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Research Article

Contribution Modeling on Condition Evaluation of Asphalt Pavement Using Uncertainty Measurement and Entropy Theory

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In view of the deficiency that traditional pavement performance evaluation index did not consider the influence of their difference on weight, the grade of the evaluation index also did not take into account intermediate state and the impact of uncertainty on the evaluation results, a determination method of pavement performance evaluation index weight based on entropy theory was developed. The unascertained measurement function of evaluation index was performed by left-half ladder distribution, and unascertained measurement matrix was obtained. The index weight was calculated by minimum entropy theory, and the practicability of this method was verified through a concrete example finally. The results show that there were different weights in different samples, which depended on index measurement function and were the overall characterization of comprehensive measurement of every index. The method which is based on the given weighting factor did not conform to the engineering facts. It was difficult to identify the importance of the pavement performance evaluation index in different samples. The balance of the various indexes is better to be considered in the proposed method, and the comprehensive situation of pavement performance is really reflected, which improves the evaluation of the reliability.

1. Introduction

It is of great sense, value to evaluate the pavement condition in a science and reasoned way for getting more out of the service living of highway structure [1]. In the service process, different diseases come into view as on the asphalt pavement under the heavy loading and changeable environment [2, 3]. For effects of these diseases on pavement performance, different evaluation models and classification methods were adopted in countries all over the world [4]. For instance, the Federal Highway Administration (FHWA) systematically discussed asphalt pavement diseases based on the mechanism of damage generation and severity and classified them into several forms, including crack, settlement, and rut [5]. In China, the pavement maintenance department suggested that there are four main diseases, such as crack, surface loosening, distortion, and so on [6]. Moreover, the relegation of pavement condition decreases the service quality of highway and increases the risk of traffic accidents [7]. Consequently, effective detection and treatment of pavement diseases are essential to sustain the operation of the whole transportation system.

In general, it is very important and meaningful for the sustainability of pavement system to evaluate the health of highway network in vast regions with different terrain and climate [8]. Federal Aviation Administration (FAA) has confirmed that in-time maintenance guided by accurate evaluation model can save up to 75–80% of the cost than that with the relatively poor management [9]. Therefore, pavement condition evaluation is a fundamental part of maintenance decision activity as well as a challenge in pavement engineering [10]. The evaluation of highway condition first appeared with the Present Service Index (PSI) in USA [11]. Mejias and Rushing [12] provided a set of evaluation criteria based on pavement conditions, traffic, and environmental factors through research and calculation, which helped to reasonably select the optimal cost-benefit ratio of conservation measures. Pantuso et al. [13] introduced an approach to analyze the time sequence of maintenance treatments using the survey data of the falling weight deflectometer (FWD). The purpose of pavement management is to provide a reliable pavement condition evaluation model to realize the optimization process of pavement life and resource allocation [14]. At present, many researches have adopted a simple method to predict the damage condition of pavement performance through the preset classification and weight of each evaluation index [15, 16]. However, this way cannot be applied to characterize the influence of the difference of each evaluation index on the contribution of decision-making results [17]. Moreover, influence factors on pavement condition are many and complicated, and its process involves design, construction, and operation. For example, asphalt pavement is subjected to the repeated action of vehicle load and the alternation of climate and environment [18]. In addition to these external factors, material properties, pavement type, construction quality, and maintenance time sequence also affect the service life of pavement [19, 20]. Therefore, the evaluation of these influencing factors usually requires long-term pavement condition data, and the credibility of the proposed evaluation model is difficult to determine due to the uncertainty of the results.

In recent years, researchers began to employ a variety of mathematical methods in performance evaluation and maintenance decision of asphalt pavement. Fakhri and Shahni Dezfoulian [21] pointed out that the limitations of uncertain factors and human effects were inevitable in the evaluation process, and the Artificial Neural Networks (ANNs) were applied to establish the relation between testing data and pavement surface distresses. Despite this attempt, these models did not present the determination of subjective influences and their weight on pavement evaluation. In another effort, Bianchini et al. [22], based on the principal-component analysis (PCA), tried to determine the variance contributions of each distresses on the condition assessment of asphalt pavement. This method could capture the representative variance as the comprehensive evaluation value to avoid possible misevaluation of subjective factors and redundant information. In the pavement management, the reliability and weight of testing data represent a concern because of the difficulty of directly evaluating the pavement condition. Elhadidy et al. [23] established a simply decision-making model to associate international roughness index (IRI) and pavement condition index (PCI). The multi-objective decision-making evaluation to classify the contributions of PCI, running quality index (RQI), rutting depth index RDI, and antislide performance index (SRI), exploiting the radar map of entropy weight, was also investigated by Yao et al. [24]. Their algorithm was tested to be simple and have strong practicability. Nevertheless, the further study needs to be carried out since the selection of evaluation function lacks relevant theoretical basis only using simple geometric average. Sun and Gu [25] provided a new idea for the selection of maintenance countermeasures that the method of multiphase fuzzy statistics was applied to identify the pavement damage and the pavement smoothness, which was related to the project prioritization. However, its applicability was still limited since this evaluation method was derived from the experience of engineering experts in Beijing. Therefore, due to different climates and pavement surface types in each region, contribution models for pavement surface evaluation need to be recalibrated using local data, including weights for each factor.

