International Journal of Recent Research and Review, Vol. XVII, Issue 2, June 2024
ISSN 2277 – 8322

Technical Due Diligence: Road Safety & Existing Pavement Condition Assessment of Gwalior-Jhansi National Highway

Shalini Chakraborty[1], Deepak Mathur[2]

Department of Civil Engineering (Transportation),
Kautilya Institute of Technology & Engineering, Jaipur
[1] shalini.chakraborty22@gmail.com, [2] mathurdeepak1507@gmail.com

Abstract: **Technical due diligence for national highways involves a thorough assessment of the current infrastructure to ensure its reliability, safety, and compliance with legal standards. This comprehensive evaluation process encompasses the analysis of the highway's structural integrity, surface condition, drainage systems, and traffic management. Conducting technical due diligence for highway projects is crucial for ensuring the viability, safety, and sustainability of infrastructure development. This thesis examines the comprehensive evaluation techniques used in assessing national highway projects, focusing on key aspects such as structural integrity, environmental impact, and regulatory compliance.**

The study adopts an approach that integrates civil engineering principles to provide a detailed understanding of the due diligence process. Through case studies and empirical data, the research identifies common issues and best practices in the technical assessment of highway projects.

Specifically, this dissertation includes a case study of the Gwalior-Jhansi Section of NH-44, featuring an assessment of the existing pavement and assets based on data collected using a Network Survey Vehicle (NSV). The findings aim to assist highway engineers and designers in identifying shortcomings in road safety and proposing effective solutions to enhance the safety of road users

Keywords: Technical due Diligence, Pavement Risk Assessment, Asset Evaluation, Investigations, Road Safety Audit, Blackspots, Financial Analysis, Economic Sustainability.

I. INTRODUCTION

National Highways Authority of India (NHAI), an autonomous agency of the Government of India (GoI), is responsible for the development, maintenance and management of National highways network in India. There are currently approximately 1, 32,500 kilometers of national highways in India, constituting approximately 2.2% of India's entire road network but carrying approximately 40% of total road traffic. Therefore, it is essential to know the drawbacks and shortcomings in road safety and try to provide efficient solutions for the safety of road users. Here comes the importance of technical due diligence in making the projects safe, feasible & sustainable. It aids in assessing the project's technical viability in terms of its design, construction process, and materials utilized. Possible hazards and the technological limitations necessary to successfully mitigate them by assessing the technical requirements and confirming that they adhere to the necessary standards.

Various studies have suggested ways to improve road safety through study of accident data. Their study efforts allowed them to draw certain conclusions.

S Nuli and et.al (2022) has studied literature review on road safety audit and black spot Identification. The iRAP program is used in this study to conduct a safety audit of a rural road that runs from the Rallaguda bridge to Vardhaman College of Engineering. Star ratings are used to measure the safety levels for both rural and urban areas. Additionally, a number of steps were recommended to raise the standard of safety for regular users of the roads. Lastly, the steps to lessen mishaps in these areas were also recommended. (Ho, 2020) study developed back-end image recognition software that leverages existing road inspection methods and equipment. Figure 1 shows the data collection flow table. The goal was to improve inspection efficiency by automating the identification of road damage. The observations from this automated system can then be converted into PCI values, following ASTM D6433-16 standards, to provide a numerical representation of road quality. The system uses a vehicle-mounted traffic recorder and imaging device with Wi-Fi transmission capabilities. By analyzing the relationship between captured images vehicle speed, it accurately assesses road conditions. The Simple Linear Iterative Clustering (SLIC) Super pixels algorithm is employed to detect and categorize pavement damage into various types such as patches, potholes, longitudinal cracking, and crocodile cracking.

