Evaluation of flexible pavement performance based on HDM-4 and international roughness index

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Abstract. The HDM-4 aids in estimating the deterioration of the pavement as well as the intricate interactions between the environment, vehicles, the surface, and the structure of the pavement. It predicts how the roads will deteriorate over time due to the increased traffic. The current study was carried out at Hyderabad, particularly roads which are subjected to the heavy traffic. The study was adopted for Dhulapally to Bahadurpally (DB), Gandimaisamma to Bowrampet (GB), Gandimaisamma to Medchal (GM), and Kompally to Dhulapally (KD). Among these roads commonly observed distress was collected like patches, alligator cracking, pothole, rutting, and edge drop etc. This papers describes the current and future performance of the roads (10 years), the progress of the distress were predicted using the HDM-4. The study addresses the major causes of distress and their reasons of given section. The study concluded the prediction of pavement life for 10 years in terms of IRI values of the different sections. The study revealed the failure of roads section due to distress for the period of 10 years with and without maintenance, it also helps in decision making for apply further maintenance treatment of this particular routes.

Keywords. Patches, potholes, Rutting, Alligator cracking, IRI, and HDM-4.

1 introduction

Since the last few decades, the pavement management system (PMS) and economic evaluation of highway projects have been widely adopted in developing nations. The development of technology to support the pavement structure has led to a significant increase in the PMS. The HDM-4 tool has been used for two decades by numerous road agencies worldwide. The development of expanded urbanization is impacted the asphalt design and it has been seen during the most recent couple of many years. As a result, it puts more stress and strain on the pavement, which causes fatigue, potholes, rutting, patches, edge drop, and other problems.

The road inventory data gathered from the four distinct sections of one-way directional traffic are described in the various studies. The HDM-4 tool is used to evaluate and predict the function data from the four routes in order to improve the roads' performance. [1] assessed the pavement using models at the project and network levels, as well as calibrating it using the appropriate performance models. The crumbling models were created and contrasted and eight areas. [2] the cracking, roughness, and potholes served as the basis for the HDM-4 calibration of the performance model. The observed and predicted values included variation ranging from 10.8 percent to 28.2 percent for cracking and variation ranging from 15.4 percent to 39.4 percent for ravelling. For potholes, the higher variability ranges from 0 percent to 66%, while the roughness values range from 2.1% to 15.1 percent. The development of a pavement deterioration model for rural roads in India was the subject of a discussion [3]. The models were developed for unbounded layer of asphalt with ravelling, breaking, pothole and edge break, movement models. The root mean square error (RMSE) and absolute error (AAE) are used to develop the calibration factors. [4] The study demonstrated that future pavement performance can be predicted using curve distress and the expansion of traffic consideration. In light of financial considerations, it is essential information for alternative pavement maintenance strategies. [5]. describes the GENEPAV and HDM-4 for improved pavement maintenance management in relation to periodic and routine maintenance based on crack sealing, patching, and rut levelling. [6]. elucidate the performance of flexible pavement right now and the development of distress using HDM-4 for urban roads in the future. The KINLAYER and HDM-4 were utilized to evaluate stress prediction and the stress that is observed with current traffic. The annual average daily traffic (AADT) was used as the basis for 15 years of road maintenance assistance. [7]. says that the study aims to use HDM-4 and KENLAY to predict how well flexible pavement will perform and to recommend the most appropriate maintenance for the structure of flexible pavement. [8]. [9] evaluated the pavement's functional performance in mixed traffic conditions. Which include the IRI, surface distress such as rutting, patching, cracking, and ravelling, and the geometric characteristics of the roads using equipment called "Road Measurement and Data Acquisition system (ROMDAS)." The Falling Weight Deflectometer (FWD) is also used to examine the structural evaluations. The study [10] examines the significant road maintenance and the selection of the best financial planning projects. Streets are assessed as far as recovery and rebuilding in view of the monetary, political, and financial rules. The study [11] outlines rehabilitation strategies for a variety of pavement conditions. It is affected by the climate, traffic volume, load, road condition, and other environmental factors. The pavement management system (PMS) case study of Portugal is discussed [12]. As part of the AASHTO design method, PMS currently provides the pavement performance prediction model and is useful worldwide. It's a substitute of interstate turn of events and the executives (HDM-4) to foresee the exhibition of asphalt. The four-year data are used to address the various rural roads' deterioration in [13]. HDM-4 Models were used to calibrate the models for roughness, ravelling, and pothole progression [14] discuss the other types of pavement maintenance, such as road rehabilitation and preventive maintenance, as well as the highway project's performance under financial consideration.

