard evaluation system of environmental protection and water conservation for the railway construction projects targeting the construction unit with flexibly selected indices in different construction stages is built in combination with the characteristics of construction projects in stages and variety of units involved in the construction and the importance being attached to the practicability and operability. This will be supplementary to the environmental protection management system for railway construction projects, thus linking up the environmental protection and water conservation of railway with the responsibility of the construction units and promoting the implementation of measures for environmental protection and water conservation.

2 Building Evaluation Systems for Environmental Protection and Water Conservation

2.1 Building the flow

The building of the flow for evaluation system of environmental protection and water conservation is shown in Fig.1.

2.2 Index selection principles

(1) Principle of all-roundness. From a longitudinal perspective, the railway environmental protection and water conservation covers the whole process of engineering and construction from railway location and alignment section, design and construction for which the concepts of environmental protection and water conservation should all be taken into account. From a transversal perspective, all the environmental protection and water conservation should be ensured to strictly abide by and implement the relevant laws and regulations and make clear the management contents and targets

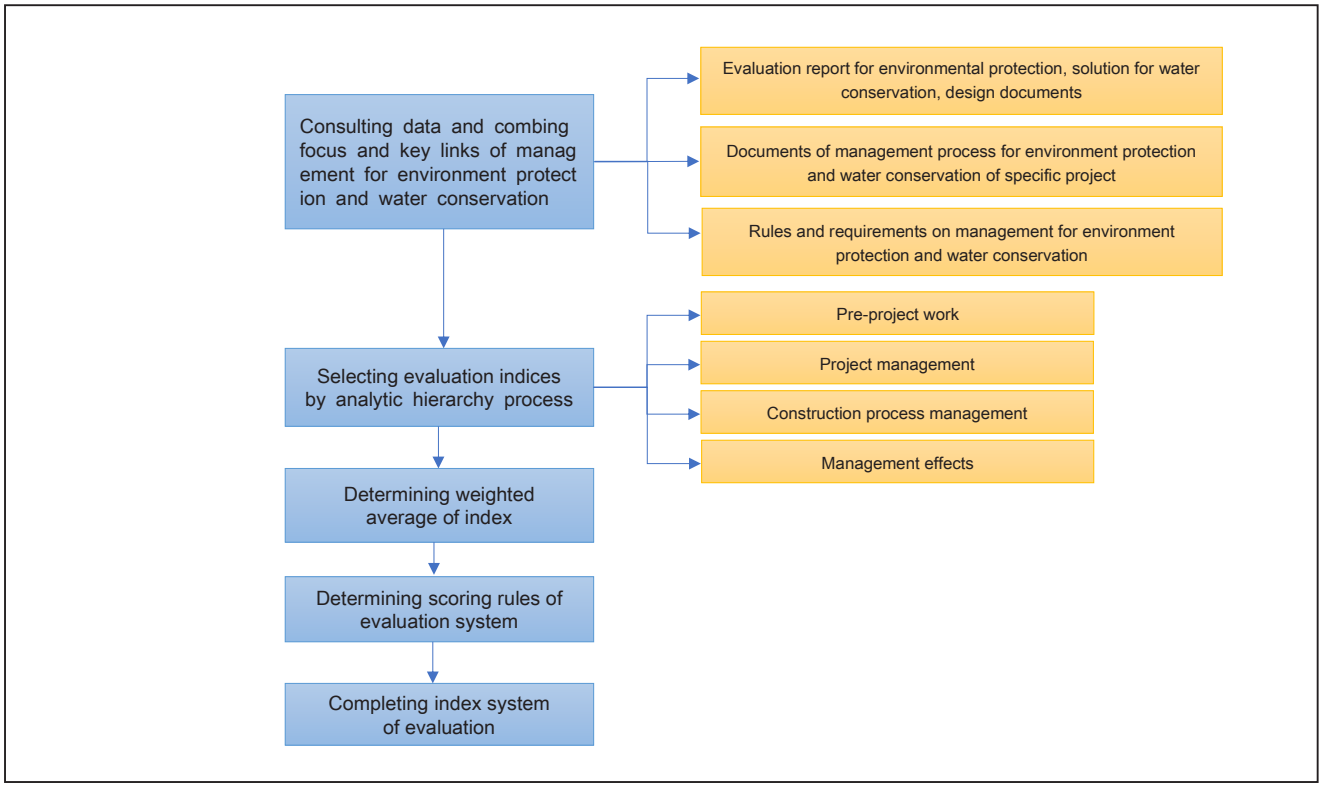

Fig.1 Building the flow for evaluation system of environmental protection and water conservation

based on the contents of environmental protection and water conservation for each stage. The index system built must be able to reflect the evaluation target or the key elements of the previous hierarchy in an all-round way and with no omission and fully reflect the completeness and comprehensiveness of the evaluation contents.