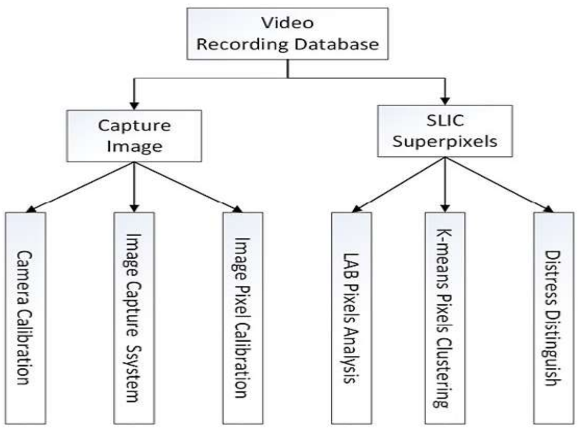


Figure 1: Data Collection Flow Table (Ho, 2020)

(Marcelino et al., 2018) study explores the selection and use of technical parameters and performance indicators, which are essential for effective pavement management. While using more parameters generally leads to a more accurate assessment of pavement conditions and more effective maintenance decisions, the cost of data collection makes it crucial to balance the amount of data gathered with the actual needs of the management process. This paper introduces a new method for developing pavement condition indicators using a machine learning algorithm known as regularized regression with lasso.This approach aims to achieve an optimal balance between data collection and practical needs. Machine learning techniques, particularly this general-purpose method that iteratively learns from data, offer a promising solution for obtaining more accurate results and deeper insights into pavement characteristics. **M Keymanesh and et.al (2017)** has studied Identification and Prioritization of (Black Spots) without Using Accident Information. Based on the road's geometric layout and a survey with multiple expert participants, the research's suggested method for identifying black spots identified 10 of the locations reported as black spots by traffic police, and the results of the prioritization were in good agreement with the reports from the police. Consequently, this technique might be applied in situations where accident data and statistics are not accurately documented because of either a deficiency in the necessary infrastructure or insufficient training of the registering agents. **(Radopoulou & Brilakis, 2015)** study introduces an innovative and cost-effective method for detecting and tracking pavement patches using video data from parking cameras. By leveraging image processing techniques, the method addresses the need for frequent, low-cost pavement assessments. The approach was tested using images and videos collected from local roads in Cambridge, UK, with the video data processing done in real-time on a desktop PC. Initial experiments with 70 images demonstrated substantial improvements in detection accuracy when texture information was included, achieving 82% precision and 86% recall. Further validation with a database of 4000 video frames yielded even higher performance, with 84% precision and 96% recall, while maintaining a manageable memory consumption of 250 MB RAM. This method shows great promise in transforming everyday vehicles into ubiquitous sensors for pavement monitoring, potentially eliminating the need for expensive dedicated survey vehicles and manual inspections. **(Fallah-Fini et al., 2015)** discusses a dynamic efficiency measurement model designed to evaluate the performance of highway maintenance policies, explicitly capturing the inter-temporal dependencies between input consumption (i.e., maintenance budget) and output realization (i.e., improvement in road condition). They build on a micro-representation of pavement deterioration and renewal processes to study the impact of allocating scarce maintenance budgets over time. The paper provides a measure of efficiency that contrasts optimized budget allocations with actual ones. This model is applied to an empirical dataset of pavement conditions and maintenance expenditures from 2002 to 2008, covering seventeen miles of interstate highway in a Virginia county. (Pantha et al., 2010) have developed a GIS-based integrated model for road repair and maintenance that considers both road pavement components and roadside slope stability. They emphasize the importance of including roadside slope maintenance annual road maintenance programs, which is particularly critical for mountainous regions. The GIS analysis demonstrates that integrating both pavement and roadside slope conditions can enhance the administration and management of maintenance planning. The study includes the creation of a pavement inventory map, a pavement maintenance priority map shown in Figure 2, a landslide inventory map shown in Figure 3, and a landslide susceptibility map. These type of map can assist road agencies in planning maintenance programs more effectively.