2 Methodology

The current study addresses the performance of the roads under a mixed-traffic condition. The study examines traffic forecasts for the present and the future of the existing roads as per the IRC – (Traffic code). It discusses their maintenance strategies and the progression of distress of the different routes for 15 years.

In this study, deterioration models were developed using the performance data collected from twenty rural road sections in Kerala for a period of four years. Models were developed for ravelling, pothole and roughness progression and were. validated. These models were used to calibrate HDM-4 deterioration models for rural roads in Indi. In this study, deterioration models were developed using the performance data collected from twenty rural road sections in Kerala for a period of four years. Models were developed for ravelling, pothole and roughness progression and were. validated. These models were used to calibrate HDM-4 deterioration models for rural roads in India.
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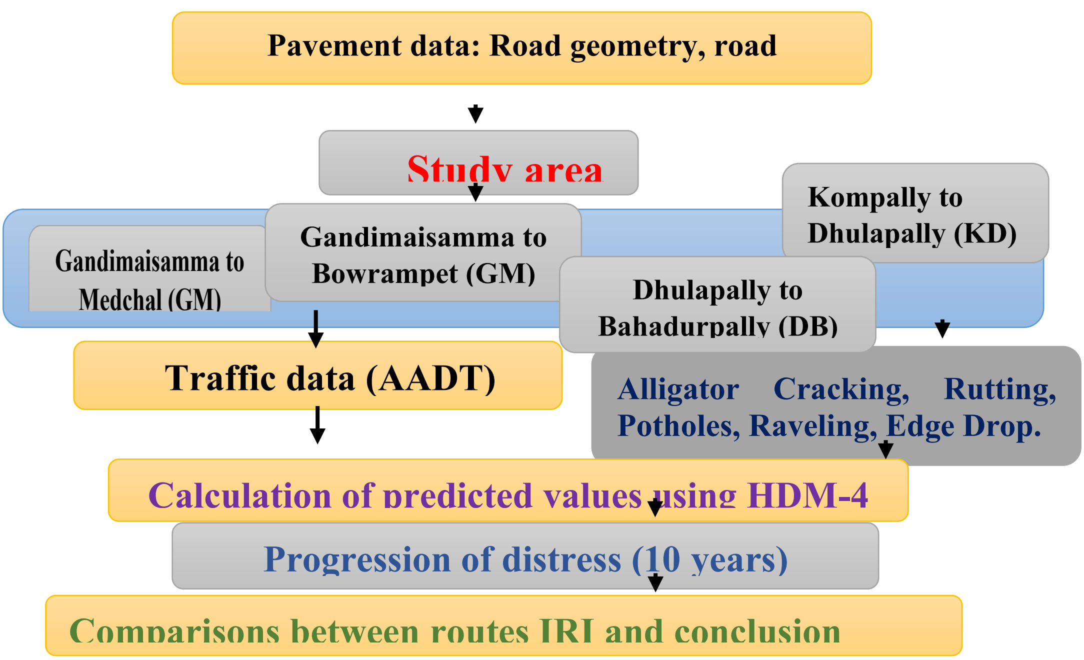

3.0 Study Area

The particular routes are selected based on major distress by visival inspection this routes are having similar distress and traffic.Data were collected along the following routes in order to evaluate the current and future performance of the roads: Gandimaisamma to Bowrampet (GB), Dhulapally to Bahadurpally (DB), Gandi Maisamma to Medchal (GM), and Kompally to Dhulapally (KD).

