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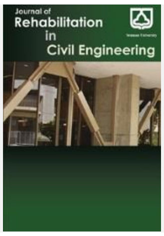

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Prioritization Comparison of TOPSIS and AHP to IRC: A Case Study of Kurukshetra Roads

Ankit Sharma [1]; Praveen Aggarwal [2,*]; S.N. Sachdeva [2,3]

1. Ph.D. Candidate, Department of Civil Engineering, National Institute of Technology Kurukshetra, Haryana-136119, India
2. Professor, Department of Civil Engineering, National Institute of Technology Kurukshetra, Haryana-136119, India
3. Vice Chancellor, Kurukshetra University, Kurukshetra, Haryana-136119, India

* Corresponding author: *ankitsharma336@gmail.com*

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ABSTRACT

The ever-growing requirements for pavements need regular maintenance. Prioritization of pavement maintenance using the multi-criteria-decision-making (MCDM) method is an established method. This study prioritizes roads in Kurukshetra district, Haryana, India, using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Analytical Hierarchy Process (AHP). Indian Roads Congress (IRC) standard for prioritization of roads in India is used as a benchmark to compare the ranking provided by both methods. TOPSIS outperformed the two methods, with a Spearman correlation coefficient value of 0.78 and an Index of Agreement value of 0.88. Compared to the IRC method's fixed weight assignment for rank calculation, the TOPSIS method offers a distinct advantage.

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1. Introduction

India has a huge road network which has grown exponentially in past 70 years, reaching around 62 lakh km. Maintenance of road network is equally important as construction. Timely maintenance not only makes the transportation system efficient but also controls speedy deterioration of the pavement. Limited resources necessitate prioritization for road maintenance. In order to make logical decisions for prioritization multiple data related to pavement performance is required. Involvement of numerous decisive factors and pavement characteristics makes decision-making complicated[1]. Multiple criteria decision-making (MCDM) methods are useful in such multi-dimensional problems.

In MCDM analysis, pavement condition is indicated as a single decisive value. This objectivity of the method not only helps in decision-making but also to build confidence in the same. Numerous MCDM methods have been used in past studies to solve real-life decision-making problems [2–7].

Prioritizing pavements for maintenance has both a subjective and an objective approach. The subjective aspect assigns weightage to different distresses depending upon their importance, and the objective aspect is related to distress magnitude.

In the present study, selected stretches with flexible pavement were evaluated for different distresses and prioritized for maintenance using the method proposed in IRC:82-2015 and two MCDM approaches, i.e. TOPSIS and AHP. Ranking orders obtained through TOPSIS are closer to IRC as compared to AHP.

2. Literature review

Maintaining a healthy road network is crucial for national development [8]. With time, pavements deteriorate and undergo various distresses[9], which poses a significant challenge for management agencies. A huge fund is required to maintain the road assets[10]. A substantial gap exists between the budgetary allocations for highway maintenance and the required funding[11]. The Standing Committee on Transport also highlights the shortage in funds allocated for the maintenance of roads in India [12]. This gap necessitates prioritization for the maintenance of road network. Simultaneously, different research agencies around the globe have stressed the importance of pavement maintenance prioritization[13–16].

Torres et al. [17] compared two methods of MCDM, namely the Analytical Hierarchy Process (AHP) and Choosing By Advantages (CBA), for integrating sustainability in pavement management. The other prominently used MCDM methods discussed in past studies include Analytic Network Process (ANP), Decision Making Trial and Evaluation Laboratory (DEMATEL) [18], AHP, ELECTRE II, ELECTRE III, ELECTRE IV, and Copeland [19]. Different MCDM methods differ in the aggregation of the decision parameters and can yield different results [20].

In a recent study, Nautiyal et al. presented the integration of AHP in GIS to prioritize the pavements in India [21]. Perla et al. [22] used artificial neural networks and support vector machines to predict IRI using distresses. Another study compared VIKOR and TOPSIS to prioritize maintenance[23]. Saluja et al. [6] compared the Pavement Surface Quality (PSQ) with the TOPSIS method for prioritization. Sirin et al. [24] identified 29 essential factors, classified into six categories, affecting pavement performance.

Although quoted research has made valuable contributions to the development of holistic pavement maintenance prioritization solutions[2,25,26], these techniques often rely upon data collected through sophisticated instruments and intricate procedures. Making them impractical for developing countries with limited resources and infrastructure[25,27–29].

Indian Road Congress (IRC) method of ranking for maintenance prioritization assigns fixed weightages to the identified distresses. Hardly any study has compared the results of IRC method with that of MCDM methods.

There exists a critical need for a more accessible and objective method for pavement maintenance prioritization in such contexts. This study addresses these gaps regarding flexible input parameters and variable weights to enhance decision-making in maintenance prioritization.

3. Study area and data collection

The selected study area is district Kurukshetra of Haryana state in India. Figure 1 depicts the study area. The selected stretches are 5 to 6 years old, 5.5m wide, flexible pavement, and constructed under the Pradhan Mantri Gram Sadak Yojna (PMGSY) [30]. Figure 2 provides a broad outline of the methodology followed in the study.

