Comprehensive Evaluation of Social Benefits of Power Transmission and Transformation Projects Based on Entropy Method Optimization

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Abstract. Power transmission and transformation projects, as Infrastructure construction projects, the scientific nature of their investments and the significance of investment benefits have been paid more and more attention to. At present, there are relatively few researches on social benefits evaluation index system of power transmission and transformation projects, and there is a lack of practical application of evaluating methods. With the goal of scientifically evaluating the social benefits of power transmission and transformation project, this paper extracts the social benefit evaluation indicators in the relevant domestic and foreign literature research, innovatively adopts the Entropy Method, and quantifies the relative importance of the indicators. After that, screens the original indicators and constructs the framework of conventional indexes and special indexes, then comprehensively forms a targeted evaluation index system. On this basis, uses Analytic Hierarchy Process to do the weight calculating and testing, and uses Fuzzy Comprehensive Evaluation Method to comprehensively analyze and evaluate the social benefits of power transmission and transformation projects. Then taking four large-scale power transmission and transformation projects in Henan as examples to comprehensively evaluate their social benefits, verify the feasibility and effectiveness of the method, and clarify the positive social benefits of power transmission and transformation projects.

Key words: Major Power Transmission and Transformation Projects; Social Benefits; Entropy Method; Analytic Hierarchy Process; Fuzzy Comprehensive Evaluation.

1. Introduction

In recent years, power grid has developed rapidly in China. As basic construction projects, power transmission and transformation projects have attracted much attention for the scientific nature and significant benefits of their investments. The impact of power transmission and transformation engineering construction projects involves multiple levels and dimensions. Therefore, in the comprehensive analysis and evaluation of their benefits, social impact should be the focal point to ensure that those projects can develop in harmony with the local society, economy, and environment. That is why it has important theoretical and practical significance to carry out research on the social benefit evaluation system of power transmission and transformation projects at this stage.

At present, domestic and foreign scholars have done a large number of research on economic benefits of engineering projects, but a relatively complete comprehensive analysis and evaluation system for the social benefits of engineering has not yet been proposed, and there is a lack of practical applications of those various methods and theories. The World Bank's Social Analysis Model Handbook: Social Analysis Selected Tools and Techniques [1] published in 2002 pointed out that social analysis of various investment projects should be from multiple perspectives, focusing on the behavioral characteristics of different genders, different organizations, and different roles in society. The Asian Development Bank released the latest version of the Handbook on Social Analysis: A Working Document in 2007 [2], pointed out that social analysis should include surveys, research and comprehensive analysis of project participants, as well as the analysis of social development and safety, the analysis of people of different genders, and the management of different types of social risks. Xu Wen [3] used the analytic hierarchy process to evaluate the social benefits of public projects and unified the evaluation standards of multilevel public satisfaction. Chen Hanyu [4] started with the two dimensions of "Construction Timing" and "Investment Completion" of power transmission and transformation projects, constructed investment planning decision-making models, and evaluate the scientific and rationality of investment decisions for power transmission and transformation projects.

Based on the subjective evaluation method of AHP -Fuzzy Comprehensive Evaluation proposed by most relevant researches, this paper proposes a comprehensive evaluation model that combines subjective and objective methods, the AHP -Fuzzy Comprehensive Evaluation Method optimized by Entropy Method. This model analyzes the characteristics of power transmission and transformation projects at first, extract conventional evaluation indexes suitable for evaluating the social benefits of the projects, and special evaluation indexes that combine the construction and operation characteristics of power transmission and transformation projects separately, and then, screen the indexes to construct an objective and complete evaluation index system. Next, according to the importance and influence of each level index on the upper level index, using AHP to calculate the proportion of the index and assign the weight to the index. Finally, the Fuzzy Comprehensive Evaluation Method is used to evaluate the comprehensive social benefits of power transmission and transformation projects, and the evaluation conclusion is drawn.

