Assessmentof State Highway Based on Subjective And Conjective Model

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Abstract. This study focuses on the surface assessment of flexible pavement using the HDM-4 (highway development and management) and International Roughness Index (IRI) for state highway connecting from Miyapur to Medchal. The HDM-4 road deterioration models where utilized to make an effort to simulate existing condition of pavement over the IRI models. The existing conditions of routes are evaluated under the loaded, unloaded vehicle, undulation of pavement surface, rutting and fatigue distress over the all section. The current study aims to examine the progression of distress such as rutting and fatigue cracks which areconsider in design criteria, across all routes. It also describes the condition of pavement with respective traffic growth in terms of IRI. Further study address the several other distresses affect the pavement condition which is not in account of design of pavement. But, the common distress data of particular routes were noticed as fatigue, rutting, pothole, patches, edge drop and cracking. These distresses are most often in the particular state highway (SH-216) from Miyapur to Ayodhya Cross Roads at Hyderabad. Particular routes consist of several geometric variations in design of number land, control and un control traffic intersection. Thus based on the roads geometric it divided in to in two following stretches such as Miyapur to VNR (MV), VNR to Miyapur (VM), VNR to Gandi Maissama (VG) and Gandi Maissama to VNR (GV) for the convenient of the study. This study elaborates the roughness of the pavement based on IRI value; this was measured using the bump recorder. Among all these routs which is found as higher in MV routes, it was observed due to higher number of loaded vehicle. Further which leads to the cracking in pavement, thus causes several distress over the time. Current study indicates the prediction of all distress and their periodic maintenance is essential for better pavement condition.

Keywords: HDM-4, IRI, Pavement Distress, Traffic.

1 Introduction

The process pavement evaluation involved several distresses, which are occurred due to increased traffic, method of construction of pavement, mechanical properties of pavement materials, and climate condition of pavement etc. The improper construction and insufficient quality of material used in construction of pavement leads to the early deterioration in pavement, further pavement age and increase vehicles are responsible slow deterioration of pavement section. Effective prediction of distress and maintenance of pavement is required for the better performances of the pavement. The pavement maintenance and management system (PMS) have enhanced

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significantly using the computer technology. Currently, several tool or mechanisms are available to assist the performance of the pavement;among themHDM-4 more effectively utilize the resources available for roadway maintenance and restoration.In order to assist engineers and highway administrators in making decision about pavement using HDM-4 was created as a predictive tool for potential for social, economic, and environmental effects.

The functional state of a pavement refers to its ability to provide a safe, smooth, and quiet riding surface for the general public while the structural condition refers to its capacity to handle the existing and future traffic loadings. To address the performance of the pavement section need to be identifying the major distress, rehabilitation and preservation so that helps in priorities section to allocate budgets, and determine financial needs [1]. A valuable tool for monitoring pavement performance as well as a way to create performance models that can be used to forecast future circumstances (both with and without the application of treatments) are made possible by the long-term gathering of performance data on a pavement network [2]. To ascertain the kind, severity, degree, and location of distress, visual condition questionnaires are typically conducted. There are numerous techniques for performing surveys of the condition of pavement that are used by the various entities involved. Any pavement management system must include pavement condition data in order to assess the state of the pavement, establish maintenance priorities, and anticipate future requirements [3].