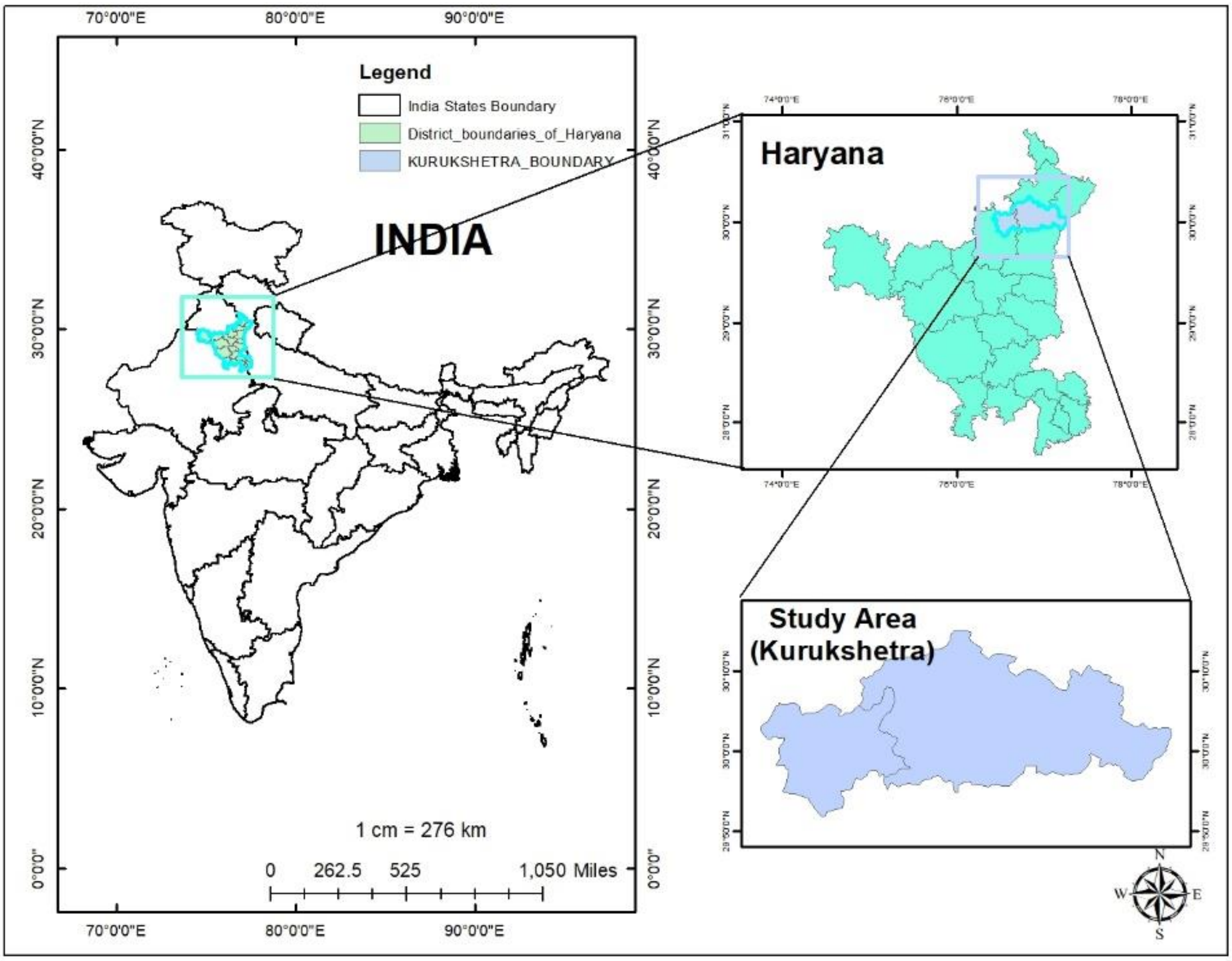

Fig. 1. Study Area.

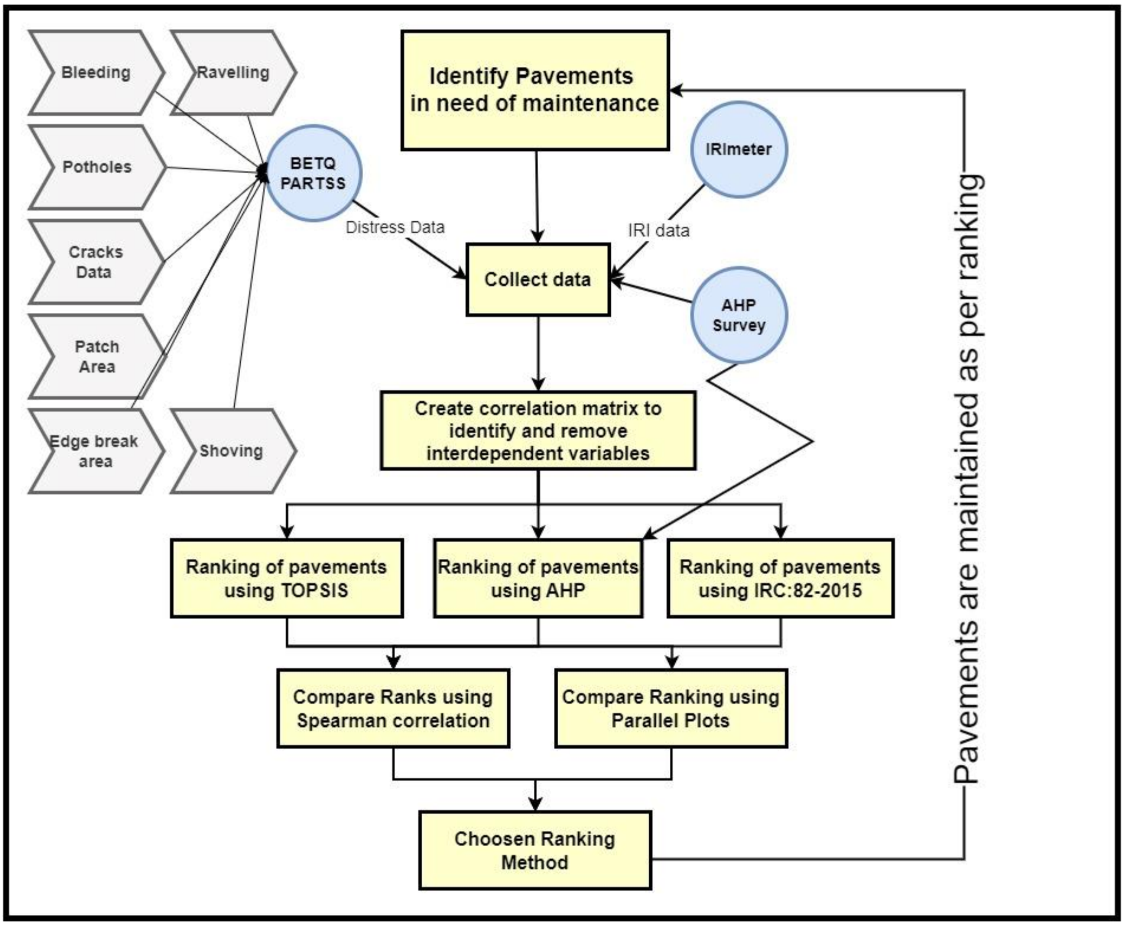

Fig. 2. Flow chart of the methodology adopted.