2. Construction of Evaluation Index System Based on Entropy Method

In the evaluation of social benefits, the selection of judgment indexes is a key link. The index weight and the importance of the index are positively correlated. The larger the index weight, the higher the index importance. Conversely, the smaller the index weight, the lower the index importance. And most of the social benefit evaluation indexes of power transmission and transformation projects are difficult to quantify. Therefore, this article chooses the Entropy Method that can objectively measure the importance of qualitative indicators, and filters the evaluation indexes by calculating their relative importance in the overall system.

2.1 Screening of Conventional Indexes for Social Benefit Evaluation of Transmission and Distribution Projects

Generally, the evaluation of social benefits of construction projects should be analyzed from the perspective of social development, considering the impact of projects construction on the society, on economy, and on natural ecological resources [5].

This study selected representative research literature [1-2, 5-8] from many domestic and foreign social impact evaluation research results, and adopted the method of bibliometrics to aggregate the social benefit evaluation indicators proposed, analyze and get the complete set of original indexes.

First, process the raw data. Further sorted and summarized the original index set, and the original conventional index framework system table for the social benefit evaluation of power transmission and transformation projects was obtained.

And then, Construct the judgment matrix. Based on the original conventional index system obtained by literature review and analysis, use the expert scoring method to score each index to obtain the initial judgment matrix of conventional indexes of social benefits. Normalize the original matrix and construct the normalized index matrix Y_{ij}, calculate the entropy weight W_i of each index, and the information entropy E_i of each index, according to the information entropy calculation formula:

$$E_i = -k\sum_{j=1}^{n} p_{ij} \times \ln p_{ij}$$

Tab. 1 Original Conventional Indexes for Social Benefit Evaluation of Power Transmission and Transformation Projects

First Level Index	Second Level Index	Third Level Index
Social Development (A_1)	Sustainable Social Development (B_1)	New Technology Development and Application (C_1)
	Improvement of Social Living Standards (B_2)	Regional Traffic Improvement (C_2)
		Income Distribution (C_3)
		Employment (C_4)
		Number of People Out of Poverty (C_5)
		Impact on Social Stability (C_6)
		Urbanization (C_7)
		Innovation of People's Ideological Concept (C_8)
Economic Development (A_2)	National Economic Development (B_3)	Economic Net Present Value of the Project(ENPV) (C_9)
		Tax Benefits (C_{10})
	Regional Economic Development (B_4)	Regional Output Value Per Capita (C_{11})
		Local Fiscal Revenue (C_{12})
		Resident Disposable Income (C_{13})
		Land Appreciation (C_{14})
	Optimal Allocation of Resources (B_5)	Capacity Output (C_{15})
Environmental Development (A_3)	Ecological Cost (B_6)	Cost of Water Resources (C_{16})
		Cost of Atmospheric Resources (C_{17})
		Cost of Land Resources (C_{18})
		Natural Landscape Management Costs(C_{19})
		Investment in Environmental Protection(C_{20})
		Comprehensive Ecological Improvement Costs(C_{21})
	Resource and Environmental Cost (B_8)	Cost of Construction Materials (C_{22})

Calculate the difference coefficient D_{ij} of each index and the entropy weight W_i of index i, which is the impact of the index on the whole system. Sort the factors according to their influence degree, remove the factors that have no significant impact on the overall goal, and then, using the remaining indicators to form the evaluation index framework of the overall goal, and the conventional index screening is completed.

2.2 Screening of Special Indexes for Social Benefit Evaluation of Transmission and Transformation Projects

Most power transmission and transformation projects are complicated systematic projects, and their social benefits are highly comprehensive, including the economic benefits of promoting rapid economic growth and elevating resource value, the social benefits of improving regional quality of life and driving employment, as well as the environmental benefits of energy conservation, consumption reduction and pollution reduction. Consult literature related to power transmission and transformation projects, we can collect and summarize relevant indicators, and obtain the screened original special index set.

Similarly, use entropy weight method to select the significantly important indexes for the social benefit evaluation of power transmission and transformation projects. On this basis, the social benefit evaluation index system of power transmission and transformation projects is constructed.