The World Bank suggested IRI as a standard statistic to correlate and calibrate roughness assessments in Brazil in 1982 [4]. An effort was made to link the asphalt pavement's condition to its roughness [5]. Data from numerous sites in the San Francisco Bay area were evaluated for the relationship between pavement deterioration and IRI, Further Significant potholes, patching, and rutting were shown to have the highest association to IRI, but stripping and corrugation had a lower correlation [6]. Hozayen has investigated the impact of asphalt concrete ravelling on pavement roughness, examined how crack sealing, chip sealing, and sand sealing affected the roughness of flexible pavements utilized on state and interstate roadways [7]. They noted that applying 19 maintenanceactions to new pavements had minimal benefits for roughness reduction and that doing so on older pavements had higher benefits [8]. In another study investigated how different maintenance practices, such as slurry seal, chip seal, crack seal, and thin overlays, affected pavement roughness [9]. Karim and Lee did a study to look into and evaluate the connection between pavement discomfort and IRI, the relationship between pavement surface roughness and different types of discomfort was examined in a study conducted in the United States [10]. Further, study were conducted over the 462 pavement portions from 37 projects around the state of Michigan were included in the study [11]. In another study the relation between the pavement distress and the ride quality were evaluated and suggested the better maintenance strategies [12]. Study examined the connections between pavement roughness and distress indicators such as cracks, ravelling, rut depth, and patchwork [13]. A network survey vehicle (NSV) was utilized to collect pavement distress data on four national roads in India, These data were used to create linear and nonlinear regression models between roughness and distress parameters [14]. The utilization and application of HDM-4 in the recent year become necessary assist the performance of the roads, the few study were noticed with HDM-4 in urban road evaluation [15-17]. A generalized equation is devised to connect the roughness index (RI) value at a standard speed of 32 km/h to the RI value under different additional speed situations using the statistical package for the social sciences, or SPSS, software [18]. This study demonstrates the application of the HDM-4 model to determine the optimal Maintenance and Rehabilitation (M&R) strategy for each road section. It also includes a comparative analysis of scheduled versus condition-responsive M&R strategies [19-20]. The case study examined various maintenance activities, including as patching, overlaying, resurfacing, crack sealing, and overlaying. The report includes a breakdown of the unit expenses related to each of these maintenance tasks [21] The procedure of calibrating and modifying the model will be explained in depth in this paper about experiences extreme humidity, heat, and a substantial amount of monthly precipitation along with the outcomes of the calibration process for two chosen long-term pavement performance (LTPP) sites [22]. This research uses a back-propagation neural network methodology to evaluate the relationship between pavement distress and the International Roughness Index (IRI) [23].

Several studies are stated that the various distress and their maintenance in their investigation, but the studies are not yet noticed that those distress are not consider in design of pavement. Based on the previous study model development and validation of models, the applications of these studies are noticed difficulties in the field to predict damages. The studies are essential to predict the progression of distress with respective growing traffic condition. Further, the study also describes the consideration of major distress in design. In view of the above, the current study briefly discussed about distress progression, and their importance in design consideration. It also ranking of pavement section based on rutting, fatigue, and IRImodel.

2 Methodology

Step 1: Routes selection based on similar data,

Step 2: Data collection such as geometric data, Traffic data, distress data manually, and photography

Step 4: Evaluation of IRI value using mobile bump recorder and predicted for the 10 years using HDM-4

Step 5: Predication of distress data using HdM-4 model for 10 years based on existing data

Step 6: prediction and Progression of distress data and IRI values with respective current and future traffic with respective years. Further, making decision routes based on obtained distress and IRI.

Fig. 1. Rutting of pavement along the length.

Fig. 2. Fatigue of pavement along the length.

3 Traffic Flow Statistics

Large enough samples are occurred during manually counted traffic. The Representation of this traffic includes two-wheeled vehicles (TW), passenger cars (PC), buses (BUS), and light commercial vehicles (LCV) High commercial vehicles (HCV). A categorized volume count of the 10 hours of motorized and non-motorized vehicle observations was used. The traffic data was collected Vehicle access was allowed during peak hours, and summits in the morning and evening were combined. Absorbed traffic data were entering in to the hdm-4 system to predict the traffic volume on each route. The project analysis were contoured are the all stretches noticed increase traffic volume. The growth of the traffic volume also predicted using IRC the predicted traffic from HDM-4 and IRC code will have localizable variation. The study observed the maximum growth in vehicles more notice in VNR to Miyapur direction from the last 2 years data set. Which is affined due to faster development affinities in inter structure as well as. The study area of current research is shown in fig1.