3.1 Data collection

For the selected road stretches, data related to various pavement distresses and International Roughness Index (IRI) were collected using BETQ-PARTSS and IRImeter, respectively. Roads were divided into 104 sections of 500m each. In BETQ-PARTSS, for videography, a camera (Figure 3 (a)) is mounted through a stand (Figure 3 (b)) at the top of the vehicle (Figure 4).

After installation, the equipment is calibrated as per manufacturer guidelines (Figure 5). The collected video is processed using BETQ SemiDistress software (Figure 6) to measure distress. Distresses used in the study are described in Table 1. The data is extracted using BETQ-PARTSS software in '.csv' format.

Fig. 3. (a). Camera.

Fig. 3. (b). Mounting Stand for BETQ-PARTSS.

Fig. 4. The mounting stand is fixed on the top of the vehicle.

The sample data output for different road sectionsis tabulated in Table 2. Measured distresses were converted in terms of pavement area percentage.

Fig. 5. Calibration of the equipment.

In order to understand the statistical spread of various distresses, Violin plots are used (Figure 7) [31]. The violin plot integrates elements of the box plot and the density plot, providing a comprehensive visualization of the data distribution, including central tendency, spread, and potential skewness.

Table 1. Description of various distresses.

Abbreviation	Variable name	Description
V1	Pothole %	The area of potholes in the pavement section is represented as a percentage of the total area of the pavement.
V2	Alligator %	This variable represents the area for alligator cracks per total pavement area.
V3	Longitudinal/Transverse Cracks %	It represents the longitudinal and transverse cracks of the pavement area per total pavement area.
V4	Ravel %	It represents the percentage of the pavement area where ravelling has occurred.
V5	Patch Area %	It represents the pavement area in percentage where the patching has been done.
V6	Bleeding %	It represents the area of pavement in percentage where bleeding has occurred.
V7	Edge Break Area %	It represents the percentage of the area of pavement suffering from edge breaking.
V8	Shoving %	It represents the percentage area of pavement where shoving is visible.
V9	IRI (m/km)	It represents the pavement's International roughness index in terms of meters per km of the length of the pavement.

Table 2. Sample data set for various pavement distresses.

Section No.	Pothole % (V1)	Alligator % (V2)	Longitudinal/ Transverse cracks % (V3)	Ravel % (V4)	Patch Area % (V5)	Bleeding % (V6)	Edge Break Area % (V7)	Shoving % (V8)	IRI (m/km)
1	0.23	1.11	0.17	0.99	0.00	0.11	0.92	0.00	3.67
2	0.56	3.25	0.09	1.65	0.41	0.42	0.44	0.00	3.65
3	0.41	0.14	0.01	0.08	0.00	0.40	0.00	0.00	3.08
4	0.18	0.04	0.10	0.14	0.00	0.46	0.03	0.00	2.65
5	0.17	0.11	0.04	0.18	0.00	0.12	0.60	0.00	2.79
6	1.31	0.00	0.46	0.05	0.00	0.00	0.00	0.00	9.08
7	2.26	0.04	2.48	0.32	0.00	0.01	0.00	0.00	3.53
8	0.26	0.03	0.08	0.86	0.00	0.00	0.00	0.00	3.15
9	0.03	0.00	0.35	1.47	0.24	0.07	0.08	0.07	3.08
10	0.68	0.00	0.06	0.64	0.14	0.00	0.00	0.00	3.44
11	0.70	0.00	0.27	1.75	0.04	0.00	0.00	0.23	2.98
12	0.36	0.00	0.08	2.01	0.01	0.00	0.25	0.11	2.68
13	0.02	0.00	0.08	2.05	0.10	0.00	0.00	0.00	3.06
14	0.28	0.00	0.02	3.37	0.14	0.00	0.00	0.00	3.47
15	0.18	0.00	0.35	2.00	0.00	0.00	0.60	0.00	4.12

It can be observed from the violin plots that the pavements considered in this study have a small spread of distress magnitudes. The variables i.e. pothole, longitudinal/transverse cracks, bleeding, and edge break area have maximum values of less than 1%. Such small distress magnitude makes the decision-making process a big challenge for decision-makers.

The spread for alligator(%), ravelling (%) and IRI is comparatively very large, and relying the maintenance operations solely on these distresses is discouraged [32–34]. It is suggested that the decision-making process must include a vast range of defining features for the problem [20,35].

Studies suggest including all the parameters collected in decision-making [36–40]. Hence, maintenance prioritization of pavements with small magnitude distresses calls for an objective/ data-driven approach.

The dots in the figures represent the individual observations. The bulb of the plot represents the probability distribution of the individual variable. Figure 7(a) shows that although the variables in the different sections have a high range, the probability distribution of the variables (pothole, longitudinal/transverse cracks, bleeding, edge break area) lies close to zero. The patch area and shoving in the pavements are low and can be attributed to the low volume of commercial traffic on the PMGSY roads[27,30]. However, ravelling (Figure 7 (c)) has a higher percentage of occurrence in the sections than other distresses. The violin plot for IRI values in Figure 7(d) reveals that while various distresses are minimal across all sections, some exhibit high IRI values. This statistical spread of values suggests that even limited distress can significantly impact pavement smoothness.

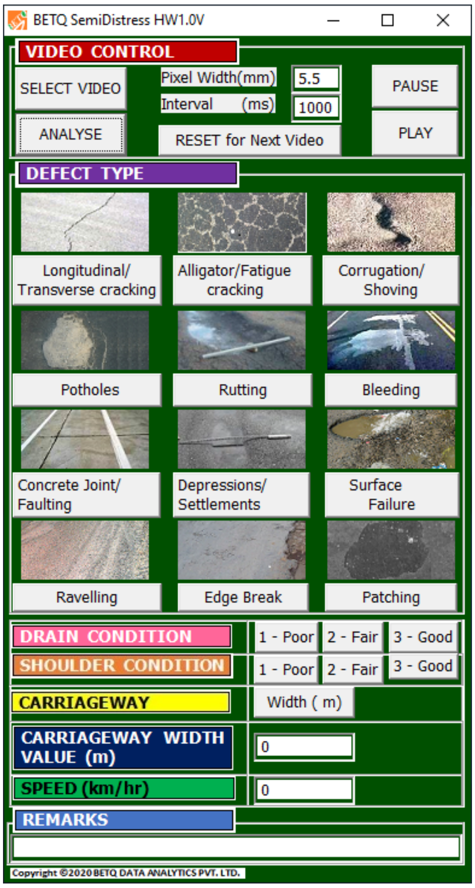

Fig. 6. BETQ SemiDistress software window.