Tab. 2 Original Special Indexes for Social Benefit Evaluation of Power Transmission and Transformation Projects

First Level Index	Second Level Index	Third Level Index
Social Development (A_1)	Improvement of Domestic Life (B_1)	Growth of Household Electrical Appliances (C_1)
		Growth of Power Distribution Capacity (C_2)
		Reduction of Power Limitation Duration (C_3)
	Improvement of Social Life (B_2)	Increase in New Energy Transportation (C_4)
		Increase in Medical Power Consumption (C_5)
		Reduction in Benchmark Price Rise (C_6)
	Sustainable Development (B_3)	Sustained Benefits of System Safety (C_7)
Economic Development (A_2)	Efficiency Improvement of Power Grid System (B_4)	Improvement of Power Quality (C_8)
		Improvement of Power Utilization Efficiency (C_9)
	Impact on Optimal Allocation of Resources (B_5)	Decrease in Standby Investment (C_{10})
		Energy Transport Pressure (C_{11})
Environmental Development (A_3)	Environmental Effect on Noise (B_6)	Cost of Noise Pollution Control (C_{12})
		Mechanical Noise Pollution (C_{13})
	Effect on Power Structure (B_7)	Fossil Energy Consumption (C_{14})

3. AHP-Fuzzy Comprehensive Evaluation Model

3.1 AHP-based index weight calculation

Invite experts in the fields of electric power construction, economics, and sociology to score the importance of each level indexes relative to the previous level indexes in the established index system, and construct the corresponding judgment matrix A.

$$A = (a_{ij})_{n\times n} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} = \begin{pmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & 1 & \cdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{pmatrix}$$

Calculate the maximum eigenvalue λ of the judgment matrix, and the weighted vector in each hierarchy, and then, check the consistency of the judgment matrix.

Normalize the column vector of judgment matrix A, then sum and normalize the results again to obtain the weight matrix and maximum eigenvalue of indexes at all levels for the overall objective.

Solve the weight vector to the whole ranking and check its consistency, when the consistency index $CR^k<0.1$, it can be considered that the consistency of the evaluation model at layer k passes the test. Thus the index weight of each level can be obtained.

3.2 Fuzzy comprehensive evaluation of social benefits of power transmission and transformation projects

Based on the fuzzy set theory, the power transmission and transformation project to be evaluated is evaluated by single factor first, then the final evaluation result is calculated by comprehensively considering the weight distribution of each single factor relative to the whole.

In this process, the comprehensive evaluation indexes of social benefits of power transmission and transformation projects is divided into three levels. It is determined that the evaluation set of factor sets at all levels in the index system is V = [very good, good, general, poor, very poor], and the measurement scale vector is H = [5, 4, 3, 2, 1], so as to obtain the evaluation set of factors at all levels.

Construct the evaluation matrix at all levels and calculate the evaluation vectors. Experts from power supply companies, government departments, enterprises and institutions are invited to fill in the questionnaire to evaluate and score the performance of power transmission and transformation projects at all levels. Based on the statistics and arrangement of the survey results, the single factor evaluation is carried out for each element of the three levels from the third level, and the single factor fuzzy evaluation matrix R is obtained. Then the corresponding comprehensive evaluation vector B can be obtained from the weight of indexes with the formula:

$$B=W^T \cdot R$$

Where W is the weight of each index.

Thus the evaluation results of each evaluation index can be obtained. According to the Maximum Subordination Principle, for the evaluation results of the indexes, among the five levels of subordinate degree, evaluation result with the largest value is regarded as the experts recognized evaluation of the social benefits of power transmission and transformation projects.

4. Model Application Analysis

In this paper, the survey results of four power transmission and transformation projects of 500 kV and above in Henan province are taken as the original data to verify the above methods and evaluation system.

4.1 Index screening

20 experts in the field of power engineering construction and social economy were invited to score the 22 original indexes of the four power transmission and transformation projects, thus the statistical table of the scores of conventional indexes for social benefit evaluation was obtained. And then, the information entropy and entropy weight corresponding to each index are calculated by normalization.