The weight of evaluation parameters is viewed as the relative importance in assessing the pavement performance and identifying the prioritize projects for the overall pavement maintenance [26]. Meanwhile, its weighted average operation can describe the quantitative distribution of contributions of different aspects of the tested object through mathematical tools [27]. The application of analytic hierarchy process [28], fuzzy mathematics [29], genetic algorithm [30], and grey system [31] has been proved to improve the evaluation results of pavement condition. However, the determination of the weight has not been fully solved that the essential attribute of the index weight cannot be reflected, resulting in the deviation between the evaluation grade and subjective feeling. Attention should be paid to the differences in the application of rating results considering different regions and climates.

In view of the above issues, the objective of this paper is to propose a calculable method to determine the contributions of condition evaluation parameters based on the unascertained measure and minimum entropy theory. This approach takes into account the difference of each index, the intermediate state of evaluation index classification, and the uncertainty of influencing factors. One case study of a highway in Hunan province is used to illustrate the method through the collected data including PCI, RQI, RDI, and SRI.

2. Methodology

Figure 1 illustrates the methodology of the research, which determines the reasonable weight of evaluation factors of pavement condition through steps, based on unascertained measure and minimum entropy theory.

2.1. Evaluation Indicators. The research and application of engineering structure reliability theory is one of the effective ways to solve the problems of uncertain structure analysis and design. Pavement structure is a huge and complex system engineering. There are many factors that affect pavement condition, and these factors have a lot of uncertain information, which have a great influence on pavement condition evaluation.

In China, the deterministic evaluation method of given weight is adopted by traffic management departments. Two evaluation parameters are proposed, including maintenance quality indicator (MQI) and pavement quality index (PQI). These indexes can be calculated, respectively, by

$$\text{MQI} = w_P \text{PQI} + w_S \text{SCI} + w_B \text{BCI} + w_T \text{TCI}, \tag{1}$$

$$\text{PQI} = w'_P\ \text{PCI} + w'_R\ \text{RQI} + w'_R\ \text{RDI} + w'_S\ \text{SRI}, \tag{2}$$

where w_p, w_s, w_B, and w_T are, respectively the weights of the PQI, the subgrade condition index (SCI), the bridge (tunnel,

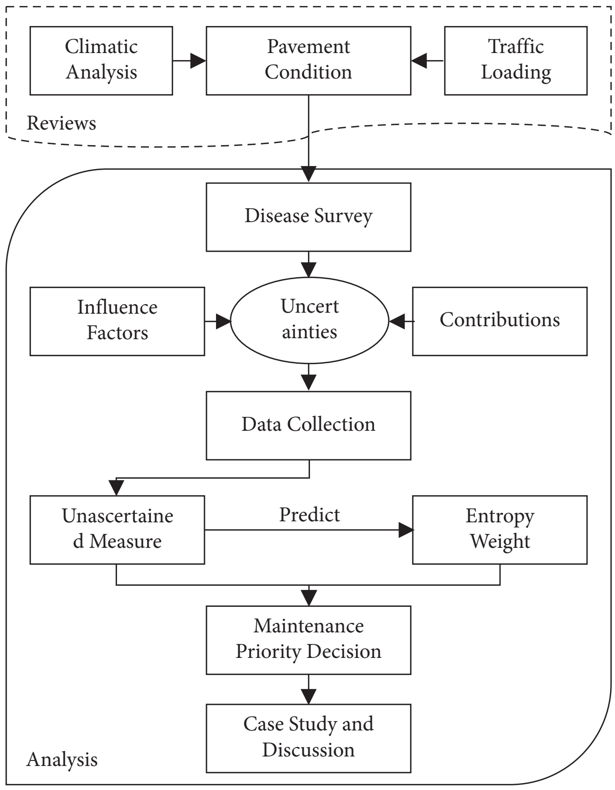


Figure 1: Flow diagram of study methodology.

culvert) condition index (BCI), and the traffic-facility condition index (TCI) in the MQI evaluation, respectively; w_p', w_s', w_B', and w_T' are, respectively, the weights of PCI, RQI, RDI, and SRI in the PQI evaluation.