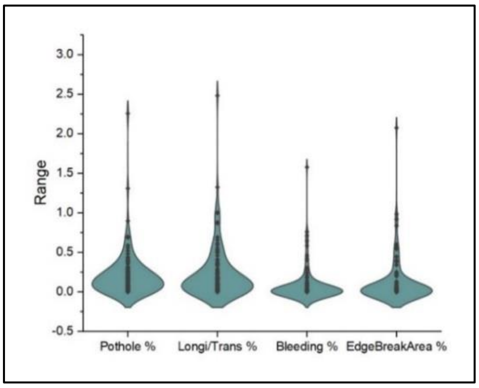

Fig. 7. (a) Violin plot for Pothole, Longitudinal /Transverse cracks, Bleeding, Edge Break Area.

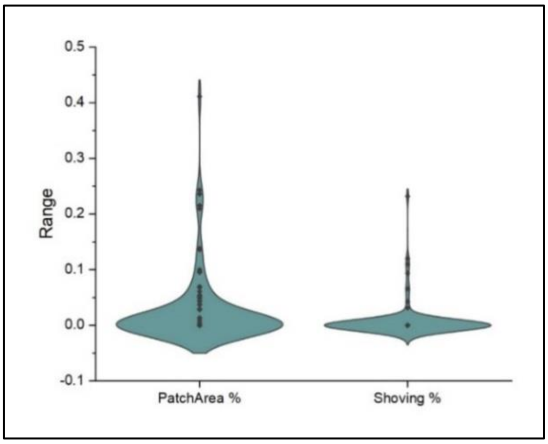

Fig. 7. (b) Violin plot for Patch area and Shoving.

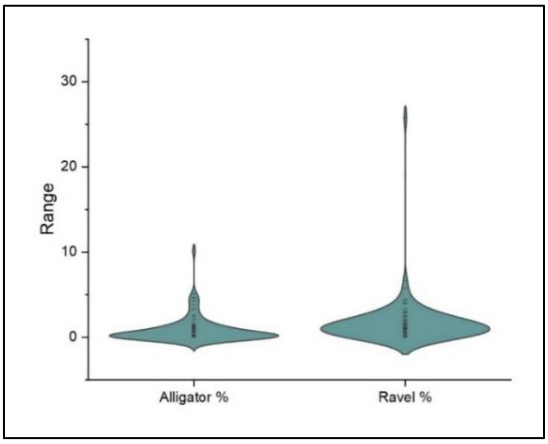

Fig. 7. (c) Violin plot for Alligator cracks and Ravel.

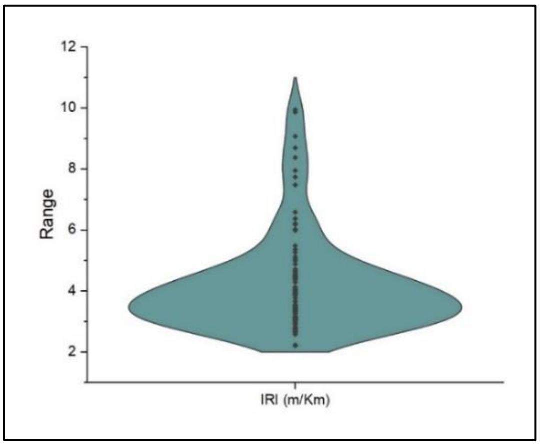

Fig. 7. (d) Violin plot for IRI.

4. Correlation among various distresses

The correlation matrix was developed using Microsoft Excel to understand the interdependence of the collected distresses (Figure 8). This analysis is aimed to identify similarities among various distresses. Variable 'edge break area' and 'alligator cracks' are correlated with each other. Both represent the cracking aspect of pavement deterioration. However, most of the distresses exhibit weak correlations with each other, which shows that each distress represents the deterioration of pavement in different aspects, and the distresses are not interdependent.

	Pothole %	Alligator %	Longitudinal/Transverse cracks %	Ravel %	Patch Area %	Bleeding %	Edge Break Area %	Shoving %	IRI
Pothole %	1								
Alligator %	-0.116	1							
Longi/Transverse cracks%	0.416	0.421	1						
Ravel %	0.035	0.140	0.028	1					
Patch Area %	0.084	0.119	-0.039	0.025	1				
Bleeding %	0.031	0.066	0.104	-0.055	0.040	1			
Edge Break Area %	-0.015	0.559	0.097	0.000	0.160	0.162	1		
Shoving %	0.120	-0.081	-0.064	0.003	0.034	0.044	0.087	1	
IRI	0.030	0.026	0.087	-0.068	-0.126	0.088	-0.034	-0.086	1

Fig. 8. Correlation matrix for various distresses.

The approach of developing correlation matrices with Principal Component Analysis (PCA)[41,42] to reduce the number of variables is avoided in the present study, as removing variables based on weak correlations harms the model's performance. Therefore, all pavement distresses were retained in the analysis to ensure a comprehensive assessment.

5. Calculations of ranks by IRC:82-2015

The first revision of the "Code of Practice for Maintenance of Bituminous Road Surface" IRC:82-2015 [43] is a comprehensive guideline for maintaining bituminous road surfaces in India. This code outlines systematic procedures and criteria to assess road conditions and prioritize them for maintenance activities.

First, all existing pavement conditions are evaluated for different distresses. Different distresses considered for Major District Roads (MDRs) and Rural Roads (ODR and VR) are tabulated in Table 3. Depending upon the level of distress, a particular road section is assigned a rating for that particular distress. Similarly, road section is rated for different distresses. Each distress rating is multiplied by a fixed weight assigned to that particular distress (Table 4). The final rating value is calculated by taking an average of the weighted rating values of all distresses.

Table 3. Pavement Distress Based Rating for MDR(s) and Rural Roads (ODR and VR).