Tab. 4 Calculation Results of Entropy Weights of Conventional Indexes for Social Benefit Evaluation of Transmission and Distribution Projects

	E_i	D_i	W_i
C_1	0.9992	0.0008	0.0059
C_2	0.9945	0.0055	0.0416
C_3	0.9992	0.0008	0.0062
C_4	0.9947	0.0053	0.0402
C_5	0.9988	0.0012	0.0088
C_6	0.9991	0.0009	0.0071
C_7	0.9974	0.0026	0.0199
C_8	0.9989	0.0011	0.0084
C_9	0.9943	0.0057	0.0428
C_{10}	0.9953	0.0047	0.0354
C_{11}	0.9982	0.0018	0.0138
C_{12}	0.9962	0.0038	0.0285
C_{13}	0.9996	0.0004	0.0030
C_{14}	0.9988	0.0012	0.0093
C_{15}	0.9983	0.0017	0.0125
C_{16}	0.9761	0.0239	0.1809
C_{17}	0.9860	0.0140	0.1056
C_{18}	0.9914	0.0086	0.0652
C_{19}	0.9989	0.0011	0.0081
C_{20}	0.9876	0.0124	0.0941
C_{21}	0.9712	0.0288	0.2182
C_{22}	0.9941	0.0059	0.0445

According to the calculation results, the 14 indexes with weights greater than 0.01 are of significant importance, so the 14 indexes are selected as the conventional indexes for the evaluation of social benefits of power transmission and transformation projects.

The next step is the screening of special indexes. Invited experts to score the influence of special indexes of the four projects, and the initial score matrix was obtained. Then calculate the entropy weights of these special indexes. According to the calculation results, 12 indexes with weights greater than 0.01, which are of significant importance, are selected as special indexes for the evaluation of social benefits of power transmission and transformation projects.

Based on the conventional and special indexes screened by entropy weight method, and classified and summarized according to the second and third level indexes, the social benefit evaluation index system of power transmission and transformation projects is formed.

Tab. 5 Social Benefit Evaluation Index System of Power Transmission and Transformation Projects

First Level Index	Second Level Index	Third Level Index
Social Development (A_1)	Improvement of People's Living Standards (B_1)	Growth of Household Electrical Appliances (C_1)
		Growth of Power Distribution Capacity (C_2)
		Reduction of Power Limitation Duration (C_3)
	Improvement of Social Living Standards (B_2)	Employment (C_4)
		Urbanization (C_5)
		Increase in New Energy Transportation (C_6)
		Reduction in Benchmark Price Rise (C_7)
	Sustainable Social Development (B_3)	New Technology Development and Application (C_8)
		Sustained Benefits of System Safety (C_9)
Economic Development (A_2)	Efficiency Improvement of Power Grid System (B_4)	Improvement of Power Quality (C_{10})
		Improvement of Power Utilization Efficiency (C_{11})
	National Economic Development (B_5)	Economic Net Present Value of the Project (ENPV)(C_{12})
		Tax Benefits (C_{13})
	Regional Economic Development (B_6)	Local Fiscal Revenue (C_{14})
		Regional Output Value Per Capita (C_{15})
	Optimal Allocation of Resources (B_7)	Capacity Outpu (C_{16})
		Decrease in Standby Investment (C_{17})
		Energy Transport Pressure (C_{18})
Environmental Development (A_3)	Ecological Cost (B_8)	Cost of Water Resources (C_{19})
		Cost of Atmospheric Resources (C_{20})
		Cost of Land Resources (C_{21})
	Living Environmental Cost (B_9)	Investment in Environmental Protection (C_{22})
		Comprehensive Ecological Improvement Costs (C_{23})
		Cost of Noise Pollution Control (C_{24})
	Resource and Environmental Cost (B_{10})	Fossil Energy Consumption (C_{25})
		Cost of Construction Materials (C_{26})

4.2 Index weight calculation

Invited 20 experts in the fields of electric power construction, economy and sociology again to score the relative importance of first level indexes, and the judgment matrix of the relative importance of first level indexes to the whole, second level indexes to first level indexes, and third level indexes to second level indexes was obtained. After that, used AHP to calculate the weights of first level indexes, and tested the consistency of the calculation results.