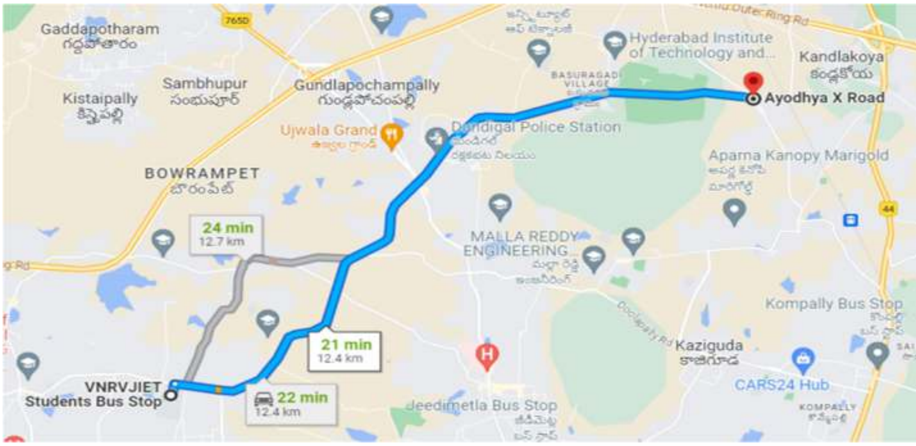

Fig. 3. Study route from VNRVJIET to Ayodhya X road.

4 Data Analysis and Discussion

The annual average traffic data for all the segments is illustrated in Fig. 6. The current traffic data for these segments has been recorded based on peak hours and estimated for annual average daily traffic across various routes. Among these segments, the MV stretch shows the highest traffic volume, recorded as 24000 AADT for the year 2023, and is projected to reach 53000 AADT by 2032.

4.1 Rutting

The permanent or irreversible distortion brought on by traffic inside the pavement layers, which, if directed into wheel routes, accumulates over time and manifests as a rut, is known as rutting. Fig 4 represented the obtain rutting over the all section, that considered for the design of pavement section. It shows the progression year by year.

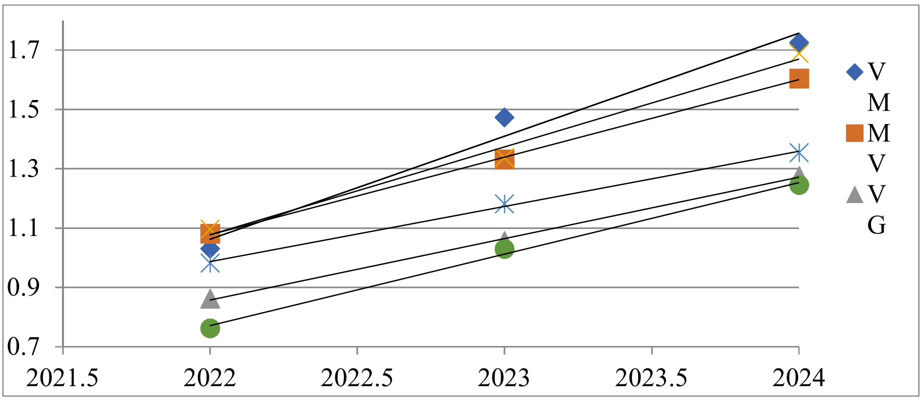

Fig. 4. Analysis ofrutting using linear regression.

The obtained progression of the rutting were found as the maximum in MV routes where the relation is found the $R^2 = 0.9999$. It is represented the higher development in rutting models. It was found as higher traffic loaded vehicles carrying civil activities in particular area. Whereas the other roués are also subjected with similar traffic. Table 1 presents the regression models and their corresponding R^2 values for each route.

Table 1. Shown the rutting of all stretches.