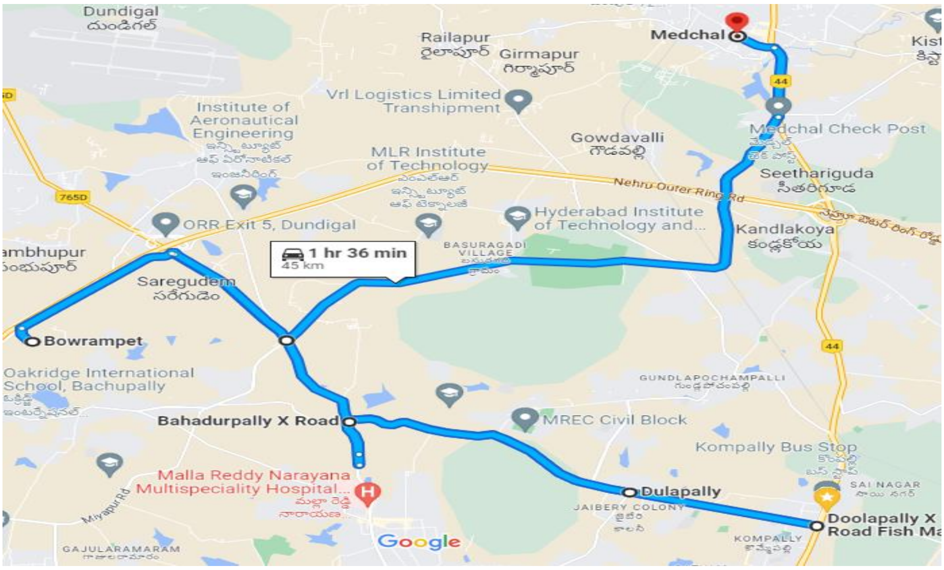

Figure. **1.** Study area

4.0 Data Collection

The data of the routes are collected by manually at possible locations and photos and videos at higher traffic area. The data were exacted from theb photos and videos in the laborator.The current traffic is estimated at each routes and predected traffic is measured according to the obtained traffic as per IRC for the 10 years. The below figure show the example of distress on different routes. figure 1 indicate the rutting of route 1, figure 2 show the ravelling of stretch 2, the major distyress of the routes are potholes and patch are shown in figure 3 and figure 4 for GM and VNR to Miyapur respectely.

Figure. 2. Rutting deformation

Figure. 3. Ravelling

Figure. 4. Mesurement of Potholes

Figure. 5. Measuring of Cracks

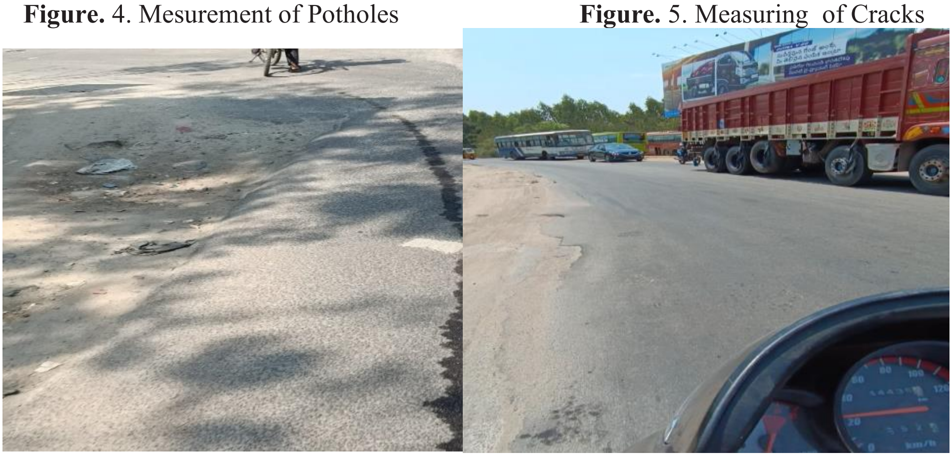

Figure. 6. Mesurement of Edgedrop

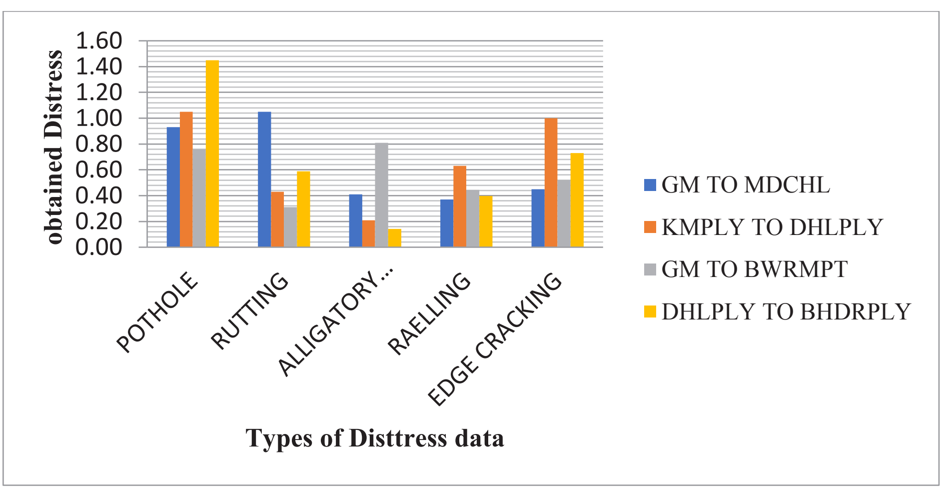

Figure. 7. Respresentation of distress data

Table 1 represent the maximum distress of each sections. During the data collection. It was noticed that the deep pothole of 1.45mm on AM routes and minimum is 0.76 in GA section. Similar way, maximum and minimum values of different distress are presented in table 2.