Tab. 6 First Level Index Weights and Consistency Test Results

	A_1	A_2	A_3	W	λ	CI	RI	CR
A_1	1	1/5	1/2	0.118				
A_2	5	1	4	0.681	3	0.012	0.58	0.021
A_3	2	1/4	1	0.201				

The weight of the first level indexes in the overall evaluation index system is as follow.

$$W=[0.118\quad 0.681\quad 0.201]^T$$

The corresponding weight values of the second and third level evaluation indexes can also be obtained by the same way, and then the consistency test of hierarchical total ranking is carried out. According to the calculation, $CR^{(A\text{-}B)}$, $CR^{(B\text{-}C)}$ are both less than 0.1, so the overall ranking consistency of all levels meets the requirements.

The weights of all indexes are shown in the table below.

Tab. 7 Overall Index Weights

First Level Index	Index Weight	Second Level Index	Index Weight	Third Level Index	Index Weight
A_1	0.118	B_1	0.0443	C_1	0.0256
				C_2	0.0083
				C_3	0.0104
		B_2	0.0443	C_4	0.0281
				C_5	0.0098
				C_6	0.0033
				C_7	0.0029
		B_3	0.0148	C_8	0.0098
				C_9	0.0049
A_2	0.681	B_4	0.0148	C_{10}	0.0111
				C_{11}	0.0037
		B_5	0.3997	C_{12}	0.2998
				C_{13}	0.0999
		B_6	0.2206	C_{14}	0.1472
				C_{15}	0.0735
		B_7	0.0606	C_{16}	0.0249
				C_{17}	0.0158
				C_{18}	0.0199
A_3	0.201	B_8	0.0211	C_{19}	0.0127
				C_{20}	0.0063
				C_{21}	0.0021
		B_9	0.1280	C_{22}	0.0944
				C_{23}	0.0238
				C_{24}	0.0099
		B_{10}	0.0519	C_{25}	0.0173
				C_{26}	0.0346

4.3 Evaluation value calculation based on Fuzzy Comprehensive Evaluation Method

Invited 20 experts from power supply companies, government departments, enterprises and public institutions to score the performance of the four power transmission and transformation projects at various levels. After normalization, a series of fuzzy evaluation matrices of third level factors can be obtained. Taking the index Improvement of People's Living as an example, the comprehensive evaluation vector can be obtained from its fuzzy evaluation matrix and the corresponding third level factor weight.

$$BB_1=W_1^T\cdot RB_1=[0.579\ 0.187\ 0.234]\cdot\begin{bmatrix}0.400 & 0.367 & 0.200 & 0.033 & 0\\ 0.300 & 0.467 & 0.133 & 0.100 & 0\\ 0.367 & 0.367 & 0.167 & 0.100 & 0\end{bmatrix}$$

$$=[0.374\quad 0.385\quad 0.179\quad 0.061\quad 0]$$

On the basis of fuzzy evaluation of the third level factors, BB_1, BB_2, ..., BB_{10} can be obtained and thus forms the fuzzy comprehensive evaluation matrix of the second level factor set. After that, the corresponding comprehensive evaluation vector of the second level factor set BA can be obtained. From BA_1, BA_2, BA_3, the fuzzy comprehensive evaluation matrix R of the first level factor set can be obtained, and then the comprehensive evaluation vector B corresponding to the whole system can be formed.

$$B=W^T\cdot R=[0.118\quad 0.681\quad 0.201]\cdot\begin{bmatrix}0.381 & 0.356 & 0.178 & 0.085 & 0\\ 0.313 & 0.373 & 0.232 & 0.082 & 0\\ 0.371 & 0.382 & 0.189 & 0.058 & 0\end{bmatrix}$$

$$=[0.332\quad 0.373\quad 0.217\quad 0.078\quad 0]$$

According to the Principle of Maximum Membership Degree, among the five grades of membership degree, 0.373 is the largest value, which will be used as the comprehensive membership degree value of the social benefit index of the four power transmission and transformation projects in this study. Its comment value is "good", indicating that experts are relatively satisfied with the social benefit of these power transmission and transformation projects. About 33.2% of the experts were very satisfied with it, while 92.1% (that is 33.2%+37.2%+21.7%) shown approval to the overall social effects of these four projects. Set the score of comment set as [100 80 60 40 0], then the corresponding score U of indexes Social Development, Economic Development, and Environmental Development in B is as follows.