The above method assumes that the calculated weight of the pavement condition evaluation index is constant. For the calculation of MQI, w_p is 0.7, w_s is 0.08, w_B is 0.12, and w_T is 0.10. Although it is simple and easy to operate, the evaluation process does not consider the impact of the difference of evaluation indexes on the weight, nor does the classification of evaluation indexes consider the intermediate state, and there is ambiguity in the characteristics and categories of pavement conditions. Therefore, the credibility of the evaluation cannot be known because a large number of uncertain factors may be ignored to cause completely wrong evaluation results. These issues will severely mislead the maintenance management system to guide the timely and reasonable pavement maintenance process.

2.2. Data Collection. Pavement condition refers to the damage degree and service level of pavement under the long-term combined action of load and environment. Under different pavement structure composition, material ratio, climatic conditions, and traffic load, the main characteristics and severity of the disease are different, resulting in a great difference in the attenuation of pavement condition, which will also determine the probability distribution characteristics of the pavement condition evaluation index parameters.

In this study, the pavement diseases of several expressways in operation in Hunan province were investigated and analyzed by means of laser 3D intelligent pavement inspection vehicle and manual investigation. These road segments are from plain microknoll area, mountain heavy hilly area, or typical mountain area, respectively. Due to the wide area involved and the long opening time, the cases studied are representative in terms of engineering geological conditions, traffic load, pavement structure, pavement material properties, and so on. Therefore, the data acquisition results can reflect the influence of different conditions on the probability distribution of pavement condition evaluation indexes.

2.3. Uncertainty Measurement Theory. In recent years, unascertained measure theory has been widely used in slope stability evaluation, tailings dam, and tunnel safety evaluation. As a mathematical method to study unascertained information, unascertained measure theory can quantitatively analyze the unascertained size or unascertained state of the evaluation object, which can avoid the subjectivity of evaluators and the limitations caused by other mathematical methods and improve the scientificity and practicability of evaluation.

It supposes n groups of objects to be evaluated, such as $x_1, x_2, x_3, \ldots, x_n$, which constitute the domain U, also known as the evaluation object space. For a single evaluation object x_n, suppose there are m test indicators $D_1, D_2, D_3, \ldots, D_m$. The evaluation index space can be represented by $D = \{D_1, D_2, D_3, \ldots, D_m\}$. X_{ij} represents the measured value of evaluation object x_i on evaluation index D_j. F is the property space in the U, representing the degree to which x has a certain property (or state) to be evaluated.

If the measured value x_{ij} belongs to the kth evaluation grade C_k, $\mu_{\mathrm{ijk}} = \mu(x_{ij} \in C_k)$ can be expressed. μ satisfies $0 \le \mu(x_{ij} \in C_k) \le 1$. Meanwhile, μ is defined as unascertained measure according to additivity and normalization criteria. Measure evaluation matrix of single index $[\mu_{ijk}]_{m\times p}$, as follows:

$$\left(\mu_{ijk}\right)_{m\times p} = \begin{bmatrix} \mu_{i11} & \mu_{i12} & \cdots & \mu_{i1p} \\ \mu_{i21} & \mu_{i22} & \cdots & \mu_{i2p} \\ \cdots & \cdots & \cdots & \cdots \\ \mu_{im1} & \mu_{im2} & \cdots & \mu_{imp} \end{bmatrix}. \quad (3)$$

If there are k kinds of specific properties in the property space F, k-1 equal or nonequal points (a) can be inserted into the distribution interval of measured values. It is assumed that the measured value x_{ij} is at the evaluation level C_i, and its position is to the left of the equinox point a_i. When the measured value x_{ij} changes from left to right (i.e., from a_i to a_{i+1}), the degree of the measured value in the evaluation level C_i gradually weakens. When the measured value changes to a_{i+1}, the degree of the measured value in the evaluation grade C_i decreases to 0. At this point, when the measured value changes from a_i to a_{i+1}, the degree of the measured value x_{ij} in the evaluation grade C_i increases from

0 to 1. Therefore, the degree to which the measured value is in a certain evaluation level is within the interval of [0, 1].

