Check for updates

Research on Performance Evaluation and Influencing Factors of County-Level Highway Maintenance Projects

Xueqian Niu*

Liaoning Technical University, Huludao, Liaoning 125105, China

*734928700@qq.com

Abstract. To address the issues of ambiguous performance evaluation and difficulties in identifying key influencing factors within county-level highway maintenance projects, this study constructs a performance evaluation indicator system encompassing five dimensions: technical, economic, social, environmental, and management. The AHP-entropy weight combination method was employed to determine indicator weights. Combined with the fuzzy comprehensive evaluation method, the performance of Q County's 2023 maintenance projects was quantitatively assessed, and key influencing factors were identified using multiple linear regression. Findings indicate that technical and social performance constitute core dimensions within the evaluation framework, with pavement condition index and public satisfaction emerging as key indicators. The county's maintenance projects achieved an overall performance rating of 'Good', though pavement condition and emergency response times remain significant shortcomings. Fiscal investment and technology adoption rate exerted a markedly positive influence on performance, whereas average daily traffic volume demonstrated a significant negative impact. The integrated 'indicator-evaluation-factor' analytical framework proposed herein provides theoretical underpinnings and practical guidance for scientific decision-making and refined management in county-level highway maintenance.

Keywords: County-level highways, Performance evaluation, Fuzzy integrated evaluation, AHP-Entropy weighting method, Influencing factors

1 Introduction

Entering the third decade of the 21st century, China's transportation focus is shifting from "large-scale construction" to "equal emphasis on construction and maintenance, with maintenance as the priority."[1] Consequently, the quality and efficiency of county-level highway maintenance have become a core bottleneck for road network development. Current maintenance efforts face challenges like insufficient funding, inconsistent technical standards, personnel shortages, and unscientific decision-making, leading to inefficient fund utilization and the persistent dilemma of "annual maintenance yielding annual deterioration"[2]. Establishing a scientific performance evaluation system is therefore crucial. Such a system can quantify maintenance outcomes,

© The Author(s) 2026
Y. Xu et al. (eds.), *Proceedings of the 2026 5th International Conference on Engineering Management and Information Science (EMIS 2026)*, Advances in Computer Science Research 130,
https://doi.org/10.2991/978-94-6239-652-4_5

optimize funding allocation, and incentivize maintenance units. Further exploring key influencing factors will facilitate a shift from "experience-based management" to "scientific decision-making"[3], which is vital for elevating management standards.

Existing research provides a foundation for evaluating highway maintenance performance, such as the grey theory applied by Wu et al. [4]and the multi-objective optimization methods reviewed by Pourgholamali et al.[5]. Regarding influencing factors, scholars have generally focused on dimensions including management, technology, and resources [3,6]. However, these studies predominantly concentrate on higher-grade highways or specific aspects, lacking a comprehensive evaluation framework tailored to county-level roads that integrates 'technical-economic-social-environmental-management' dimensions. Furthermore, there is limited application of combined subjective and objective weighting methods.

To address the challenges of ambiguous performance evaluation and unclear influencing factors in this specific context, this study constructs a five-dimensional indicator system covering "technical, economic, social, environmental, and management" dimensions. It integrates the AHP-entropy weighting method, fuzzy comprehensive evaluation, and multiple regression for an empirical analysis of County Q. The aim is to reveal current performance status and key influencing factors, providing a theoretical basis and practical guidance for transforming maintenance management towards "scientific prevention."

2 Performance Evaluation Indicator System

2.1 Principles for Identifying Indicators

To ensure a scientific and practical performance evaluation system for county-level highway maintenance, a multi-dimensional indicator framework must be established based on the following core principles: First, comprehensiveness: The framework should cover the entire project lifecycle and key domains—including technical conditions, economic benefits, social services, ecological protection, and internal management—ensuring logical connections between indicators and integrating macro effectiveness with micro outcomes. Second, representativeness: Indicators must align with the regional and public-welfare nature of county highways, focusing on core aspects such as pavement performance and user experience, while excluding irrelevant factors to enhance precision and validity. Third, operability and quantifiability: Indicators should be clearly defined, with standardized calculation methods, to ensure data accessibility, measurability, and comparability. This supports credible and applicable evaluation results. Finally, regional specificity: The system must reflect county-level realities—such as funding models, management mechanisms, and technical standards—to avoid misalignment with higher-level road evaluations and ensure local relevance and practical guidance.