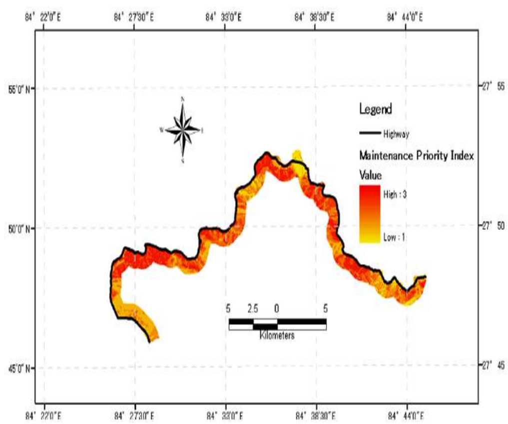


Figure 2: Maintenance Priority Map (Pantha et al., 2010)

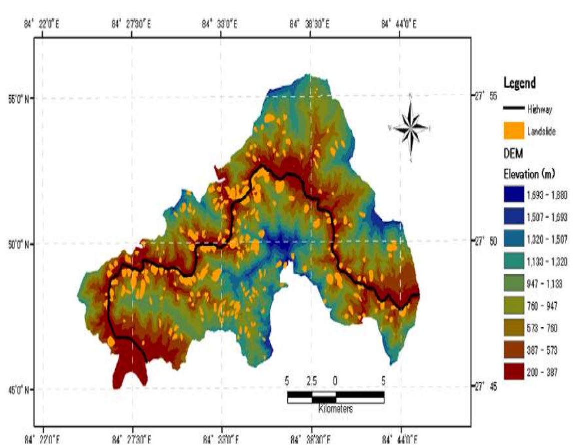


Figure 3: Landslide inventory Map (Pantha et al., 2010)

II. METHODOLOGY

A. *Visual Inspection of Site*

The basic aim of visual inspection is to find the weakest portion of the highway and to establish safety among the road users. Following points are visually inspected:

- Existing pavement conditions
- Intersections/Crossroads
- Major water bodies
- Major cross drainage structures
- Bottlenecks in road alignment

B. *NSV-Network Survey Vehicle*

To access the condition of existing pavement and assets, investigations are carried out using Network Survey Vehicle (NSV).

Network Survey Vehicle is manual method where each distress needs to assess using video data. In these systems all outputs are linked via a highly accurate distance measuring instrument and DGPS system.

C. *Laser Profile System*

The data collected includes International Roughness Index (IRI), Ride Number (RN), Rut Depth and Longitudinal / Transverse Profile of Road.

D. *Digital Imaging System*

The system comprises the latest digital camera technology and produces crisp, high-resolution video frames to ensure a continuous digital record of the roadway. The calibrated video cameras accurately log digital images of roadside assets against other parameters such as distance and GPS.

E. *Falling Weight Deflectometer (Fwd.)*

Falling Weight Deflectometer is a non-destructive pavement testing device which provides accurate data on the response of the pavement to dynamic loads by simulating actual wheel loads in both responses and duration. This allows more accurate and rapid measurement of pavement deflection under load than traditional methods.

F. *Test Pits, Core Cutting and Material Investigations*

The following field investigations are carried out:

- Pavement Composition of the Project Stretches
- Subgrade Characteristics and Strength

G. *Road Safety Audit*

- Review of past data and identification of accident blackspot locations along the Project Stretches
- Field investigations to understand the current safety concerns along the Project Stretches and specifically at the identified accident prone locations
- Identification and prioritization of improvement proposals based on requirements as immediate, medium term and long term to provide safer driving conditions

H. *Socio and Economic Profile of Area*

The aspects covered include demography, employment pattern, state income and major economic sectors including transport infrastructure. The profile discusses the past performance and the present scenario and also presents a broad assessment of the perspective growth of the economy as a basis for estimating the future growth in transport demand.