In this study, unascertained measure function was used to characterize the unascertained state of pavement condition evaluation indexes in different evaluation grades. There are four commonly used unconfirmed measure functions, including sinusoidal distribution, quadratic parabolic distribution, left-half trapezoidal distribution, and S-type distribution, as shown in Figure 2. In pavement engineering, the condition evaluation index adopts the evaluation method of point grade, as shown in Table 1. In order to facilitate management and data analysis, this paper adopts the left-half trapezoidal distribution for research, as shown in (4). Figure 3 shows the functional relationship between pavement condition evaluation indexes and unascertained measures.

$$\mu(x) = \begin{cases} 0, & x \le a, \\ \dfrac{x-a}{b-a}, & a < x \le b, \\ 1, & x > b. \end{cases} \tag{4}$$

2.4. Determination of Index Weight. According to the principle of minimum entropy, it is assumed that a regression model $P(x(—))$ contains N variables obtained through measurement; that is, $x(—) = \{x_1, x_2, \ldots, x_N\}$. These variables may be the main variables reflecting the characteristics of the system, and there may be some internal correlation. Then, the variables in the study set can be combined to form 2^N-2 subsets. Each subset S_i constitutes a submodel of probability density distribution function; namely, $P_S(\mathrm{x}(—)_{Si}) = P(\mathrm{x}(—)_{Si})$. Therefore, the contribution rate of each variable to the system can be calculated by studying the explanatory degree of each submodel to the system. Furthermore, this study can determine the main variables and their weight values in the prediction system.

The Logit model is used to associate the responses between variables in each submodel, as shown in (5). The binary result "1" means that the variable is associated with the goal decision result, and "0" means that the variable is not associated with the goal decision result. The coefficient β_i is obtained by fitting the measured variable data through maximum likelihood estimation.

$$R(\overline{x}) = \frac{\left[\exp\left(\sum_{i=1}^{N} \beta_i x_i\right)\right]}{\left[1 + \exp\left(\sum_{i=1}^{N} \beta_i x_i\right)\right]}. \tag{5}$$

Normalization of (5) can obtain the response probability distribution function containing a given subset of all variables, as shown in (6) and (7). The parameter Z is a normalized constant and can be obtained by fitting functions. Therefore, the minimum entropy of the corresponding submodel is shown in (8).

$$P(\overline{x}) = \frac{1/Z\left[\exp\left(\sum_{i=1}^{N} \beta_i x_i\right)\right]}{\left[1 + \exp\left(\sum_{i=1}^{N} \beta_i x_i\right)\right]}, \tag{6}$$

$$Z = \sum_{\overline{x}} \left\{ \frac{\left[\exp\left(\sum_{i=1}^{N} \beta_i x_i\right)\right]}{\left[1 + \exp\left(\sum_{i=1}^{N} \beta_i x_i\right)\right]} \right\}, \tag{7}$$

$$S(P_S) = -\sum_{i=1}^{N} P\left(\overline{x}_{s_i}\right) \ln P\left(\overline{x}_{s_i}\right). \tag{8}$$

All submodels are sorted according to the entropy value, and the effective submodel is determined according to some decision rules, namely, the first-m submodels with the lowest entropy value. At the same time, based on these models, the probability of the occurrence of each variable is calculated to determine its contribution rate to the system. According to model analysis, the higher the probability, the greater the contribution of this variable to the system. Therefore, this study can determine the main variables and relative weights of the system through the minimum entropy theory.

2.5. Calculation Procedure

(1) Determine the unascertained measure function according to the classification standard of each index.

(2) According to the unascertained measure function, the unascertained measure value of each index in the evaluation object is solved to form a single-index measure matrix.

(3) The distribution of index weight represents the importance of the index in the whole system. According to the above calculation theory, a simplified method was adopted in this study; that is, parameter w_j was used to characterize the relative importance of measurement index D_j compared with other indexes. w_j is called the weight of index D_j, which is in the range of 0–1, and the sum is 1. The weight vector of this indicator is represented as $\{w_1, w_2, \ldots w_n\}$. Therefore, the information entropy determined by the unascertained measure μ_{jik} can be expressed as follows:

$$\begin{aligned} H_j &= \sum_{i=1}^{k} \mu_{jik} \lg \mu_{jik}, \\ v_j &= 1 + \frac{1}{\lg k} \sum_{i=1}^{k} \mu_{jik} \lg \mu_{jik}, \\ w_j &= \frac{v_j}{\sum_{i=1}^{n} v_i}. \end{aligned} \tag{9}$$

3. Case Study

The detection data of asphalt pavement came from a highway in Hunan province, taking it as an example. The highway was built in 2000, and its maximum design load