2.2 Establishment of a Performance Evaluation Indicator System

Combined with the relevant evaluation standards and specifications of the Ministry of Transport, basic indicators for the technical conditions of core infrastructure such as pavements, bridges, and sub - grades are initially selected. Considering the regional and public - welfare nature of county - level highway maintenance, contents such as economic benefits, social benefits, environmental impacts, and management efficiency are supplemented to form a comprehensive evaluation framework with five dimensions: technology, economy, society, environment, and management. Through questionnaire surveys and expert consultations, the indicators are screened and improved in multiple rounds. Finally, a comprehensive performance evaluation indicator system for county - level highway maintenance projects is constructed, as shown in Table 1.

Table 1. Performance Evaluation Indicator System for Maintenance Projects

Objective Layer	Guideline Layer	Indicator Layer	Indicator Explanation
Performance Evaluation of County-Level Highway Maintenance Projects A	Technical Performance (B1)	Road Surface Condition Index (B11)	Core indicators for assessing the integrity and technical condition of road surfaces
		Subgrade Integrity Rate (B12)	Percentage of intact subgrade mileage relative to total assessed mileage
		Bridge Technical Condition Rating (B13)	structural safety and serviceability of bridges and culverts within the jurisdiction
		First-time Acceptance Pass Rate for Maintenance Projects (B14)	The percentage of maintenance projects passing final acceptance in a single attempt relative to the total number of completed projects.
	Economic Performance (B2)	Maintenance cost per unit kilometers (B21)	The ratio of total maintenance project costs to the corresponding maintenance mileage
		Compliance rate of maintenance fund utilization (B22)	Percentage of compliant funds relative to total maintenance expenditure
		Return on maintenance investment (B23)	The ratio of positive benefits to total maintenance investment costs
	Social Performance (B3)	Average travel speed improvement rate (B31)	the Effectiveness of Maintenance Works in Enhancing Road Network Pass ability
		Public satisfaction (B32)	The Social Benefits and User Experience of Highway Maintenance Services
		Traffic accident reduction rate (B33)	Percentage decrease in traffic accidents per unit of vehicle-kilometers travelled following maintenance

Environmental Performance (B4)	Maintenance Waste Recycling Rate (B41)	The percentage of total recyclable maintenance waste generated that is recycled
	Dust Control Compliance Rate (B42)	Percentage of compliant instances relative to the total number of inspections conducted
	Vegetation Restoration Rate (B43)	Percentage of vegetation restoration area relative to the total area requiring restoration
Management Performance (B5)	Maintenance Plan Completion Rate (B51)	The percentage of projects actually completed relative to the number planned for completion
	Emergency Response Time (B52)	The average time from receiving the report to personnel and equipment arriving at the scene
	Maintenance Team Professional Qualification Compliance Rate (B53)	The proportion of personnel holding nationally recognized occupational qualification certificates among the workforce.

3 Performance Evaluation and Influencing Factors Analysis

3.1 Method for Determining Indicator Weights

To ensure objective and accurate indicator weighting, this paper adopts a combined subjective-objective method. First, the Analytic Hierarchy Process (AHP) is used to determine subjective weights. step1: Construct a three - level hierarchical structure and use a nine - level scale to construct the judgment matrix A. step2: calculate the relative weights. Based on the decision matrix established in the preceding steps, compare the relative importance of the factors and compute their respective relative weights. Fourth, conduct consistency testing by calculating CR and CI. When CR < 0.1, this indicates that the consistency test is satisfied; otherwise, the data requires corresponding adjustment until it meets the requirements.

Subsequently, the entropy weight method was employed to determine the objective weights of the indicators. First, construct the evaluation matrix B, Non - dimension Alize the positive and negative indicators respectively. The processed matrix P of the indicators can then be obtained, Secondly, Calculate the entropy value of the indicator e_i .Then calculate the coefficient of variation for the indicators α_i.later calculate the entropy weights w_i .Finally, perform portfolio weighting:

$$w = \alpha\theta_A + \beta w \tag{1}$$

In the formula, $\alpha + \beta = 1$

3.2 Performance Evaluation Model for Maintenance Projects

This paper proposes to establish a performance evaluation model for county-level highway maintenance projects using the fuzzy comprehensive evaluation method. The specific steps are as follows:

First, determine the set of evaluation indicators, Secondly, determine the set of comments and the set of weights. The set of comments may be defined as V.The weighting sets may be defined as Objective layer weighting set and Criteria layer weighting set. Evaluating a specific factor within the factor set U yields a single-factor evaluation set. The criteria layer evaluation matrix B is then derived.