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Table 1. Show the different routes along with distress

Parameter	MV	VG	GA	AM	Standard values
Pothole (mm)	0.99	1.05	0.76	1.45	Samall:25mmdeep,200 mm wide Mrdium:25mm to 50 deep and 500mm wide Large:50mm deep and 500 mm wide
Rutting(mm)	1.05	0.59	0.56	0.59	20mm
Alligator Cracking (mm)	0.09	0.15	0.12	0.14	20mm
Ravelling	0.18	0.15	0.44	0.40	Loss of fines with initial stage of binder wearing Out.
Edge Cracking (mm)	0.08	0.12	0.03	0.19	Low: up to 20% high: more than 10%

5.0 Analysis of Data and Discussion

The analyses of 4 different routes are carried out using HDM-4. The input data were provided to HDM-4**,** evaluated for the current years and also predicated for the 10 years the progress of roughness of each route are developed for maintenance and rehabilitation process.

Figure 8 shows the progress of roughness of GM section initially it is indicate the lower roughness values later slowly increases and reached to 16 m\km in the year of 2027. It was noticed that the section required basic alternate before 2026, so that the structure of the pavement can be permeated but the average roughness of GB is noticed as higher at beginning and slowly progress show maximum at 2030. It is obtained due to lower traffic at particular routes (heavy traffic) it is shown in Figure 10.

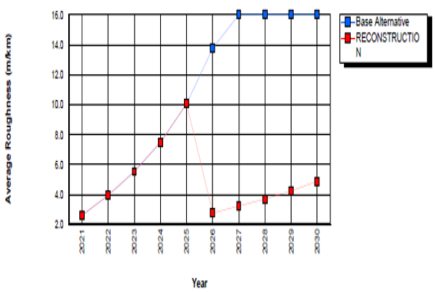

Figure. 8. Average Roughness of GM Route

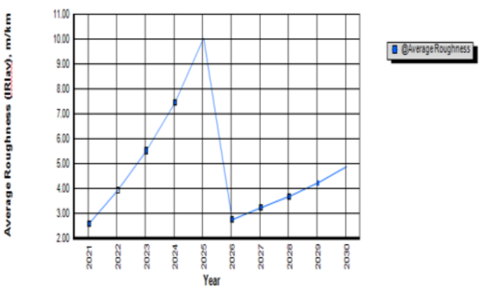

Figure. 9. Prediction data of GM

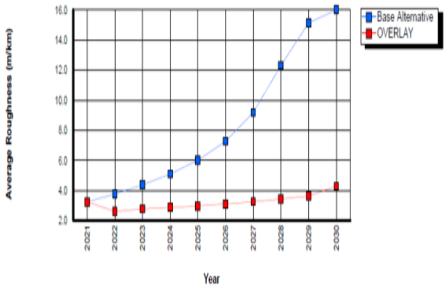

Figure. 10. Average Roughness of GB

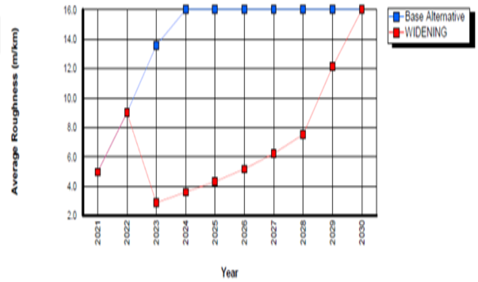

Figure. 11. Average Roughness of KD

In other hands KD section is indicate the higher roughness values. It is found the initial roughness from HDM-4 is 4.5m\km and reaches maximum of 16m\km at 2024. Particular this section was more affected among the other section, it is obtained due to the marked traffic with heavy vehicles, because of that the road section is deteriorate as easily as possible it is represent in figure 11.