III. COLLECTION OF DATA & IMPROVEMENT STRATEGIES

A. *Project description*

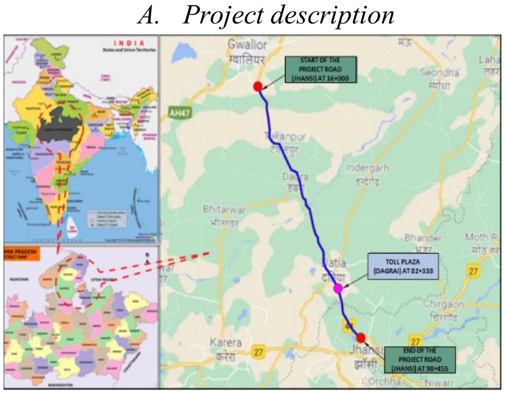


Figure 4 Map (Google earth)

Table 1 Overview of Project Stretch

Project Name	Four Laning of Gwalior – Jhansi Section of NH-44 from Km.16.000 to Km. 96.127 (Design Length- 80.127 Km) under North-South Corridor in the State of Madhya Pradesh and Uttar Pradesh.
NH No. (New/Old)	NH-44/NH-75
No. of Lanes/Configuration	Four Lanes
Length of the Project (in KM)	82.455 KM (4 Lane Length)
No. of Major Bridges (Number and Location)	3 (km 54.300, Km 86.076, km 96.180)
No. of Toll Plazas (Number and Location	01
No. of Fly Over's (Number and Location)	01

B. *Identification of Black Spots*

Location or zone where the accidents are being repeated were identified and listed below with mitigation proposal:

Table 2 Improvement on Major Junctions

Black Spots	**Chainage (Km)**		**Observation**
	From	**To**	
BS01	18+000	18+150	Ghat Section and unauthorized Access for temple at km 18+000 and Minor junction 17+500 on LHS, Over speeding of vehicle.
BS02	46+900	46+600	unsafe Separator opening and on lhs side unsafe turn for RHS village traffic to MCW (Jhansi traffic) and wrong side movement
BS03	67+000	67+500	Unsafe diverging from LHS MCW to Slip road at structure for RHS junction

a) 

b) 

Figure 5 Blackspot Proposal at:
a) Km 18+000 to 18+500 Km (BS01)
b) 46+600 to 46+900 (BS02) (Google Earth).

C. Safety Issues on Junctions along Project Stretch

There are a total of 35 junctions on this highway project (Gwalior to Jhansi) which require improvement, they can be classified as T- junctions, Y- junctions and Cross junctions.

 At Ch. 52+360 (RHS) Two-way hazard marker, TBM, Junction sign, Flag sign, stop sign, stop line and Rumble strips are missing	 At Ch. 65+655 (LHS) Stop sign and stop line is missing Damaged island with no two-way Hazard marker
 At Ch. 72+690 (RHS) TBM, stop line and rumble strip isn't provided	 At Ch. 76+800 (LHS) Junction sign, stop sign and rumble strips are not provided

Figure 6 Photographs of improper junctions

Table 3 Improvement on Major Junctions

Sl. No.	Chainage (km)	Type	Improvement strategies
1	52+360	T	Provide two-way hazard marker on junction island, Provide TBM, Junction sign and Flag sign on major road
2	52+580	Y	Provide stop line and stop sign with rumble strips on minor road Provide junction sign board on major road
3	62+120	T	Provide two-way hazard marker on junction island, Provide TBM on major road
4	72+690	Y	Provide TBM on Major road Provide stop line and rumble strip on minor road
2	21+700	T	Junction Improvement
4	22+560	Y	Junction Improvement
5	24+290	X	Junction Improvement

Table 4 Improvement on Minor Junctions

Sl. No.	Chainage (km)	Type	Improvement strategies
1	16+700	T	Provide Stop line and stop sign on minor road
2	17+530	T	Provide Stop line and stop sign on minor road
3	27+270	X	Provide Junction sign, TBM marking, Flag sign and advanced directional sign on major road Provide stop sign and stop line, Rumble strip on minor

Sl. No.	Chainage (km)	Type	Improvement strategies
			road Provide Pedestrian crossing BHS and Pedestrian crossing sign
4	28+340	X	Provide Junction sign board, TBM marking, Flag sign and advanced directional sign on major road Provide stop sign and stop line, Rumble strip on minor road