The evaluation result calculation formula is thus:

$$R_i = A_j * B_i \tag{2}$$

Similarly, a second-level fuzzy comprehensive evaluation is conducted. The final comprehensive evaluation result is obtained:$R = A * B$

3.3 Performance Impact Factor Analysis Model for Maintenance Projects

This paper proposes to employ a multiple linear regression analysis model to examine the factors influencing the performance of county-level highway maintenance projects. The model is constructed as follows:

$$S = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \tag{3}$$

In the equation, β_0 denotes the constant term, β_i represents the factor coefficient, and ε signifies the random factor.

3.4 Data Collection

This study employs a multi-faceted data collection approach. The data comprises two categories: objective data and subjective data. Objective data was obtained through reviewing publicly available documents on county government websites and conducting literature research. Subjective data was gathered using a questionnaire survey methodology. Structured questionnaires were distributed to both expert and public users to ascertain indicator weightings and satisfaction levels. Perform data cleaning, validity and reliability testing, dimensionality reduction, and other preprocessing steps on all collected raw data.

4 Empirical Analysis

4.1 Indicator Weight Calculation

To validate the performance evaluation system and influencing factors model developed by this research institute, County Q was selected as an empirical case study.

The weights for the performance evaluation indicators of highway maintenance projects were calculated using the AHP-entropy value combination weighting method, with the results presented in Table 2.

Table 2. Weighting of Project Performance Evaluation Indicators

Criteria layer	Weight	Indicator layer	Entropy value	Weight
B1	0.335	B11	0.85	0.12
		B12	0.89	0.085
		B13	0.91	0.075
		B14	0.93	0.055
B2	0.190	B21	0.90	0.070
		B22	0.92	0.065
		B23	0.94	0.055
B3	0.240	B31	0.88	0.070
		B32	0.86	0.090
		B33	0.89	0.080
B4	0.100	B41	0.92	0.050
		B42	0.96	0.025
		B43	0.96	0.025
B5	0.135	B51	0.93	0.040
		B52	0.89	0.060
		B53	0.92	0.035

4.2 Performance Evaluation of County-Level Highway Maintenance Projects

The performance outcomes of county-level highway maintenance projects were evaluated using the Fuzzy Comprehensive Evaluation Method. Firstly, the evaluation set V was defined as {Excellent (90), Good (70), Average (50), Poor (30)}; the evaluation results for each criterion layer were calculated:

$$R_1 = W_1 \times B_1 = (0.1858, 0.6207, 0.1835, 0.010)$$

$$R_2 = W_2 \times B_2 = (0.3012, 0.5885, 0.1003, 0.010)$$

$$R_3 = W_3 \times B_3 = (0.4683, 0.4184, 0.1013, 0.012)$$

$$R_4 = W_4 \times B_4 = (0.1750, 0.4900, 0.2850, 0.050)$$

$$R_5 = W_5 \times B_5 = (0.0103, 0.2015, 0.5782, 0.210)$$

A comprehensive fuzzy evaluation of the performance of county-level highway maintenance projects yields the following:

$$R_{all} = W \times B = (0.2507, 0.4963, 0.2115, 0.0416)$$

Comprehensive evaluation findings indicate that while county-level highway maintenance performance shows overall improvement, significant room for optimization remains. Performance distribution exhibits unevenness, posing risks of substandard outcomes; notable disparities exist across evaluation dimensions, with social, economic and technical aspects representing primary shortcomings. The sector remains in a transitional phase, necessitating short-term remedial action to address deficiencies and long-term expansion of strengths to drive advancement from merely meeting standards towards achieving excellence. with the results presented in Fig 1.