Defects	**Range of Distresses**		
Cracking (%)	>20	10-20	<10
Ravelling (%)	>20	10-20	<10
Pothole (%) v	>1	0.5 to 1	<0.5
Patching (%)	>20	5-20	<5
Settlement and Depression (%)	>5	2 to 5	<2
Rating	1	1.1-2	2.1-3
Condition	Poor	Fair	Good

Table 4. Weight for each Distress.

S no.	Parameter	Fixed Weight
1	Cracking	1.00
2	Ravelling	0.75
3	Potholes	0.50
4	Shoving	1.00
5	Patching	0.75
6	Settlement	0.75
7	Rut Depth	1.00

The road with minimum rating value shall be assigned topmost priority and with maximum rating the least priority in the maintenance.

6. Rank prediction through TOPSIS

TOPSIS is an MCDM approach for prioritization, having wide application in various fields of engineering, management and marketing which include scheduling, supply chain management, design engineering and manufacturing industry [4,44,45].

Ching and Kwangsun developed the TOPSIS method in 1981[46]. It is based on the approach that the chosen alternative should have the shortest path from the Positive Ideal Solution (PIS) and the longest from the Negative Ideal Solution (NIS). Literature has established following advantages of TOPSIS over other methods[46–49]:

1. It is a simple, rational, and comprehensible method to convey human-like choices.
2. It can measure the relative performance of each alternative in a simple mathematical format.
3. TOPSIS is a computationally efficient method that can handle significantly complex problems.
4. It can be extended to decision-making by a group.

The steps involved in applying TOPSIS to this study are given below:

Step 1. As per Equation (1), a decision matrix of 104 x 9 is created, where each cell represents the pavement section's distresses.

$$[D] = (x_{ij})_{mxn} \tag{1}$$

Here m = 104, and n = 9

Step 2. The matrix is then normalized using Equation (2),

$$[\mathrm{R}] = (\mathrm{r_{ij}})_{\mathrm{mxn}} \tag{2}$$

Where $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$

Step 3. In this study, variables (distresses) represent detrimental effects on pavement condition; lower the values better the situation and higher the values poor the condition. Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS) were determined using Equation (3) and Equation (4):

PIS = S^{+}= {(max r_{ij} | j ε J) where (i= 1,2,3, … m), (3)

and

NIS = S^- = {(min r_{ij} | j ε J) where (i= 1,2,3, … m), (4)

Where J = (1,2,3 .... n | J is associated with the criteria positively impacting the prioritization). The PIS and NIS for all input variables are given in Table 5.

Step 4. The Euclidean distances for each alternative were calculated using equations (5) and (6).

$$E_i^+ = \sqrt{\sum_{j=1}^{n}(x_{ij} - S^+)^2},\ i= 1,2,3, \dots m \quad (5)$$

$$E_i^- = \sqrt{\sum_{j=1}^{n}(x_{ij} - S^-)^2},\ i= 1,2,3, \dots m \quad (6)$$

The Euclidean distance of each road section to the PIS and NIS was visualized using the radial pattern chart (Figure 9). A logarithmic scale was utilized to depict variations in the Euclidean distances.

Step 5. Relative closeness to the ideal solutions was calculated using Equation (7):

$$C_i^+ = \frac{E_i^+}{E_i^+ + E_i^-},\ i= 1,2,3, \dots m \quad (7)$$

Pavement sections are ranked as per C_i^+ value; the section with maximum C_i^+ value is ranked one and subsequent ranks in decreasing order of C_i^+ values.

Table 5. Positive Ideal solution and Negative Ideal solution for all variables.

	Pothole	Alligator	Longi/Trans	Ravel	Patch Area	Bleeding	Edge Break Area	Shoving	IRI
PIS	0.0108	0.0071	0.0098	0.0124	0.0346	0.0119	0.0110	0.0851	4.7E-05
NIS	0	0	0	0	0	0	0	0	1.04E-05

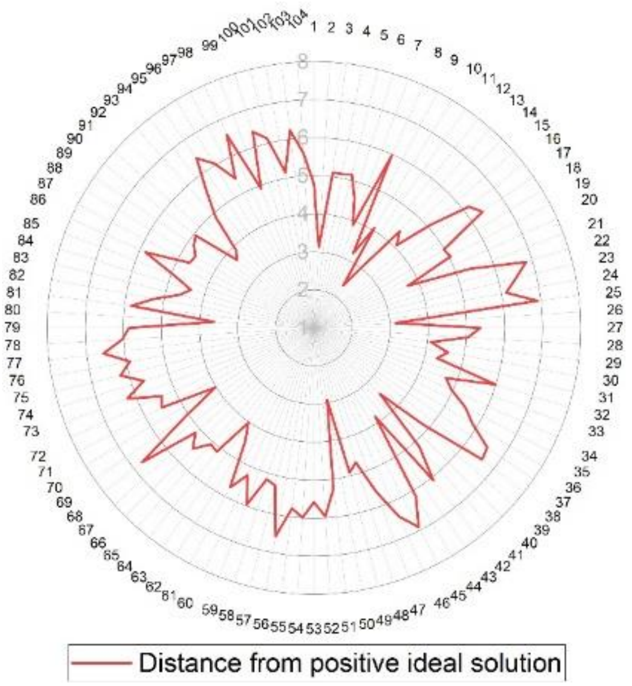

Fig. 9. (a) Distance of each pavement section from PIS.

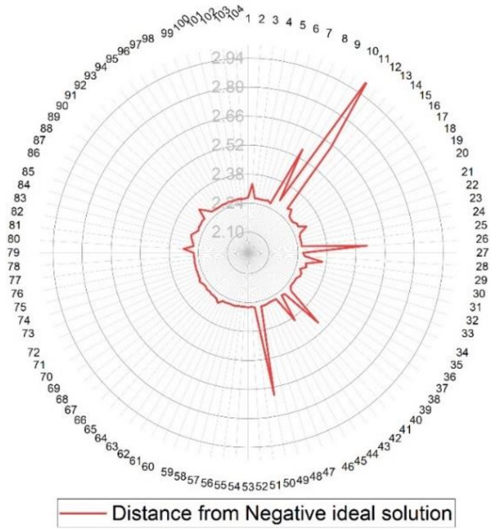

Fig. 9. (b) Distance of each pavement section from NIS.