D. *Deficiencies in safety barriers*

At Ch. 42+500 (RHS) High Embankment

At Ch. 42+950 (LHS) Damaged Crash Barrier

At Ch. 48+220 (LHS) Narrow Median

At Ch. 89+260 Damaged Crash Barrier

Figure 7 Photographs of High Embankment & Damaged Crash Barrier (NSV data)

Table 5 Identified Locations for New Thrie Beam Safety Barriers

Sl. No.	Chainage(km)		Proposal
	From	To	
1	17+210	16+990	Narrow median
2	17+750	17+860	High embankment
3	21+060	17+240	Narrow median
4	27+270	26+650	High embankment

E. *Pedestrian guardrails*

Pedestrian guardrails are an important safety element for pedestrian safety so to prevent crossing and spilling of pedestrians on to the main carriageway pedestrian Guard rail has been proposed on the following

Table 6 Identified Locations for New Thrie Beam Safety Barriers

Sl. No.	Chainage (Km)		Length (m)	Remarks
	From	To		
1	76+920	77+520	600	On Separator
2	76+920	77+630	710	On Separator
3	78+800	80+660	1860	On Separator
4	79+070	80+660	1590	On Separator

IV. ANALYSIS OF NSV DATA-PAVEMENT CONDITION

A. *Roughness*

Roughness condition details length wise for both the direction given in table below

Table 7 LHS Roughness Summary

Condition	Range	Length of LHS Outer	% LHS Outer	Length of LHS Inner	% LHS Inner
Good	<2.55	65.00	78.83%	54.00	65.49%
Fair	2.55-3.3	10.46	12.68%	20.00	24.26%
Poor	>3.3	7.00	8.49%	8.46	10.25%
Total		82.455	100%	82.4550	100%

Table 8 RHS Roughness Summary

Condition	Range	Length of RHS Outer	% RHS Outer	Length of RHS Inner	% RHS Inner
Good	<2.55	64.00	77.62%	52.00	63.06%
Fair	2.55-3.3	12.00	14.55%	24.00	29.11%
Poor	>3.3	6.46	7.83%	6.46	7.83%
Total		82.455	100%	82.455	100%

The Roughness Index observed for all 4 lanes (2-LHS and 2-RHS) are presented in the figures below:

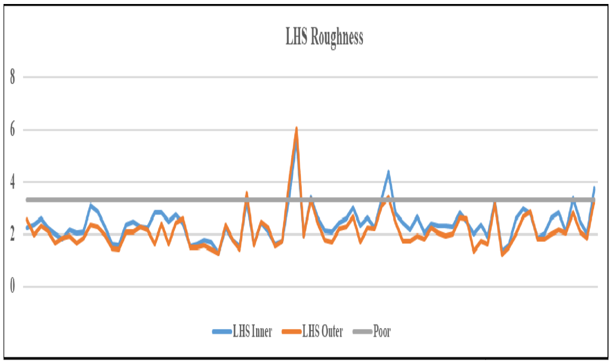


Figure 8 LHS Roughness Along the Stretch

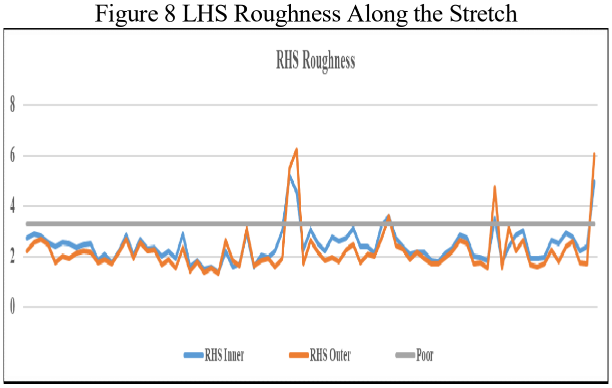


Figure 9 RHS Roughness along the Stretch

B. Rutting

Rutting is characterized by permanent deformation of the pavement in wheel path due to heavy load vehicles. It is one of the main modes of failure in asphalt mixes.