S.No	Route Code	Name of Route	Liner regression	R^2
1	VM	VNR to Miyapur	y = 0.3475x - 701.58	$R^2 = 0.9759$
2	MV	Miyapur to VNR	y = 0.262x - 528.69	$R^2 = 0.9994$
3	VG	VNR to G- Maissama	y = 0.2965x - 598.45	$R^2 = 0.9885$
4	GV	G- Maissama to VNR	y = 0.207x - 417.7	$R^2 = 0.9987$
5	AD	A-X –road to Dundigal	y = 0.186x - 375.11	$R^2 = 0.9981$
6	DA	Dundigal to A-X –road	y = 0.2415x - 487.54	$R^2 = 0.9963$

At the end of 2024, the observed rutting values for six pavement sections were compared to those generated by the Bump Recorder Rutting Progression Model, as detailed in the table. These observed values were also plotted against the model predictions in Figure 4 to evaluate their correlation. The comparison indicates that the observed rutting values are consistent across different routes, which is expected given the varying climatic conditions and traffic loads. Further, Figure 4 demonstrates a strong correlation, with an R^2 value of 0.98, suggesting that the data points align closely with the model's predictions.

4.2 Fatigue cracks

One of the major problems in flexible pavement is considered as fatigue cracking. It has been determined that the primary causes of bituminous pavement layer cracking.

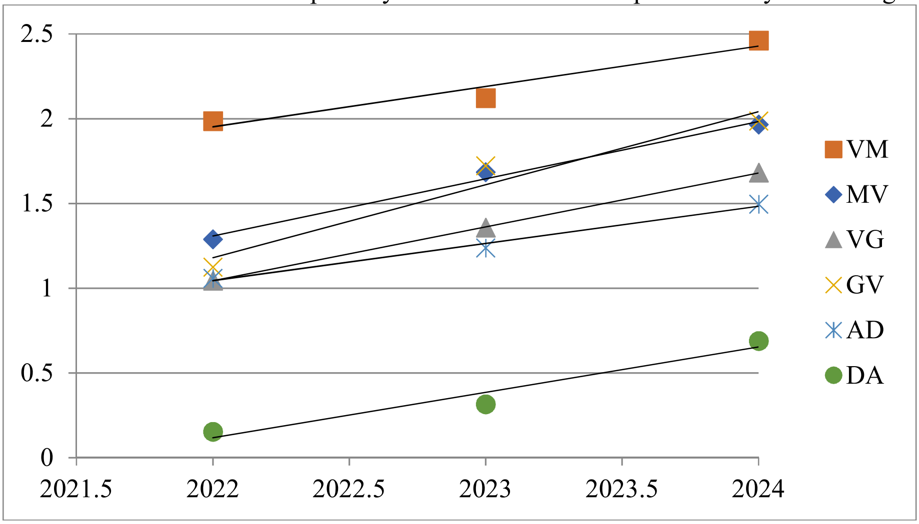

Fig. 5. Analysis offatigue cracking using linear regression.

This crack was obtained due to heavy load as well as inadequate quality of pavement material. Which is found as common cracks in all the stretches, higher among this section was noticed as 2.45 mm^2 in MV routes. It can be obtained due to heavy load, or weather condition or bad quality of the material. Fig 5 shows the obtained and predicted fatigue cracks respectively.

Table 2. IRI model for each routes.

S. No	Route Code	Name of Route	Liner regression	R^2
1	VM	VNR to Miyapur	y = 0.238x - 479.28	$R^2 = 0.9434$
2	MV	Miyapur to VNR	y = 0.338x - 682.13	$R^2 = 0.9903$
3	VG	VNR to G- Maissama	y = 0.318x - 641.95	$R^2 = 0.9999$
4	GV	G- Maissama to VNR	y = 0.4305x - 869.29	$R^2 = 0.952$
5	AD	A-X –road to Dundigal	y = 0.219x - 441.77	$R^2 = 0.9895$
6	DA	Dundigal to A-X –road	y = 0.268x - 541.7	$R^2 = 0.950$

The observed values of the fatigue cracking area for six pavement sections at the end of 2024 were compared with the observed made by the Bump recorder Fatigue cracking Progression Model, as presented in Table . Additionally, these observed values were plotted against each other in Figure 5 to evaluate the correlation between them. The comparison shows that the observed fatigue cracking area values are consistent across different routes, which is reasonable considering the varying climatic and traffic loading conditions. Furthermore, Figure 5 illustrates that the R^2 value of 0.99 for the plot of observed fatigue cracking areas indicate a strong correlation, with the data points closely aligning with the models predictions.