7. Rank prediction using AHP

Thomas L. Saaty developed AHP in the 1980s [39]. It is a commonly used tool by decision-makers to evaluate alternatives and deal with complex problems. AHP uses a mathematical approach to aid decision-making and divide complex problems into a hierarchy of criteria and sub-criteria.
The AHP method relies on the decision-maker's subjective judgments and opinions, and subjective judgments are converted to numerical values to make them objective. Relative weights and priorities are derived for each decision-maker's judgment and combined for priority ranking as output.

7.1 Methodology

The steps involved are depicted through a flow chart (Figure 10). A pairwise matrix (Equation 8) is populated using comparison attributes C_i and C_j. C_i represents the importance of ith attribute when compared with jth attribute, and C_j represent the importance of jth attribute when compared with ith attribute.

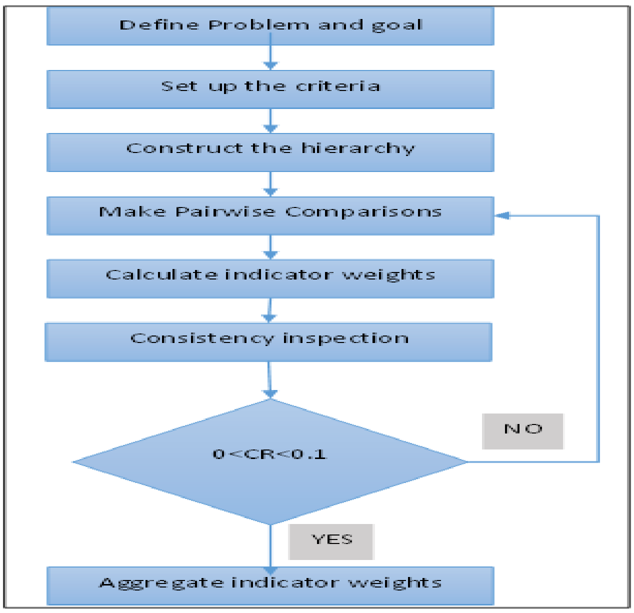

Fig. 10. Flow chart for AHP.

$P=(p_{ij})$ (i , j = 1, 2, 3, 4,.., n), (8)
Where p_{ij} is subjected to following constraints:
Constraint 1: if $p_{ij} = \alpha$, then $p_{ji} = 1/\alpha$, $\alpha \neq 0$
Constraint 2: Value of 'α' is assigned as per Saaty Scale (Table 6)
Constraint 3: diagonal elements in the matrix are equal to 1

Table 6. Saaty Scale for Pairwise matrix.

Intensity of Importance	Meaning
1	Equal importance
3	Moderate importance
5	Strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate values between the two adjacent judgments

Individuals were asked to provide the relative importance of each distress. The pairwise comparison matrix populated by first participant is shown in Figure 11. The abbreviations mentioned in Table 1 are used to represent respective variables. Similarly, data was collected from all the participants.

	V1	V2	V3	V4	V5	V6	V7	V8	V9
V1	**1**	3	3	1	8	9	9	8	2
V2	1/3	**1**	1	1/2	9	6	5	3	1
V3	1/3	1	**1**	1/3	8	8	3	1	1
V4	1	2	3	**1**	9	8	9	9	3
V5	1/8	1/9	1/8	1/9	**1**	1	1/3	1/3	1
V6	1/9	1/6	1/8	1/8	1	**1**	1/2	1/6	1/6
V7	1/9	1/5	1/3	1/9	3	2	**1**	1/3	1/9
V8	1/8	1/3	1	1/9	3	6	3	**1**	1/8
V9	1/2	1	1	1/3	1	6	9	8	**1**
Sum	**3.6**	**8.8**	**10.6**	**3.6**	**43**	**47**	**39.8**	**30.8**	**9.4**

Fig. 11. Pairwise comparison matrix for first participant.

Consistency index (CI) for pairwise comparison of each participant is calculated using Equation (9)

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{9}$$

Where λ_{max}= largest eigenvalue of the pairwise comparison matrix, and n = 9, the number of matrix elements.
The natural log for each element of the pairwise comparison matrix (Figure 11) is calculated as shown in Fig. 12.

Using the collected survey data in Fig. 11 and 12, the natural exponential function is calculated as explained below and highlighted in the second last column of Fig. 12. The second last column in Fig. 12 calculates the natural exponential function by the ratio of 'sum of row elements' and 'number of criteria'. i.e.

$$\exp\left(\frac{1.09861+1.09861+2.08+2.19722+2.19722+2.07944+0.693}{9}\right) = 3.57$$

The last column represents the row-wise geometric mean (RGMM) of the distresses [50], i.e. (3.57*100)/14 = 26%, where 14 is the sum second last column. The largest eigenvalue (9.78036) is obtained by matrix multiplication of the last row (Fig. 11) and the last column (Fig. 12).

Ln(A) for calculation of RGMM												**RGMM**
1	-	1.09861	1.09861	-	2.07944	2.19722	2.19722	2.07944	0.69315	-	3.57	26%
2	-1.09861	-	-	-0.69315	2.19722	1.79176	1.60944	1.09861	-	-	1.72	13%
3	-1.09861	-	-	-1.09861	2.07944	2.07944	1.09861	-	-	-	1.40	10%
4	-	0.69315	1.09861	-	2.19722	2.07944	2.19722	2.19722	1.09861	-	3.61	27%
5	-2.07944	-2.19722	-2.07944	-2.19722	-	-	-1.09861	-1.09861	-	-	0.30	2%
6	-2.19722	-1.79176	-2.07944	-2.07944	-	-	-0.69315	-1.79176	-1.79176	-	0.25	2%
7	-2.19722	-1.60944	-1.09861	-2.19722	1.09861	0.69315	-	-1.09861	-2.19722	-	0.38	3%
8	-2.07944	-1.09861	-	-2.19722	1.09861	1.79176	1.09861	-	-2.07944	-	0.68	5%
9	-0.69315	-	-	-1.09861	-	1.79176	2.19722	2.07944	-	-	1.61	12%
											13.54	9.7804

Fig. 12. Natural log of the pairwise comparison matrix.