Table 9 LHS Inner Lane and Outer Lane Rut Depths

Condition	Rut Depth Range (mm)	Length of LHS Outer	% LHS Outer	Length of LHS Inner	% LHS Inner
Good	< 5	67.46	81.81%	4.00	4.85%
Fair	5-10	14.00	16.98%	69.46	84.23%
Poor	> 10	1.00	1.21%	9.00	10.92%
Total		82.455	100%	82.455	100%

Table 10 RHS Inner Lane and Outer Lane Rut Depths

Condition	Rut Depth Range (mm)	Length of RHS Outer	% LHS Outer	Length of RHS Inner	% RHS Inner
Good	< 5	64.00	77.62%	3.00	3.64%
Fair	5-10	18.46	22.38%	69.46	84.23%
Poor	> 10	0.00	0.00%	10.00	12.13%
Total		82.455	100%	82.46	100%

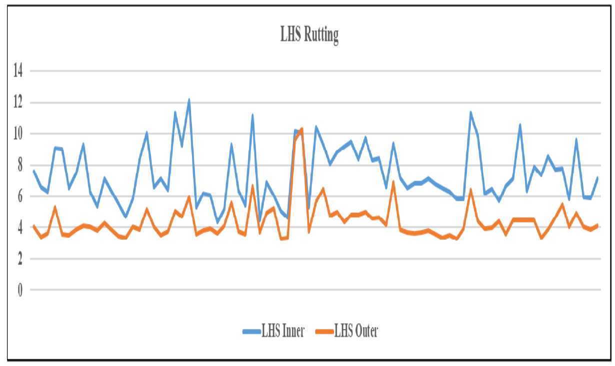


Figure 10: LHS Rut Depth along the Stretch

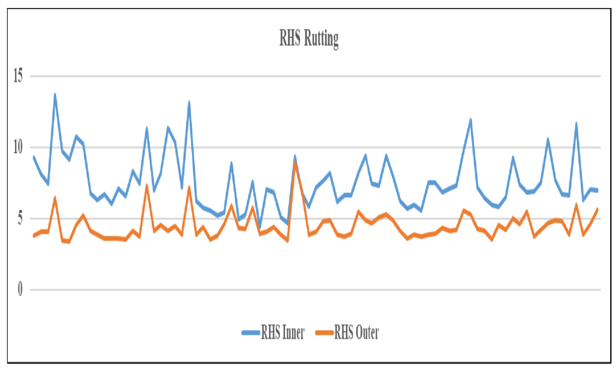


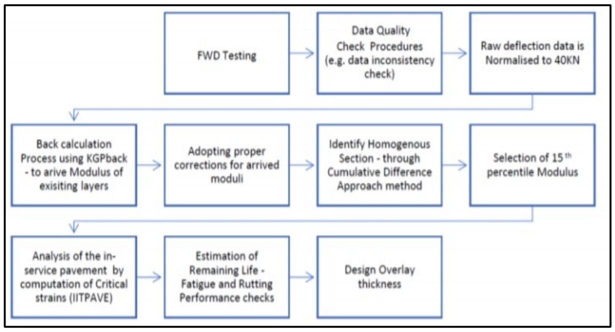
Figure 11 RHS Rut Depth along the Stretch

It is observed that Rutting was similar in both lanes for LHS and RHS. And there are some locations where rut depth is more than 10.

C. Determination of structural strength of pavement using FWD and remaining life in flexible pavement

The structural adequacy of the existing pavement is demonstrated based on the study of structural performance of the pavement. If a pavement shows load associated distress like fracture, permanent deformation etc., then it is considered to have failed structurally. Among the equipment available for structural evaluation of pavements, the Falling Weight Deflectometer (FWD) is extensively used