4.3 International Roughness index (IRI)

At the end of 2024, the observed regression area values for six pavement sections were compared to those generated by the Bump Recorder Regression Area Progression Model, as detailed in the table. These observed values were also plotted against the model predictions in Figure 6 to assess their correlation.

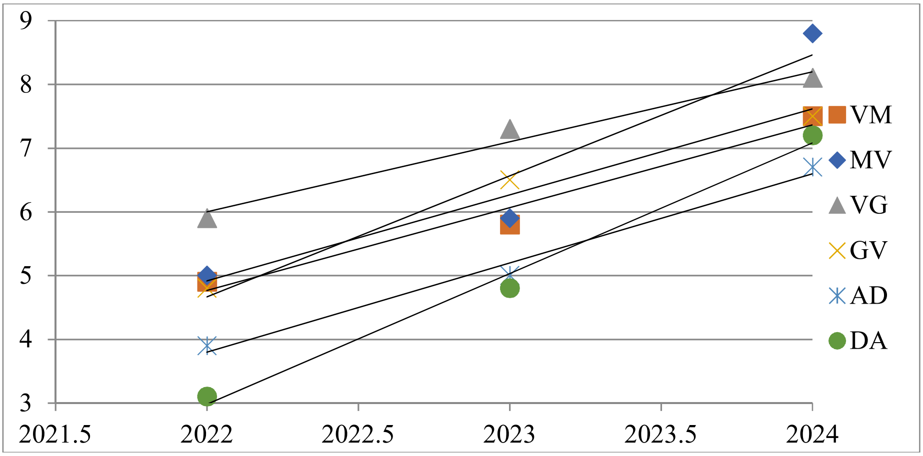

Fig. 6. Analysis ofIRI using linear regression.

The comparison shows that the observed regression area values are consistent across different routes, which is expected due to the varying climatic conditions and traffic loads. Furthermore, Figure 6 illustrates a strong correlation, with an R^2 value of 0.96, indicating that the data points closely align with the model's predictions.

Table 3. IRI model for each route.

S. No	Route Code	Name of Route	Liner regression	R^2
1	VM	VNR to Miyapur	y = 1.3x - 2623	R^2 = 0.969
2	MV	Miyapur to VNR	y = 1.1x - 2218	R^2 = 0.975
3	VG	VNR to G- Maissama	y = 1.9x - 3837	R^2 = 0.915
4	GV	G- Maissama to VNR	y = 1.35x - 2724	R^2 = 0.978
5	AD	A-X –road to Dundigal	y = 1.4x - 2827	R^2 = 0.984
6	DA	Dundigal to A-X –road	y = 2.05x - 4142	R^2 = 0.990

Table 3 represent obtained IRI values, strong relation with predicted roughness in all routes (R^2). It was collected and plotted in one direction of the road in lane only, which may have the all other distress away from the wheel direction. It was purely measured undulation in one lane, which may not accurate for the evaluation of the pavement to make decision for the maintenance. Fig 6 show the major distress occupies over the all section, which are not well address. Further, the IRI will not effective to address condition of the pavement in terms of age, climate characteristic, subjected load characteristics etc. thus the alternate model such as HDM-4 were chosen to make the decision on pavement maintenance to aim the better ad effective manner.