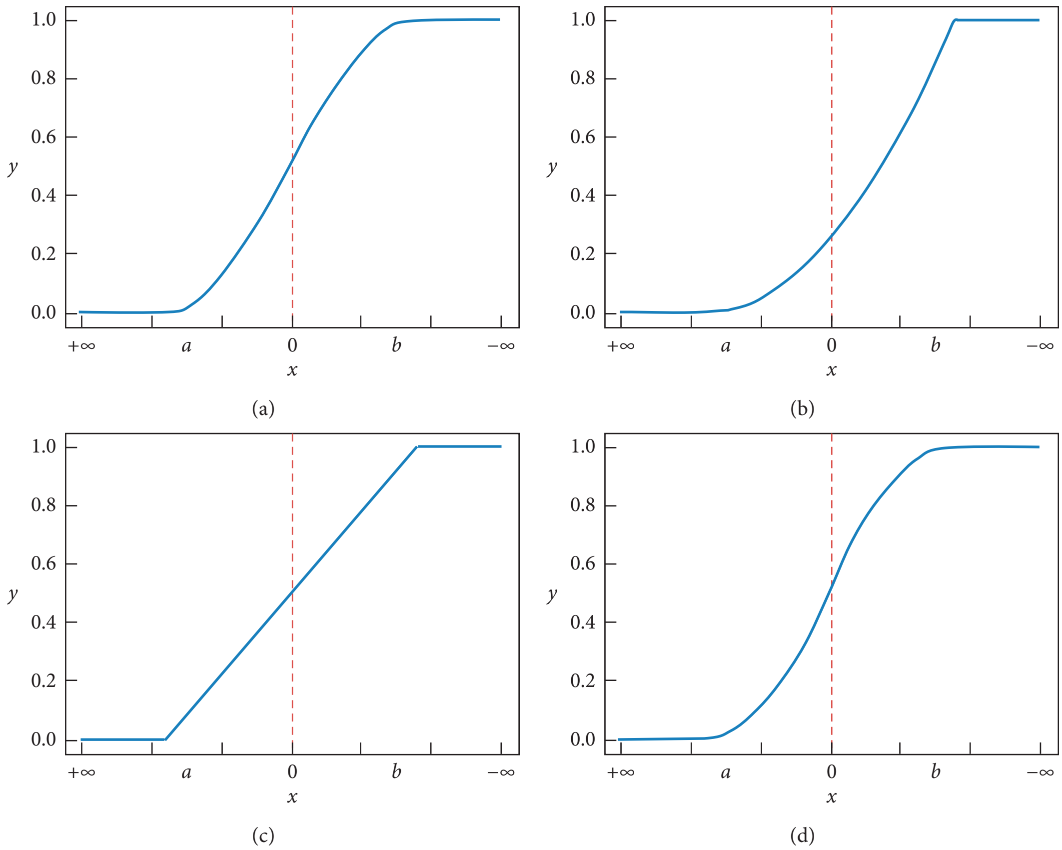


FIGURE 2: Distribution of unconfirmed measure functions. (a) Sinusoidal curve; (b) quadratic parabolic curve; (c) left-half trapezoidal curve; and (d) S-type curve.

TABLE 1: Evaluation standard of highway technical condition.

Evaluation level	Excellent	Good	Medium	Inferior	Poor
Range of index	≥90	80–90	70–80	60–70	< 60

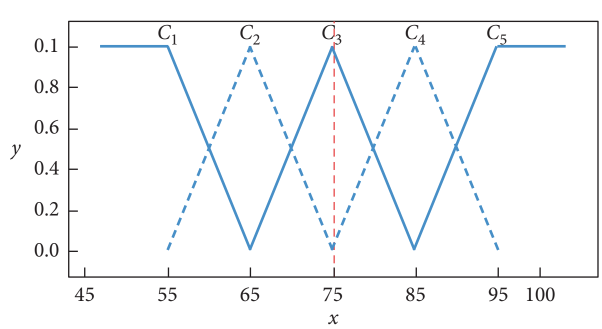


FIGURE 3: Unascertained measurement function of evaluation index in PQI and MQI.

times is 6.581×10^7. The climate is humid and hot in southern China. Table 2 presents the design pavement structure.

Using the above method, the weight of different evaluation indexes in PQI evaluation of pavement condition was investigated. Each sample represents the 1000 m section as the basic assessment unit. The pavement condition evaluation results are shown in Figure 4. The subindexes of pavement condition were collected according to China's highway technical condition assessment standard.

4. Results and Discussion

4.1. Analysis of Uncertainty Measurement. According to the steps in Section 2.5, the unascertained measure values of the four conditions' rating indicators are solved. Using the

Table 2: Main parts of pavement structure.