A sequence of FWD data analysis and snapshot of applications used for analysis are presented in figures below.




```
####################################################
#         !!!  THANKS FOR USING KGPBACK  !!!       #
#              THE RESULTS ARE GIVEN BELOW         #
####################################################

################
#  INPUT DATA  #
################
No.of Layers                            =  3
FWD Load (N)                            = 40000.00
Contact Pressure (MPa)                  =  .56
No.of Deflection points                 =  7
Deflections measured using FWD (mm)     =  .32200   .26500   .22200   .17500   .14000   .08200   .05600
Radial distances from centre of load(mm) =    .0  200.0  300.0  450.0   600.0   900.0  1200.0
Layer thickness (mm)                    = 190.00 360.00
Poisson ratio values                    = .35 .35 .35
Layer Modulus (MPa) Ranges Selected :-
(a) Bituminous Surfacing                =  750.0   3000.0
(b) Granular Base                       =  100.0   500.0
(c) Subgrade                            =   40.0   160.0


################
# OUTPUT DATA  #
################

Backcalculated Layer Moduli are:
Surface (MPa)  =    2661.3
Base (MPa)     =     114.9
Subgrade (MPa) =     160.0
```

Figure 12 Typical KGPBACK Output

V. CONCLUSION

The main outcomes of study of the existing highway stretch NH-44 Gwalior-Jhansi section of the state Madhya Pradesh and Uttar Pradesh are given below:

- Three blackspots were identified at different chainages for which suitable safety and improvement measures was proposed such as provision of speed limit sign, merging and diverging of lanes, proposal of acceleration and deceleration lanes, provision of access roads and islands, proposal of road signages and road markings.
- At few junctions, safety issues were identified along the highway stretch and suitable improvement strategies were proposed such as signages, markings, etc.
- Safety barriers, pedestrian guard rails. U-turn and median openings, service roads and slip roads were proposed wherever found inadequate or missing along the highway stretch.
- It is observed that in LHS 78.83 % of Project Stretch has a Roughness value in good condition, whereas in fair condition is 12.68% and Poor condition is 8.49%. in RHS 77.62% of Project Stretch has a Roughness value in good condition, whereas Fair Condition is 14.55% and Poor Condition is 7.83%.
- Further, it has been observed that in LHS 81.81% of Project Stretch has a Rutting value in good condition, whereas Fair Condition is 16.98% and Poor condition is 1.21%. in RHS 77.62% of Project Stretch has a Roughness value in good condition, whereas Fair Condition is 22.38 % and Poor condition is 0.00%.
- Considering the condition of the existing pavement and after analyzing the same, milling has been provided in the range of 30-50mm, overlay provided on LHS and RHS in the range of 30-50mm (for BC) and 50mm (for DBM) proposed at few locations.

VI. FUTURE SCOPE

- This study provides the basics of technical due diligence which can be performed for other highways also, to find out the issues and provide improvement strategies.
- By performing the technical due diligence studies, cost analysis of the improvement and rehabilitation works may be studied in the future research.
- Pavement assessment is necessary to analyse the situation of highway which leads to proper bidding.
- Consultancies will benefit with ample technical due diligence projects since the

operation and maintenance completely depends on the Pavement Evaluation and its Road Safety Audit.

- Further study may be conducted for carrying out the evaluation and assessment of highway through different techniques and by using different advance software.
- Technical due diligence works will enhance the safety of highways for public uses.

ACKNOWLEDGEMENT

I express sincere thanks to Prof. (Dr.) K.C. Roy, Professor and Principal, Kautilya Institute of Technology & Engineering, Sitapura, Jaipur for his kind cooperation and extendible support.

Words are inadequate in offering my thanks to Er. V.K. Modi, Associate Professor, H.O.D of CE Department, for consistent encouragement and support for shaping this report in the presentable form.

I would also like to express my thanks to all supporting CE faculty members who have been a constant source of encouragement for the successful completion of the project.

Also, my warm thanks to KAUTILYA INSTITUTE OF TECHNOLOGY & ENGINEERING, JAIPUR who provided me this opportunity to carry out this prestigious Project and enhance our learning in various technical field.