(2) Principle of science. The index selection should fully reflect the scientific connotation and aims of environmental protection and water conservation for railway construction projects, have scientific bases and sources so as to have clear targets, definite concepts and accurate definitions, for which there should be internal linkages but with no repetition among the indices.

(3) Principle of comparability. The evaluation indices must reflect the common attributes of the evaluation object and the common things of the evaluation object attributes.

(4) Principle of independence. The indices of the same hierarchy in the index system must be independent from each other with no mutual overlapping and inclusion, no existence of causality and no derivation from one index to the other.

(5) Principle of operability. Indices need to be selected that will be easy to observe and acquire based on the current supervision means and technical levels for environmental protection and water conservation. More direct indices and few indirect ones, and more quantitative indices and few qualitative ones should be adopted to ensure the accuracy and practicality of each index data and give priority to the principle of practicality in project evaluation and social services.

2.3 Analytic hierarchy process

The Analytic Hierarchy Process (AHP) refers in essence to a method of decision-making for conducting the qualitative and quantitative analyses on the basis of resolving the relevant elements of the decision-making issues into the hierarchies of target, norm and solution. AHP generally divides the decision-making issues into three hierarchies and makes the division of them into four hierarchies for studies in view of the complexity of the railway construction projects:

(1) Target hierarchy. The target hierarchy indicates the aims of problem solution with the evaluation of environmental protection and water conservation for railway construction projects as the overall target.

(2) Norm hierarchy. The norm hierarchy is the grade 1 indices of assessment and the evaluation system is the one for evaluation of whole process for railway construction projects. The grade 1 indices are therefore divided into four norm hierarchies for pre-project work, project management, construction process management and management effects based on the stages of the whole process for environmental protection and water conservation management.

(3) Sub-norm hierarchy. The sub-norm hierarchy is the grade 2 indices of assessment and the corresponding indices of different sub-norm hierarchies, with which selections are made based on the analyses on the indices of different sub-norm hierarchies in combination with the *Handbook of Engineering and Technological Management of Environmental Protection and Water Conservation for High-speed Railways*, the acceptance report of environmental protection, the acceptance report of water conservation as well as the situations of construction sites.

(4) Concrete index hierarchy. The concrete index hierarchy is the grade 3 indices of assessment and the corresponding indices of different sub-norm hierarchies, which are the indices of concrete scoring when conducting an actual evaluation, laying emphasis on the operability of indices and adopting the direct indices as far as possible.

2.4 Evaluation indices

A total of four grade 1 assessment indices (norm hierarchy), thirteen grade 2 assessment indices (sub-norm hierarchy) and forty-three grade 3 indices (concrete index hierarchy) are selected from the evaluation indices of evaluation system for environmental protection and water conservation by way of analytic hierarchy process based on the index selection principles. The concrete indices are shown in Table 1.

2.5 Computing of weights for norm hierarchy and sub-norm hierarchy

2.5.1 Computing method

(1) Building judgment matrix. Uniform matrix method is adopted when determining the weight between different factors C for different hierarchies to make a comparison between two factors. The scale methods for judgment matrix element a_{ij} are shown in Table 2.

Judgment matrix is to be formed from discussions by expert team and comparisons between two factors are conducted for different element hierarchies and index hierarchies by experts. If there are n numbers of essential factors or indices to be involved in the comparisons, the matrix built will be n order matrix, for which the results can be as follows:

$$A=(a_{ij})_{n\times m}=\begin{pmatrix} \frac{C_1}{C_1} & \frac{C_1}{C_2} & \cdots & \frac{C_1}{C_n} \\ \frac{C_2}{C_1} & \frac{C_2}{C_2} & \cdots & \frac{C_2}{C_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{C_n}{C_1} & \frac{C_n}{C_2} & \cdots & \frac{C_n}{C_n} \end{pmatrix}$$