Layer	Thickness (cm)	Material
Upper surface course	5	SBS modified AK-16I asphalt mixture
Middle surface course	6	SBS modified AK-20I asphalt mixture
Lower surface course	7	AC-25I asphalt mixture
Base course	40	6% cement stabilized macadam
Subbase course	20	4% cement stabilized macadam

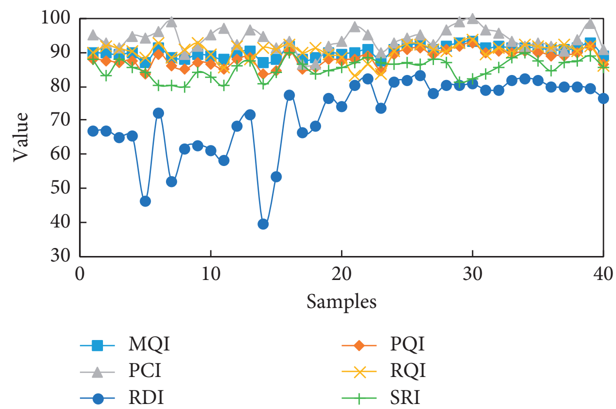


Figure 4: Collected data of pavement condition evaluation.

function relation in (4), the unascertained measure matrices of PCI, RQI, RDI, and SRI with single index were established as follows. According to (9) and (10), the weights of each index are 0.3253, 0.1856, 0.2316, and 0.2575, respectively. Complete calculation results are shown in Table 3.

$$\begin{aligned}\text{PCI} &= [\,0\ \ 0\ \ 0\ \ 0\ \ 1\,],\\ \text{RQI} &= [\,0\ \ 0\ \ 0\ \ 0.529\ \ 0.471\,],\\ \text{RDI} &= [\,0\ \ 0.825\ \ 0.175\ \ 0\ \ 0\,],\\ \text{SRI} &= [\,0\ \ 0\ \ 0\ \ 0.715\ \ 0.285\,].\end{aligned} \tag{10}$$

Figure 5 shows the proportion radar diagram of PCI, RQI, RDI, and SRI. The results show that for different samples, the importance of evaluation indexes in the evaluation system is different. The single indicator measure covers C_1, C_2, C_3, C_4, and C_5, namely, all levels. In the single indicator measure of PCI, C_4 and C_5 play a leading role, and the proportion of C_5 is about 0.8. In the single indicator measure of RQI, C_3, C_4, and C_5 play a leading role, with C_4 and C_5 in the majority, accounting for about 0.4 and 0.55 on average. The single index measures C_1, C_2, C_3, and C_4 of RDI play a leading role, and the proportion of C_3 is much higher than that of C_1, C_2, and C_4, indicating that the status of subindex RDI in this sample group is poor, and most of the RDI evaluation grade is medium. Therefore, attention should be paid when determining the index weight. The single index measures C_3 and C_4 of SRI play a leading role, accounting for about 0.3 and 0.6 on average. The subindex SRI in this sample group is not in good condition, and most of SRI is rated as medium or good, so its importance in the whole evaluation system should also be reflected.

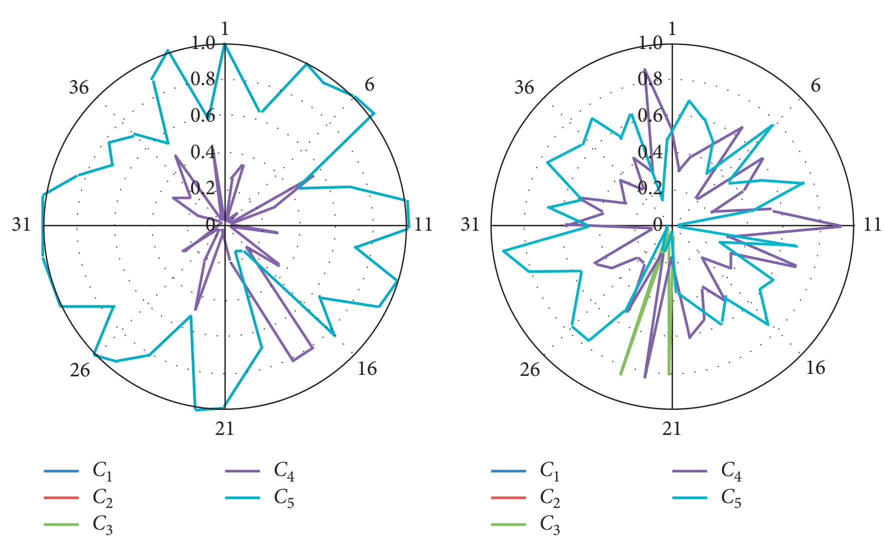
4.2. Comparison with Standard Method. Figure 6 shows the weight representation of different subindexes in PQI evaluation. The results show that it is particularly important to determine the weight of indicators to accurately evaluate the pavement condition. Each index in different samples has different weight, which depends on the measure function of each index and is the overall representation of the comprehensive measure of each index.