REFRENCES

1) S Nuli and et.al (2022) "A Study on Road Safety Audit and Black Spot Identification".
2) K.N Thakare and et.al (2021) "A Review on the Study of Different Black Spot Identification Methods".
3) Ho, M. C. (2020). AUTOMATIC IMAGE RECOGNITION OF PAVEMENT DISTRESS FOR IMPROVING PAVEMENT INSPECTION.
4) L Bisht and et.al (2019) "Assessing the Black Spots Focused Policies for Indian National Highways".
5) Marcelino, P., Lurdes Antunes, M. de, & Fortunato, E. (2018). Comprehensive performance indicators for road pavement condition assessment.
6) M Keymanesh and et.al (2017) "Identification and Prioritization of (Black Spots) without Using Accident Information".
7) R.R. Sorate and et.al (2015) "Identification of Accident Black Spots on National Highway 4 (New Katraj Tunnel to Chandani Chowk)".
8) Radopoulou, S. C., & Brilakis, I. (2015). Patch detection for pavement assessment.
9) Fallah-Fini, S., Rahmandad, H., Triantis, K., & de la Garza, J. M. (2010). Optimizing highway maintenance operations
10) Shalon Hakkert and Victoria Gitelman (2014) "Thinking about the history of road safety research: Past achievements and future challenges".
11) Lech Michalski and Stanislaw Gaca (2014) "Tools for road infrastructure safety management- Polish experiences".
12) Parikh V. A. and Dr. Jain A. M. (2014) "Road Safety Audit: Development of an accident model for Urban area", International Journal of Engineering and Research, vol 2, issue 2|ISSN:2321-9939
13) E Dupont and et.al (2013) "Multilevel analysis in road safety research".
14) Shah, Y. U., Jain, S. S., Tiwari, D., & Jain, M. K. (2013). Development of Overall Pavement Condition Index for Urban Road Network.
15) Ohm, B.-S., Jung, D.-H., Lee, S.-H., Choi, J.-Y., & Kim, Y.-M. (2022). Process Improvement and Application of Pavement Management System Based on Pavement Conditions in Jeju Island
16) Joshua Reid Jones et. Al. (2013) "field data collection conducted by the Utah Local Technical Assistance Program (Utah LTAP) in conjunction with the Utah Department of Transportation".
17) Rajan J Lad and Bhavesh N Patel (2013) "the study of existing roadway condition and identified the black spots in the study area".
18) Pradeep Kumar Agarwal and Rakesh Mehar (2013) "A Methodology for Ranking Safety Hazardous Locations Using Analytical Hierarchy Process" (AHP)".
19) Singh & Suman (2012) "accident analysis and developed prediction model on National Highway (NH-77)".
20) E.K. Reshma (2012) "Prioritization of Accident Black Spots Using Gis".
21) Tarek Sayed et. Al (2011), "the use of several recently developed community-based, macro-level CPMs".
22) Dr Jain. S.S. and Singh P.K. (2011) "Road Safety Audit for Four Lane National Highways"
23) Pantha, B. R., Yatabe, R., & Bhandary, N. P. (2010). GIS-based highway maintenance prioritization model: an integrated approach for highway maintenance in Nepal mountains.
24) Fallah-Fini, S., Triantis, K., Rahmandad, H., & de la Garza, J. M. (2015). Measuring dynamic efficiency of highway maintenance operations.
25) V Eksler (2008) "Exploring Spatial Structure behind the Road Mortality of Regions in Europe".

26) G Yannis and et. al (2008) “Impact of enforcement on traffic accidents and fatalities: A multivariate multilevel analysis”.
27) IRC:67-2022 "Code of Practice for Road Signs (Fourth Revision)"
28) IRC:35-2015 "Code of Practice for Road Markings (Second Revision)"
29) IRC:115-2014 "Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements Using Falling Weight Deflectometer (FWD) Technique"
30) IRC: SP:84-2019 "Manual of Specifications and Standards for Four Laning of Highways (Second Revision)"
31) IRC: 73 -2023 “Geometric Design Standards for Non-Urban (Rural) Roads”
32) Census 2001 & 2011