Using Equation (9), CI is calculated for each participant. For the calculation of consistency ratio (CR), Equation (10) is used, where the Random Index (RI) is taken as 1.45 for n = 9 [51]

$$CR = \frac{CI}{RI} \tag{10}$$

Since CR value of first participant is less than 10%, the pairwise comparison matrix is consistent. The consolidated weights for each distress are calculated using Equation (11).

$$C_{ij} = \exp(\sum_{k=1}^{N} \ln\,(p_{ij\,(k)})) \tag{11}$$

Where C_{ij} is an element of the consolidated decision matrix, N is the number of participants, and p_{ij} is the pairwise value for different distress assigned by participants. The consolidated decision matrix is obtained, as shown in Fig. 13.

	V1	V2	V3	V4	V5	V6	V7	V8	V9
V1		4.08	4.35	1.31	4.01	4.32	4.11	1.62	1.66
V2	0.24		1.13	0.52	2.47	2.83	1.72	0.98	0.67
V3	0.23	0.88		0.57	2.57	2.04	1.28	0.79	0.65
V4	0.76	1.93	1.76		2.81	3.29	2.49	1.69	1.48
V5	0.25	0.40	0.39	0.36		0.88	0.33	0.21	0.62
V6	0.23	0.35	0.49	0.30	1.13		0.47	0.36	0.60
V7	0.24	0.58	0.78	0.40	3.02	2.11		0.58	0.43
V8	0.62	1.02	1.27	0.59	4.74	2.79	1.72		0.78
V9	0.60	1.50	1.53	0.67	1.62	1.67	2.31	1.29	

Fig. 13. Consolidated decision matrix.

The average of each row is calculated to get the weights. The weights calculated in the study are shown in Fig. 14.

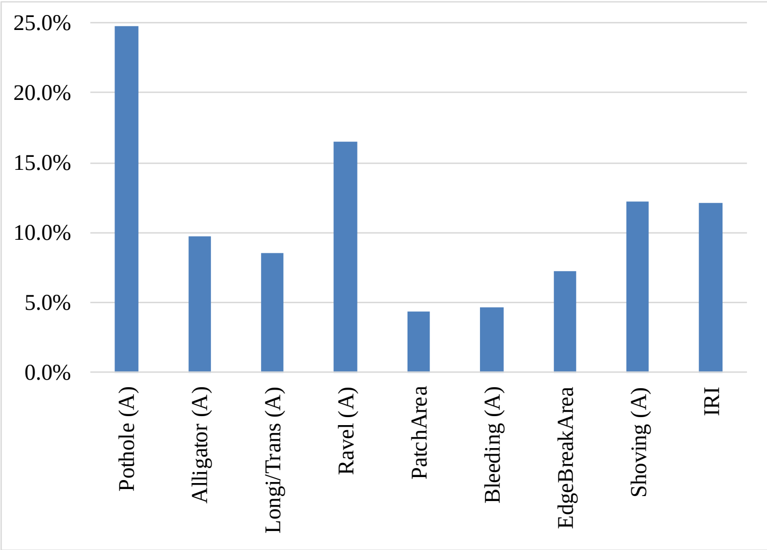

Fig. 14. Weights for each variable.

The pavements' overall priority weight (PW) is computed using Equation (12).

$$PW = \sum_j W_j X_{ij} \tag{12}$$

Where W_j= weights assigned to distress, and

X_{ij}= magnitude of the distress for that pavement section.

The pavement section with the highest priority weight is ranked one, and accordingly, ranks are assigned to all the sections under consideration.

8. Results and discussion

For a huge road infrastructure, maintenance prioritisation is always required, particularly in developing countries, because of scarce resources. IRC 82 (2015) classifies pavement sections as Good, Fair, and Poor based on distress level. Maintenance is prioritised based on section classification after assigning fixed weight to different distresses. However, there is limited scope to account for other than predefined distresses.

In the present study, two MCDM approaches, i.e. TOPSIS and AHP, are also used for maintenance prioritization [39,52,53]. Obtained ranks by both methods are compared with IRC ranks (Figure 15). In order to assess the level of fitment statistical analysis is performed using Spearman rank correlation coefficient and Index of agreement value[54]. Spearman's rank correlation coefficient is a nonparametric measure designed to assess the strength and direction of a monotonic relationship between two variables.

Spearman's rank correlation coefficient is calculated using Equation (13), and results are presented in Table 7.

$$\rho = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \tag{13}$$

Where 'ρ' is the Spearman rank correlation coefficient,
d_i is the absolute difference between the two ranks of pavement section 'i',
and 'n' is the number of observations for which the correlation coefficient is to be calculated.

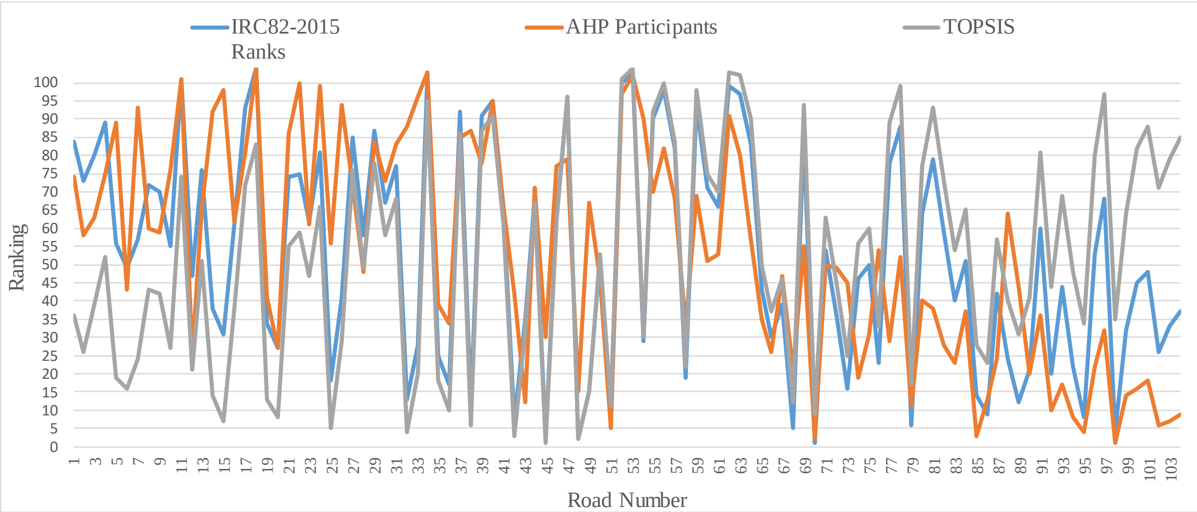

Fig. 15. Comparison of Ranks for TOPSIS and AHP.