For the current assessment standard in China, the evaluation model is suggested by fixed weights of each index, which is 0.35, 0.4, 0.15, and 0.1, respectively. Taking sample 5 as an example, the on-site investigation of this section is shown in Figure 7. Rut is a typical disease of this section. However, the weight of rut depth index in the current standard is only 0.15, so the importance of rut typical disease is not reflected, and there is a deviation from subjective feeling, which is obviously not in line with reality.

The weight information entropy weight method of pavement condition index proposed in this study can overcome the disadvantages of the traditional pavement condition evaluation method based on given weight without considering the influence of the differences of each index on the weight. It also solves the problems of

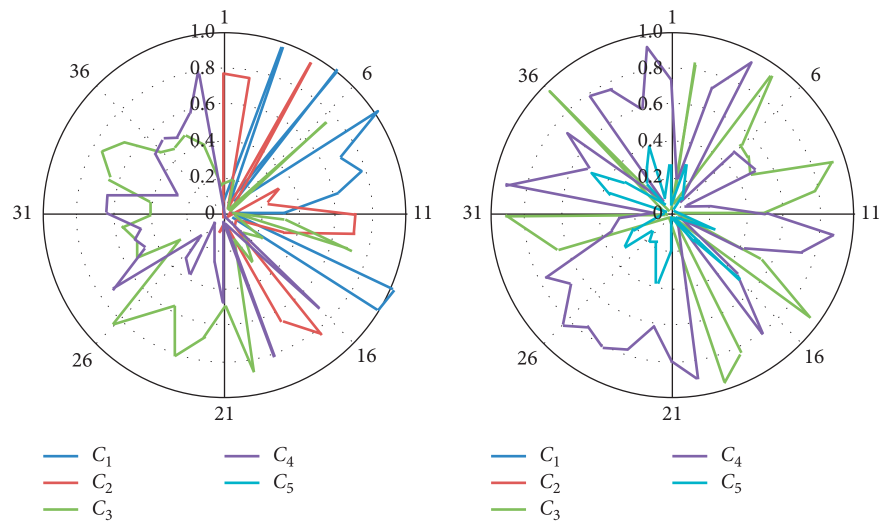
Table 3: Results of weights of each evaluation index.