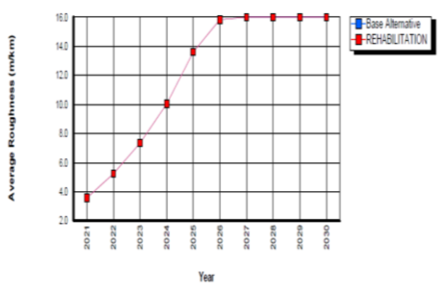

Figure.12. Average Roughness of BD HDM-4

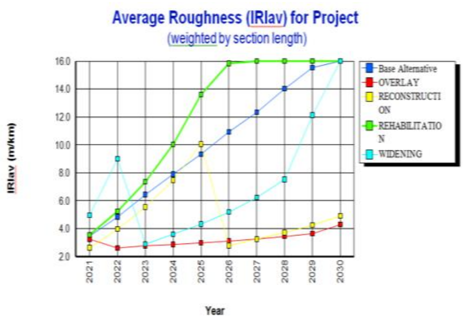

Figure. 13. Average roughness overall route

In case of B to D section, the roughness progress is lower due to diversion of traffic is take places and particular routes subjected to traffic. The average roughness of routes is found at 2029 it is represented in figure 12.

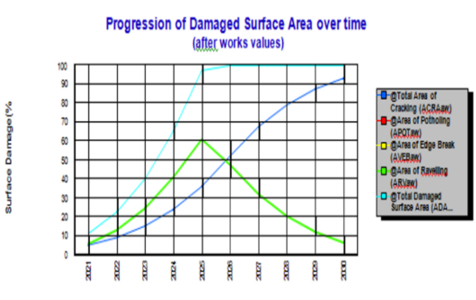

Figure. 14 Overall surface in HDM-4

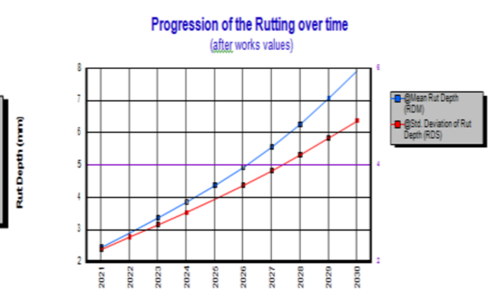

Figure. 15. Rut depth of different road of HDM-4

The rutting distress on routes is found as lower than the other distresses such as potholes, patches etc it may be the design consideration of pavement criteria. The main rut depth and statistics of rutting of all routes are predicted and presented in figure 15. It is observed that the causes of potholes distress need to be considered for design of pavement so that the maintenance of these routes will be effective.

The average roughness of the project is developed for all the routes with and without maintenance for the 10 years period. The figure 13 show the progress of distressed without maintenance of 10 years of road network. It is indicated the rapid rate of deterioration of the existing pavement. It is also observed the future damage of this routes\ section. But the required maintenance of pavement of particular interval shows the better performance. It helps in taking decision when to apply a maintenance renewal coat for existing pavement at regular interval of maintenance.

Table. 2. IRI value of different routes

S.NO	**Route**	**IRI**	**D**	**IRI**	**IRI**
1.	GM	= 0.593+0.0471(D)	12cm	=0.593+0.0471(12)	8.750m/Km
2.	GB	= 0.593+0.0471(D)	4.5cm	=0.593+0.0471(4.5)	8.040m/Km
3.	KD	= 0.593+0.0471(D)	16cm	= 0.593+0.0471(16)	9.698m/Km
4.	DB	= 0.593+0.0471(D)	5.5cm	=0.593+0.0471(5.5)	8.520m/Km

It is found that all the routes reaching the higher values. Which shows the there is a need of maintenance requirement of road sections.

Conclusions

This study describes the distress progression and IRI values by using the HDM-4. It has been seen that potholes and patches are more and influence surface and its service life of pavement. The following are the conclusions are drawn from investigation.

1. The International Roughness Index (IRI) were measured for the all the sections, using the Merlin apparatus. Among this sections KD routes has higher values of 9.698 m/km and other routes are poses the GB-8.040 m/km, and GM-8.750 m/km, DB – 8.520 m/km. it is noticed that this routes are required the immediate maintenance to achieve the better performance.
2. The study observed the high-traffic routes are affected with severe problems like pothole and patches and cracks are more and potholes, Figure 7 Shows the distress at all the routes.
3. The study revealed that more distress was evident in KD routes and the progress of the distress also obtained higher using the HDM-4. It is found the initial roughness from HDM-4 is 4.5m\km and reaches maximum of 16m\km at 2024.
4. The majority of edge cracking occurred between DB (1.90 m^2) routes. The study benefits the analysis of route and help in priority decision making for the maintenance of road network.

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