The Index of agreement (Equation 14) is used to quantify the degree to which the two rankings align. It allows for a detailed understanding of ranking similarity. It is a measure to make comparisons between models [55].

$$\text{Index of agreement} = 1 - \frac{\sum(P_j - O_j)^2}{\sum(|P_j - \bar{O}| + |O_j - \bar{O}|)^2} \tag{14}$$

Where P_j = rank calculated by the model,

O_j = rank calculated by IRC method

$\bar{O}$ = average of ranks calculated by IRC

Table 7. Rank comparison with IRC:82-201.

	TOPSIS	AHP
Spearman correlation coefficient*	0.78	0.62
Index of agreement *	0.88	0.79

*Higher values are better.

It was observed from Table 7 that a higher Spearman correlation coefficient and Index of agreement values for TOPSIS indicate a better correlation with IRC than AHP.

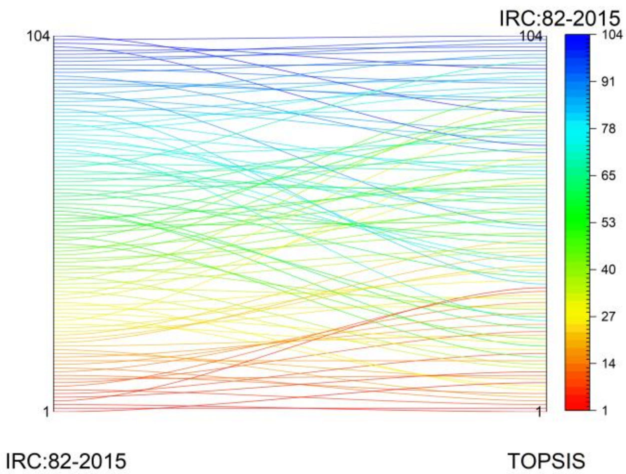

Fig. 16. Parallel plot for rank comparison between IRC and TOPSIS.

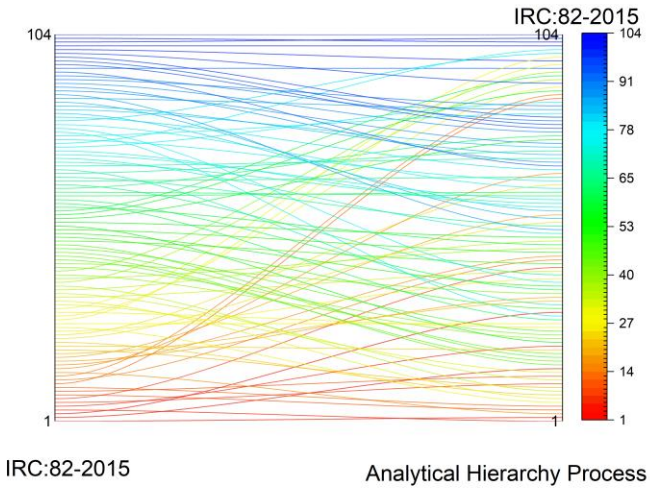

Fig. 17. Parallel plot for rank comparison between IRC and AHP.

For visual comparison, parallel plots are generated between IRC vs TOPSIS and AHP ranking (Figures 16 and 17). Through horizontal lines, IRC ranks are compared with TOPSIS and AHP ranks. It is observed that TOPSIS rankings correlate better with IRC ranks than AHP.

Ranking through TOPSIS can be further enhanced by assigning weightage to different distresses, incorporating factors such as traffic on the road stretches, importance/level of road and land use, etc.

9. Conclusion

In this study, pavement maintenance prioritization has been done using two multi-criteria decision approaches, i.e. TOPSIS and AHP. The proposed methodology has been used to schedule the maintenance of 104 road sections of Kurukshetra district of the Haryana region in India. The variables included in the study are surface distresses (potholes, alligator cracks, longitudinal cracks, ravelling, patch area, bleeding edge break area, and shoving) and IRI of the pavement. The correlation analysis of the chosen variables reveals mild correlation among the variables, and hence, no distress was removed from the analysis. The pavements were ranked using the TOPSIS and AHP methods and ranks obtained from both methods are compared to IRC, a standard method for ranking Indian roads. The Spearman rank correlation coefficient for the ranks obtained by TOPSIS and AHP compared to IRC was 0.78 and 0.62. The Index of agreement values for TOPSIS and AHP are 0.88 and 0.79, respectively. As observed from the values, TOPSIS method outperforms the AHP analysis as the TOPSIS ranks matches well with the IRC ranks. A high degree of consistency is also observed from the parallel plots, highlighting both method's ranking capabilities.

The TOPSIS method overcomes the limitation inherent in the IRC method, which relies on fixed weights assigned to different distresses. TOPSIS employs a relative ranking system, positioning each pavement section based on its proximity to an ideal choice for maintenance. This integral objectivity makes the TOPSIS ranking a robust and better approach for maintenance prioritization.

The AHP method, while offering some flexibility in incorporating expert opinions through variable weights, yielded lower concordance with the IRC method. The lower concordance suggests that the subjective nature of AHP weighting might introduce inconsistencies in ranking, particularly when compared to a standardized approach like IRC. Hence, TOPSIS is a more reliable and secure approach for ranking the pavements due to its emphasis on objectivity.

The study results prove that the TOPSIS method provides a viable tool for making data-driven and objective pavement maintenance decisions on Indian roads. The authors recommend using TOPSIS as a prioritization method for the maintenance prioritization of Indian roads.

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Conflict of interest

The authors declare no conflict of interest in any form regarding the work presented in the present manuscript.

Author Contribution statement

Ankit Sharma: Writing-Original Draft, Review & Editing, Data curation, Analysis.

Praveen Aggarwal: Conceptualization, Methodology, Investigation, Project administration.

S.N. Sachdeva: Supervision, Manuscript review, Investigation, Project administration.

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