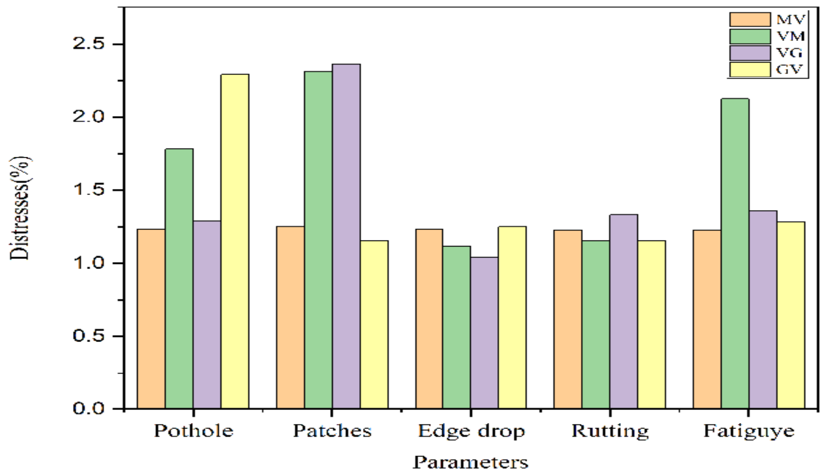

Fig. 7. Analysis ofIRI using linear regression.

Fig 7 represented the over view of distress in all the sections. As discussed the design of pavement is based on rutting, fatigue cracking which is noted that the failure occurs after than these distress. It was clearly noted that the maintenance distress like pothole, patches are occupied in all the sections. Than the design consideration distress which required the poor performance of road. Further if may to extend and create damage in underlying layer.

5 Pavement Maintenance Using Hdm-4

The mean rut depth and the standard deviation were calculated using the rutting data from each route. This study shows how well some routes perform in terms of roughness while taking into account different levels of distress. The deviation rut depth and the mean rut depth are obtained similar for the year of 2028, further it was increased as 23 mm at 2032 year. This prediction of rutting of all the area indicates the faster deterioration of pavement structure.

Fig. 8. Predicted rutting over the time.

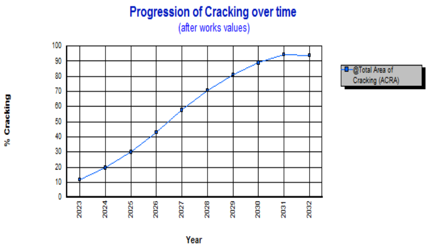

Fig. 9. Predicted Cracking over the time.

Maintenance of pavement, But the design consideration is poorly on rutting and fatigue criteria of the road section. The maintenance of pavement is challenges take due to several the distresses occurs on pavement in limited period. The HDM-4 help in predicting the all the distress cover the road. Further, it can develop different model for easy maintenance of pavement section. The predicted rutting where show in fig9. Represented the mean stranded deviation of rutting over the over for better maintenance of pavement section.

Cracking model is after shown on the road amount of cracks initially development cracking are helping to generation faster deformation of pavement. Further, lead to the development of pothole and patches over the pavement section.

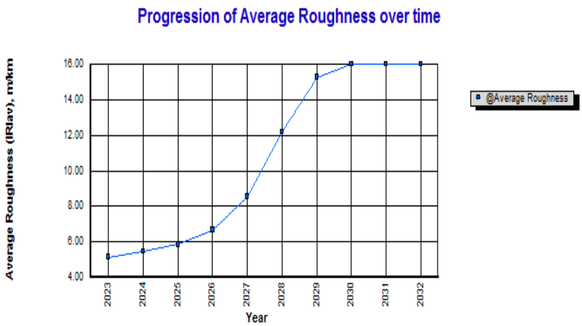

Fig. 10. Average roughness over time period.

Fig. 10 displays the average roughness for each distress for maximum duration of 10 years. The pavement suffering was depicted in the same figure form the year of 2023 to 2032 period. The current study indicatesthe all routes needs more enhancements with respective traffic and traffic to procedure the timely maintenance for safe and comfortable moment. It also address the pavement sections subjected to large loads has higher levels of distress. These distress levels include fatigue, rutting, potholes, and patches, which can contribute to early pavement section failure.