Sample	v_{PCI}	v_{RQI}	v_{RDI}	v_{SRI}	w_{PCI}	w_{RQI}	w_{RDI}	w_{SRI}
1	1.0000	0.5704	0.7119	0.7916	0.3253	0.1856	0.2316	0.2575
2	0.6612	0.6226	0.6917	0.7100	0.2462	0.2318	0.2576	0.2644
3	0.5973	0.5853	0.9681	0.7854	0.2034	0.1993	0.3297	0.2675
4	0.9710	0.5700	0.9367	0.9522	0.2831	0.1662	0.2731	0.2776
5	0.8767	0.6001	1.0000	0.8440	0.2640	0.1807	0.3011	0.2542
6	1.0000	0.6823	0.6316	0.5714	0.3466	0.2365	0.2189	0.1980
7	1.0000	0.5893	1.0000	0.5704	0.3165	0.1865	0.3165	0.1805
8	0.5711	0.5751	0.6082	0.5693	0.2458	0.2475	0.2617	0.2450
9	0.6226	0.6687	0.6612	0.8456	0.2225	0.2390	0.2363	0.3022
10	1.0000	0.5732	0.5883	0.6857	0.3512	0.2013	0.2066	0.2408
11	1.0000	0.8573	0.6105	0.5697	0.3292	0.2822	0.2010	0.1876
12	0.6316	0.6231	0.6096	0.9414	0.2251	0.2221	0.2173	0.3355
13	1.0000	0.6220	0.6096	0.8221	0.3275	0.2037	0.1996	0.2692
14	0.8937	0.5955	1.0000	0.5740	0.2918	0.1944	0.3265	0.1874
15	0.5966	0.5823	1.0000	0.8456	0.1972	0.1925	0.3306	0.2796
16	0.7320	0.6562	0.6627	0.5504	0.2814	0.2522	0.2548	0.2116
17	0.7177	0.5693	0.7576	0.9041	0.2434	0.1931	0.2569	0.3066
18	0.7128	0.5874	0.6087	0.7623	0.2669	0.2199	0.2279	0.2854
19	0.6134	0.5744	0.7299	0.9343	0.2151	0.2014	0.2559	0.3276
20	0.6988	0.5902	0.8253	0.9629	0.2271	0.1918	0.2682	0.3129
21	1.0000	0.7207	0.5694	0.8551	0.3179	0.2291	0.1810	0.2719
22	1.0000	0.7299	0.6382	0.7188	0.3239	0.2365	0.2067	0.2329
23	0.5696	0.7417	0.7696	0.8660	0.1933	0.2517	0.2611	0.2939
24	0.6758	0.5700	0.5842	0.8865	0.2488	0.2098	0.2151	0.3263
25	0.8314	0.6562	0.6163	0.8683	0.2797	0.2208	0.2074	0.2921
26	1.0000	0.6520	0.7217	0.9106	0.3045	0.1985	0.2197	0.2773
27	0.6420	0.5826	0.6270	0.7685	0.2450	0.2224	0.2393	0.2933
28	1.0000	0.5712	0.5721	0.8520	0.3339	0.1907	0.1910	0.2844
29	1.0000	0.6790	0.5697	0.5973	0.3514	0.2386	0.2002	0.2099
30	1.0000	0.8035	0.5737	0.6401	0.3314	0.2663	0.1901	0.2121
31	1.0000	0.5758	0.5831	0.7796	0.3403	0.1959	0.1984	0.2653
32	1.0000	0.5947	0.5829	0.9455	0.3202	0.1904	0.1866	0.3027
33	0.7341	0.5696	0.6042	0.7465	0.2766	0.2146	0.2276	0.2812
34	0.6158	0.6328	0.6407	0.5913	0.2483	0.2551	0.2583	0.2384
35	0.6695	0.6051	0.6068	0.8053	0.2492	0.2252	0.2259	0.2997
36	0.6184	0.5947	0.5694	0.9016	0.2304	0.2216	0.2121	0.3359
37	0.5713	0.6382	0.5710	0.8488	0.2173	0.2427	0.2172	0.3228
38	0.7671	0.5749	0.5693	0.8246	0.2804	0.2101	0.2081	0.3014
39	1.0000	0.6042	0.5783	0.6669	0.3509	0.2121	0.2030	0.2340
40	0.5773	0.7576	0.7374	0.9516	0.1909	0.2505	0.2439	0.3147



(a) (b)

Figure 5: Continued.



(c) (d)

Figure 5: Measure characterization of single index. (a) PCI. (b) RQI. (c) RDI. and (d) SRI.

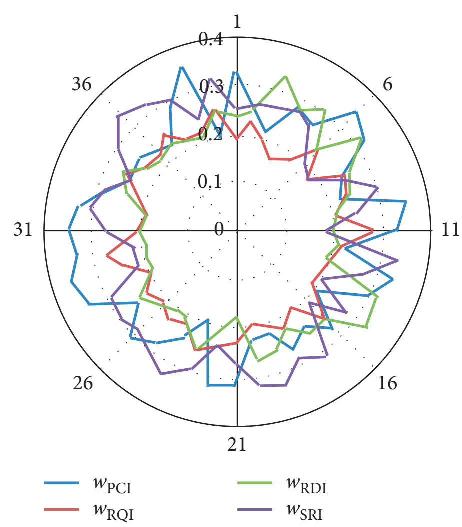


Figure 6: Weight characterization of pavement condition evaluation index.

Figure 7: Result of the rutting survey at sample 5.

not considering the intermediate state in the evaluation index grading and the influence of the uncertainty of the influencing factors on the evaluation results, which improves the credibility of the evaluation.

5. Conclusions

Unascertained measure and minimum entropy theory were introduced to study the determination method of weight information entropy of pavement condition evaluation index. The main findings of this study are as follows.

(1) There are many uncertainties and fuzziness in the process of pavement condition evaluation. The unascertained measure function is used to represent the unascertained state of each index in the grades of excellent, good, medium, secondary and poor condition evaluation, and the segmentation "order" of evaluation space is realized.

(2) For the weight of each evaluation indicator, the principle of minimum entropy analysis was applied to reduce the influence of subjective factors. The calculated result could objectively and comprehensively describe the importance of evaluation indicators and the actual situation of pavement condition.

(3) The application of fixed weight in the Chinese standard is unsuitable and difficult to identify the grade differences of pavement condition in different highway. Based on the case study, it was proved that the proposed method improved the comparability and reliability of condition evaluation for multiple pavement network, considering the unascertained measure and alterable weight of these contributions.

Data Availability

The testing data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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