Making i indicate line and j indicate column, and letting $J_{ij}=C_i/C_j$, the above-mentioned judgment matrix of comparison can be summarized as possessing the following natures:

$$\begin{cases} J_{ij}=1 \quad , \text{ when } i=j \\ J_{ij}=1/J_{ji}, \text{ when } i\neq j \\ J_{ij}>0 \quad , \quad i、j=1、2、3...n \end{cases}$$

(2) Computing the relative weighted averages of different essential factors or indices. The relative weighted averages of different factors can be computed by solving the eigen-vector and normalization of judgment matrix. Among them, the feature vector can be computed by adopting the methods such as the eigen-vector method, the least squares right method, the power method (eigen-vector method), and method and square root method, and normalization is conducted by adopting square root method in the evaluation system of environmental protection and water conservation.

Table 1 Standard evaluation system indices of environmental protection and water conservation for railway construction projects

Target hierarchy	Norm hierarchy indices	Sub-norm hierarchy indices	Concrete indices	Index category
Evaluation standard system for environmental protection and water conservation of railway construction projects	Pre-project work	Evaluation for environmental protection and water conservation	Rationality of suggestions for measures of environmental protection evaluation report	Accumulation
			Rationality of suggestions for measures of water conservation solution	Accumulation
			Quality of compilation of environmental protection evaluation report and water conservation solution documents	Accumulation
		Compliance with ecological protection red line and relevant planning	Compliance with ecological protection red line	Restriction
			Compliance with planning	Restriction
		Compliance with regulations for protective measures of ecological sensitive areas	Design scheme comparison	Restriction
		Major changes management	Examining and checking management for major changes of environmental protection and water conservation evaluation	Restriction
			Handling of formalities for major changes of environmental protection and water conservation evaluation	Restriction
	Project management	Organizational structure and system building	Improvement of organizational structure for environmental protection and water conservation management	Restriction
			Defining job responsibilities for environmental protection and water conservation management	Restriction
			Building of management system for environmental protection and water conservation	Accumulation
			Operability of management system for environmental protection and water conservation	Accumulation
		Human resources allocation	Percentage of specialization for management personnel of environmental protection and water conservation	Accumulation
			Percentage of reaching set standards of assessment for management personnel of environmental protection and water conservation	Accumulation
		Professional resources	Professional management for environmental protection and water conservation	Accumulation
	Construction process management	Solution and file management	Construction drawing examination	Accumulation
			Project data management	Restriction
			Project process files	Restriction
			Day-to-day inspection frequency for environmental protection and water conservation	Restriction
			Day-to-day inspection records for environmental protection and water conservation	Accumulation
			Supervision records of environmental protection and water conservation	Accumulation
			Special training for environmental protection and water conservation	Accumulation
		IT-based and intelligent management	Rate of completeness for data uploading	Accumulation
			Rate of timely data uploading	Accumulation
			Quality of data filling and submission	Accumulation
			Flow response	Accumulation
			Environmental online supervision equipment	Accumulation
			Water and soil erosion online supervision equipment	Accumulation
			Groundwater environmental monitoring	Accumulation
			Remote-sensing monitoring of ecological environment	Accumulation
			Intelligent monitoring of spoil grounds	Accumulation

Target hierarchy	Norm hierarchy indices	Sub-norm hierarchy indices	Concrete indices	Index category
Evaluation standard system for environmental protection and water conservation of railway construction projects	Construction process management	Acceptance management	Acceptance plan	Restriction
			Acceptance progress	Accumulation
		Implementing "three-simultaneous" measures	Compliance of design with measures of environmental protection	Restriction
			Quality assurance for implementing progress of environmental protection measures	Restriction
			Evaluation of special measures for ecological protection	Restriction
			Implementation of special measures for ecological protection	Restriction
	Management effects	Green construction indices	Total land areas of permanent occupation for engineering	Restriction
		Accidents and complaints	Accidents of ecological destruction	Restriction
			Incidents of poaching, catching and killing wildlife	Restriction
			Incidents of destroying ancient and famous trees, and cultural relics and historic sites	Restriction
			No accidents concerning environmental pollution	Restriction
			No complaints concerning environmental pollution	Restriction

(3) Consistency inspection.

First, compatibility index $CI=\frac{\lambda_{\max}-n}{n-1}$ is computed, among which the largest eigen value $\lambda_{\max}=\sum_{i=1}^{n}\frac{[AW]_i}{W_i}$, $[AW]i$ is the ith component. Consistency ratio $CR=\frac{CI}{RI}$ is then computed and RI is the average random consistency index which is the mean value of consistency index computed based on the enough numbers of random sample matrix (refer to Table 3).