6 Ranking of Pavement and Maintenances Treatment

Finally ranking of pavement using HDM-4, based on the NPV values. And the IRI values based maintenance strategies need to address in this paper. The IRI model on each route indicates the roughness ever the pavement. This is represented in fig11. Initial IRI values are shown the permissible limit, further extended of deration such as 2024, 2025 etc., describe the IRI values. Which is represented the faster deterioration of pavement in recent 2 year.

Table 4. Rankling of pavement section based on HDM-4 IRI values.

Sections	HDM-4 ranking	IRI ranking	MPI ranking
Ayodhya to Dundigal	5	5	4
Dundigal to Ayodhya	6	6	6
VNR to Miyapur	2	4	2
Miyapur to VNR	1	1	1
Gandimaisamma to VNR	4	3	3
VNR to Gandimaisamma	3	2	5

Table 4, represents the measure IRI ranking and obtained IRI ranking the HDM-4. The HDM-4 ranking was available based on NPV/cost of section. The lower ranking of the pavement section is immediately attention so that the further progression distresses can prevent them from major damage under the laying layer. This ranking system shows similar numbers by IRI and HDM-4, But HDM-4 helps in predicting the cost of each section with respective years.Thus the HDM-4 prediction and evaluation is more reliable for better maintenance. Further predicted IRI values and type of maintenance were persecuted in fig11.

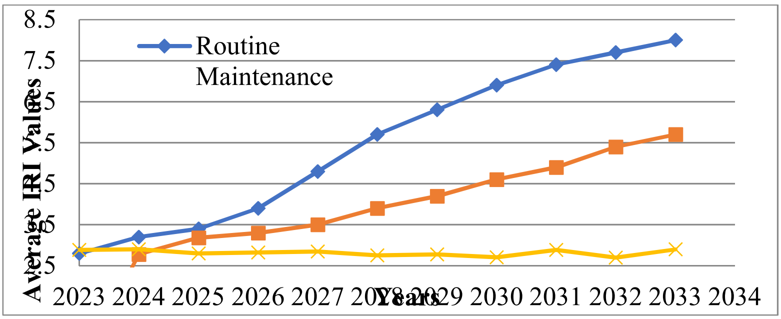

Fig. 11. IRI values and required treatment over the years.

Based on the IRI progression values and HDM-4 model, there are several treatments are noticed, alternate treatments are sectioned in fig11.Among these treatment methods, routine maintenance proposed the routes for every years. In absence of routine maintenance, the alternate method over proposed as surface design and year thus of pavement to reinforce the performance of pavement criteria.

7 Conclusion

The investigation mentioned above has led to the following conclusions:

- In MV routes, where the relationship is discovered to be R2 = 0.9999, the obtained progression of the rutting was found to be the maximum. In rutting models, it is a representation of the higher development. specific location had higher traffic loads. However, same traffic also affects the other routes.
- The deviation rut depth and the mean rut depth are obtained for the year of 2022, further it was increased as 38 mm at 2025 year in prediction, which is observed that beyond limits. These predictions of rutting indicatethe faster deterioration of pavement structure.
- Given the various climatic and traffic loading conditions, the comparison demonstrates that the measured fatigue cracking area values are constant across routes. Additionally, Figure 5 shows that the data points closely match the model's predictions, with an R^2 value of 0.99 for the plot of observed fatigue cracking areas indicating a significant correlation.
- The pavement's age, climate, submitted load characteristics, and other conditions cannot be effectively addressed by the IRI. In order to decide on pavement maintenance in a more efficient and effective way, alternative models like HDM-4 were selected.However, HDM-4 aids in forecasting the expense of each segment with respect to the corresponding years. For improved maintenance, the HDM-4 prediction and evaluation is therefore more dependable.
- Finally based on the IRI and HDM-4 obtained values, the ranking were established to make better decision. However, study indicates the similar study area can select and adapt the result of current study.

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