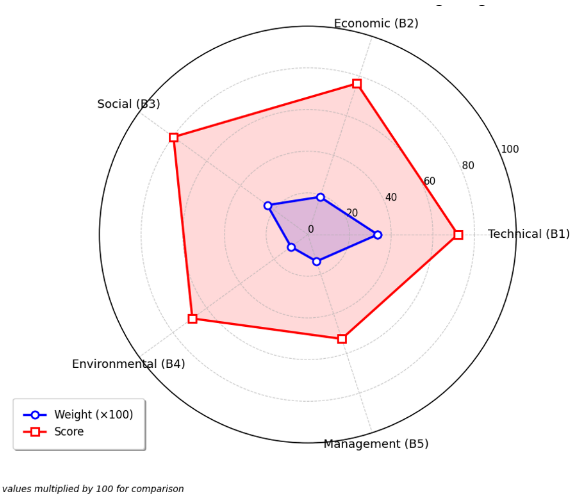

Fig. 1. Performance Evaluation Results and Indicator Weighting Radar Chart

4.3 Analysis of Factors Influencing the Performance of County-Level Highway Maintenance Projects

Based on the characteristics of county - level highway maintenance objectives, this study selects the average annual maintenance fiscal revenue, the adoption rate of maintenance technology, the average daily traffic volume, the professional level of maintenance personnel, the average annual frequency of severe weather occurrences, and the average annual frequency of maintenance as independent variables, and constructs a multiple linear regression model with the comprehensive performance score as the dependent variable. Q County is selected as the research area to collect data through questionnaires, and a correlation analysis of the variables is conducted. Conduct a correlation analysis and conclude that there is no linear relationship between the independent variables.

Finally, a multiple linear regression analysis was conducted, with the results presented in Table 3. The analysis indicates that multiple independent variables exert a significant influence on water-saving area. Among these, the annual average fiscal expenditure on maintenance, the adoption rate of maintenance techniques, the daily average traffic volume, the professionalism of maintenance teams, the annual average frequency of adverse weather conditions, and the annual average maintenance frequency all exhibit significance levels below 0.05. The regression results demonstrate that their impact is notably pronounced.

Table 3. Results of multiple linear regression

Var	Regression coefficient	standard error	T	P
X1	0.325	0.087	3.735	0.001
X2	0.418	0.092	4.543	<0.001
X3	-0.002	0.0005	-3.982	0.000
X4	0.286	0.095	3.011	0.005
X5	-0.157	0.072	-2.181	0.036
X6	0.253	0.101	2.505	0.018

5 Conclusion

This study addresses the issues of ambiguous performance evaluation and difficulty in identifying key influencing factors in county-level highway maintenance by establishing a five-dimensional evaluation framework encompassing technical, economic, social, environmental, and management dimensions. Empirical analysis of County Q, employing both the AHP-entropy weighting method and fuzzy comprehensive evaluation, reveals that technical and social performance constitute core dimensions. Key drivers include fiscal investment and technology adoption rates, whilst average daily traffic volume emerges as the primary limiting factor. The resulting 'evaluation-factor-countermeasure' framework provides theoretical and practical foundations for refined management and scientific decision-making in county-level highway maintenance.

In policy and management, fiscal safeguards should be strengthened to drive technological advancement and intelligent systems, with social benefits incorporated into performance assessments. Concurrently, efforts should focus on differentiated maintenance, emergency response capabilities, and workforce professionalization to enhance management efficiency.

This study provides an initial framework that may be extended to a wider range of samples in future to validate its universality, introduce dynamic monitoring and early warning mechanisms, and deepen research into green maintenance technologies under the dual carbon goals.

Disclosure of Interests

The authors have no competing interests to declare that are relevant to the content of this article.

References

1. Feng, H., & Zhang, Y. (2022). Research on the multi-attribute evaluation model for the investment results of county-level highways in new urbanization. KSCE Journal of Civil Engineering, 26 (12), 4893-4911.
2. Zhang, Y., et al. (2020). "Performance Evaluation of Rural Road Maintenance in China: A Case Study." Journal of Transportation Engineering, 146(3), 123–135.
3. Li, X., et al. (2021). "Factors Influencing the Performance of County-Level Road Maintenance: A Systematic Review." Transportation Research Part A: Policy and Practice, 145, 102–115.
4. Wu, X., Shi, X., Ke, Y., et al. (2024). "A dynamic framework for contractors to measure the performance of highway maintenance based on grey theory." Scientific Reports (Sci Rep), 14, 21893.
5. Pourgholamali, M., Labi, S., & Sinha, K. C. (2023). Multi-objective optimization in highway pavement maintenance and rehabilitation project selection and scheduling: a state-of-the-art review. Journal of Road Engineering 3(3), 239-251.
6. Ghanbari, M., & Khalid Hasani, Z. (2024). "Key Success Factors in Road Maintenance Management Projects (A Case Study of Maysan Province, Iraq)." IIUM Engineering Journal, 25(1), 102–115.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.