If consistency index CR＜0.10, it is thought that different parameters in the matrix possess satisfactory consistency and the weight vector W can be accepted. Otherwise the computing results will be ineffective and need to make the judgment again.

2.5.2 Computing results

Taking only the norm hierarchy as the example to conduct computation of weight and the computation for sub-norm hierarchy will be conducted by referring to the same method. The judgment matrix of norm hierarchy weight, the weight and the consistency inspection are shown in Table 4 and the computing results of weight are shown in Table 5.

Table 2 Scale methods for judgment matrix element a_{ij}

Scale	Meaning
1	Indicating comparison between two factors with the same importance
3	Indicating comparison between two factors with one factor being slightly more important than the other
5	Indicating comparison between two factors with one factor being obviously more important than the other
7	Indicating comparison between two factors with one factor being strongly important than the other
9	Indicating comparison between two factors with one factor being extremely important than the other
2, 4, 6, 8	Median of above-mentioned two adjacent judgment
Reciprocal	Judgment a_{ij} of comparison between factors i and j, thus judgment $a_{ji}=1/a_{ij}$ of comparison between factors j and I

Table 3 Average random consistency indices *RI*

Order numbers n	RI	Order numbers n	RI	Order numbers n	RI
1	0	4	0.90	7	1.32
2	0	5	1.12	8	1.41
3	0.58	6	1.24	9	1.45

3 Scoring Rules for Evaluation System of Environmental Protection and Water Conservation

Evaluation system for environmental protection and water conservation is an all-round standard evaluation index system for the construction units, aiming at the full-cycle and all work of environmental protection and water conservation for the railway construction projects. Taking account of the characteristics of railway construction

Table 4 Judgment matrix computing for norm hierarchy

Indices	Preliminary work	Project management	Construction process management	Management effects	Weight	Consistency inspection
Preliminary work	1	7	7/5	7/3	0.437 2	CR=0.0012<0.1 Acceptable
Project management	1/7	1	1/5	1/3	0.062 5	
Construction process management	5/7	5	1	5/3	0.312 3	
Management effects	3/7	3	3/5	1	0.188 0	

Table 5 Computing results of weight

Target hierarchy	Norm hierarchy indices	Weight of norm-hierarchy	Sub-norm hierarchy indices	Weight of sub-norm hierarchy
Evaluation standard system for environmental protection and water conservation of railway construction projects	Pre-project work	0.437 2	Environmental protection and water conservation evaluation	0.187 5
			Compliance with ecological protection red line and relevant planning	0.437 5
			Compliance with regulations for protective measures of ecological sensitive areas	0.312 5
			Management of major changes	0.062 5
	Project management	0.062 5	Organization structure and system construction	0.600 0
			Human resource allocation	0.200 0
			Professional resources	0.200 0
	Construction process management	0.312 3	Solution and file management	0.312 5
			IT-based and intelligent management	0.187 5
			Acceptance management	0.062 5
			Implementing “three-simultaneous” measures	0.437 5
	Management effects	0.188 0	Green construction indices	0.166 7
			Accidents and complains	0.833 3

projects and the operability of practical use, emphasis should be laid on the flexibility of environmental protection and water conservation for the railway construction projects, for instance making scoring by aiming only at a certain stage or making scoring by aiming only at the indices that can be checked at the site. It means that the scoring rules should be required to adapt to different conditions and still be able to compute the relatively scientific and objective scoring in the condition of making free selection of concrete indices based on the evaluation aims. Preconditions and principles for using the evaluation system of environmental protection and water conservation are therefore worked out as follows:

Making meanly distributed weights of concrete indices for each sub-norm hierarchy. As the indices of the concrete index hierarchy are freely selected each time based on the evaluation aims and on-site conditions in the process of practical use, the selected indices and their numbers will be uncertain and are stipulated for the meanly distributed weights of concrete indices under each sub-norm hierarchy. Indices are selected by adopting Analytic Hierarchy Process with an addition of the sub-norm hierarchy on the basis of the three hierarchies including the general target hierarchy, norm hierarchy and index hierarchy with the consideration of the complexity for the work of environmental protection and water conservation. There are therefore not many differences for the importance between different indices with respect to the indices of the concrete index hierarchy and the rules for the meanly distributed weights of the concrete indices under each sub-norm hierarchy are relatively rational.