$$U_1 = 0.381\times 100 + 0.356\times 80 + 0.178\times 60 + 0.085\times 40 + 0\times 0 = 80.66$$

$$U_2 = 0.313\times 100 + 0.373\times 80 + 0.232\times 60 + 0.082\times 40 + 0\times 0 = 78.34$$

$$U_3 = 0.371\times 100 + 0.382\times 80 + 0.189\times 60 + 0.058\times 40 + 0\times 0 = 81.32$$

By calculating the scores, finally obtained the ranking of the three indexes.

$$U_3 \succ U_1 \succ U_2$$

The result shows that experts believed that the power transmission and transformation projects perform best in terms of the impact of environmental development. Of course, on the whole, the scores of the three indicators are about 80, which means that the experts were quite satisfied with the social benefits of these power transmission and transformation projects and thought that the whole system is relatively good.

5. Conclusion

This paper uses the basic principles of social economics, draws lessons from the main research results of domestic and foreign institutions, industries and scholars on social benefit evaluation of projects, uses the Entropy Weight Method to judge the importance of the social benefit evaluation indexes of power transmission and transformation projects, and screens conventional indexes and special indexes to measure the social benefit evaluation of the projects, builds a targeted social benefit evaluation index system of power transmission and transformation projects, assigns weights to the indexes by Analytic Hierarchy Process, and use Fuzzy Comprehensive Evaluation Method to evaluate the comprehensive benefits of the projects, and take four power transmission and transformation projects of 500 kV and above in Henan as examples to comprehensively evaluate their social benefits. Through case analysis, the effectiveness of the evaluation method proposed in this paper is verified, and it is clear that the four projects have good social benefits. These projects have promoted the local economic, social and environmental development. The evaluation method proposed in this paper can improve the scientificity and objectivity of investment decision-making and construction scheme comparison of power transmission and transformation projects. On the other hand, it can effectively reduce project investment risks, fully optimize resource allocation, and promote the substantial improvement of investment benefits of large projects.

References

[1] Social analysis selected tools and techniques [R], Washington. D. C. USA: The World Bank, 2001.

[2] Handbook on Social Analysis: A Working Document [Z], Manila, Philippines: Asian Development Bank, 2007.

[3] XU Wen. Research on Social Benefit Evaluation of Public Projects Based on Analytic Hierarchy Process [J]. Knowledge Economy, 2018,{4}(07):38+44.

[4] CHEN Hanyu. Research on Investment Planning Decision and Benefit Evaluation of Power Transmission and Transformation Projects Based on Two Dimensions [D]. North China Electric Power University (Beijing), 2019.

[5] Judith I. M. Groot, Elisa Schweiger, Iljana Schubert. Social Influence, Risk and Benefit Perceptions, and the Acceptability of Risky Energy Technologies: An Explanatory Model of Nuclear Power Versus Shale Gas [J]. Risk Analysis, 2020, 40(6).

[6] Andrew Buckwell, Dan Ware, Christopher Fleming, James C. R. Smart, Brendan Mackey, Johanna Nalau, Allan Dan. Social benefit cost analysis of ecosystem-based climate change adaptations: a community-level case study in Tanna Island, Vanuatu [J]. Climate and Development, 2020, 12(6).

[7] Winter Sandra J, Sheats Jylana L, Salvo Deborah, Banda Jorge A, Quinn Jennifer, Rivera Brooke Ray, King Abby C. A Mixed Method Study to Inform the Implementation and Expansion of Pop-Up Parks for Economic, Behavioral, and Social Benefits [J]. Journal of urban health: bulletin of the New York Academy of Medicine, 2020.

[8] Ul Haq Shamsheer, Boz Ismet, Shahbaz Pomi, Yıldırım Çağatay. Evaluating eco-efficiency and optimal levels of fertilizer use based on the social cost and social benefits in tea production [J]. Environmental science and pollution research international, 2020.