If the indices of certain norm hierarchy are not included in the scoring, the indices of that norm hierarchy will take the mean score of the remaining norm hierarchies with the same prin-

ciple for the sub-norm hierarchy. It is stipulated for the evaluation protection and water conservation that full scores for each sub-norm hierarchy and norm hierarchy are all 100 points and the scores of the previous hierarchy will be computed based on the weights (i.e. making each sub-norm hierarchy be multiplied with the weight to acquire the score of the norm hierarchy to which the sub-norm hierarchy belongs, and so on). If certain scoring is to be conducted for certain non-selected index or indices on the norm hierarchy, it is stipulated that the scores for the indices of the norm hierarchy not included in the scoring will be equal to the mean score of the rest norm hierarchies.

Concrete indices are classified into indices of restriction and indices of accumulation. The index of restriction, in case of failing to conform with the requirements, will be scored directly at 0 point. The index of accumulation refers to the deduction of certain marks for each time or place appearance of non-conformity to the stipulation. As the numbers and the top limit of score for the concrete index are not certain, only the deduction percentages for each time or place will be stipulated in the scoring rules.

4 Authentic Proof Analyses

4.1 Project descriptions

A certain railway construction project is located in the area of eastern China, for which the length of the main line for the track is approximately 220 km, the target of design speed is 350 km/h and 72 bridges/95.44 km are to be provided for the main line accounting for 42.5% of the length for the main line. The main line is to be provided with 54 tunnel/98.743 km accounting for 44.0% of the length for the main line with the provision of 9 stations in total, one newly-built post for EMU operation and one EMU storage yard. The project is now under construction. The scoring for the on-site investigation indicates that the work of environmental protection and water conservation for the project acquires 96.9 points for the evaluation.

4.2 Evaluation analysis

According to the computing results of the weight, the weight for the pre-project work is 0.4372, that for the project management is 0.0625, that for the construction process management is 0.3123 and that for the management effects is 0.1880. As far as the magnitude of weight is concerned, the pre-project work takes the highest percentage of weight and the project management takes the lowest percentage of weight. It means that the emphases of the work for the construction units lie in the control of the alignment for environmental protection in the preliminary stage of the project, the passing of the examination and approval of the pre-project work for environmental protection and water conservation, the determination of the concrete and practical measures for environmental protection and water conservation, and the fundamental reduction of implications on environment to be caused by the project.

The main areas of scoring reduction for the project of the example lie in the unsatisfactory filling and submission of the IT-based data owing to the fact that the relevant work of the IT-based system for environmental protection and water conservation is still in the stage of deployment; the training for environmental protection and water conservation in the processes of day-to-day management and construction management is not improved enough; and there are slight deficiencies in adopting the ways of supervision for engineering and water conservation and in the aspect of specialization. More efforts should be exerted to strictly implement the relevant management stipulations for environmental protection and water conservation, enhance the training on environmental protection and water conservation, and attach more importance to the information technology in the future management process.

In addition, the project is still under construction with the relevant scoring for acceptance being not included in the current scoring, and the indices for project management, construction process management and management effects will have changes with the progress of project construction based on the actual conditions of management. The scoring results can be taken as the dynamic indices for reflecting the actual management level in environmental protection and water conservation.

5 Conclusion

The general targets of evaluation will be classified downward into a number of different components based on logic by means of data gathering and analytic hierarchy process. Emphases and key links of environmental protection and water conservation management for the full process and different stages of the railway construction projects are combined to select the main evaluation indices in the stages of design, construction and acceptance. Supplements will then be made to the evaluation indices based on the work contents, management responsibility and special emphasis of the work so as to set up the evaluation index system and conduct the computation of weights respectively. To satisfy the operability of the evaluation system for environmental protection and water conservation, prerequisites for use and scoring rules will be formulated to ensure that the said evaluation system can make the scoring for the arbitrarily selected indices based on the evaluation aims and in different specific conditions, taking account of both science and practicality. The building of an evaluation system for environmental protection and water conservation will be more important than the selection of evaluation indices and the determination of weights. As for the insufficiencies in researches on the standardization of concrete index hierarchy and the standardization of qualitative indices, further improvements remain to be made in the future researches.

(Translated by Zheng Mingda)

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