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Evaluation of Road Condition Index of NH section in Rajasthan having flexible Pavement using NSV (Network Survey Vehicle) and Determination of suitable Maintenance Involvement

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Abstract: National Highway - 458 is an important transportation link between Lambia and Raipur in the state of Rajasthan. The studied section begins near the Luni River at Lambia and extends up to the Raipur toll plaza, forming a key corridor between these two locations of Rajasthan. In addition to connecting Lambia and Raipur, this highway stretch enhances regional accessibility by linking several nearby villages, including Rabariyawas, Balunda, Jaitaran, and Kushalpura, thereby supporting local mobility and economic activities.

The Lambia–Raipur section of National Highway 458 was primarily studied to assess the maintenance requirements of its asphalt (flexible) pavement. The existing roadway consists of a 7.0 m wide carriageway, along with the paved shoulders of 1.5 m on either side of the stretch. This arrangement of road stretch facilitates the smooth and efficient traffic flow along the main carriageway.

There are different factors which cause to deteriorate the flexible pavement of the road. These factors are traffic load and effect of varying weather due to this cause the pavement to deteriorate and becomes unserviceable. To capture the distresses state of road surface, the art of laser technology-based equipment are used which are able to collect these data in vehicle operated at highway speed and records the extent of distresses existing over the pavement surface as mentioned in the IRC SP 82:2015. The pavement condition is rated on scale of 1 to 5 rating where 5 shows very good condition and 1 denotes very poor state of pavement surface.

While examine the various distresses weighted average is calculated through assigning the importance factor to each distress. In pavement deterioration, every distress have its different role to cause the damage of the road section. The computed weighted average represents the pavement condition index where it further indicates the kind of maintenance activity is to be carried out to retain the pavement in serviceable condition during the design life of pavement.

Keywords: Asphalt (flexible) Pavement, Traffic Load, NSV (Network Survey Vehicle), Laser technology-based equipment, Pavement Condition Index.

I. INTRODUCTION

General

Infrastructure growth like Highways, Railways and Bridges and Buildings in a country is the reason to grow the abundant civilization in the nation of any country in the world. Roads development in such area plays a major role by means of enhancing the social and economic growth, with the help of transfer goods and passenger from one place to another. The development is achieved by forming the large-scale interconnectivity among the various places and cities of the total state of the country. The main aim to meet the growth of transportation need in the country through a well-established road network over the large area to cover the maximum length and width of the country.

For any nation of the globe, the socio-economic progress directly linked with the well-connected infrastructure of road network. So, the investment in the field of road sector to make the good road network in the country and it also link with the development of the nation. And the state will automatically get socio – economic ability ultimately. Eventually the country and the state will both develop the road assets in the road network system in a proper way, it is very important to observe the proper plan and maintenance to reduce the disintegration in the road asset and its components especially in the case of flexible roads pavements.

In the study of Flexible Pavement Maintenance Management System, the achieving the designed service life of a road path is done by proper road maintenance and its importance in the management of road assets. We have taken the road stretches of National Highway-458 in the state of Rajasthan from "Lambia" to "Raipur" is considered to study purpose. The study section starts at km 168+290 near Lambia and continues up to km 222+535 close to Raipur in the state of Rajasthan, Pali district.

Development of Road Infrastructure in India

India is the second largest road on the earth, with total length of road is about 4.7 million km. About sixty percent of goods in the country and eighty five percent of passenger traffic are travelled by this road path. All the cities, villages and towns of the country are now connected with the good road network over the passes of time. There is increased in the road transportation over the year. Also with the development in the road sector, there is vast increment in the automobile sector and also in the transportation in the goods and services. With the increments in all this services, it helps the strength the road transportation in the India. Growing in the field of sale of automobile sector and the goods movement on the highway, reflects the expansion of highways in the country.

Necessity of examination

The road section of National Highway-458 which starts from the chainage 168+290 at Lambia and ends on the chainage 222+535 at Raipur in the Pali district of Rajasthan is selected for examine. The whole section of this stretch length is 54.245 Km is falling in the Pali district of Rajasthan. The examine road section starts from Lambia with chainage at km 168+290 and passes through the Jaitaran village at km 196+000 and ends at the km 222+535 in Raipur town. The road type of the section is two lane road and the carriageway width of the section is 7.00 meter. At the end of carriageway, both side paved shoulder with 1.5m width & the earthen shoulder whose width is 1.00 m on both side of the section. The existing road surface, in which maximum portion of the road lies in the fair condition and also provide the satisfactory riding quality to the road users. About 51% of the overall section is in good condition or about 48% lies in the fair condition and nearly around 1% is in poor condition. The average thickness of the pavement surface is nearly 450 mm. The road surface consist of bituminous surface overlying Wet Mix Macadam (WMM) and Granular Sub-Base (GSB) layers.

The main aim for the selection of this Lambia-Raipur road section of National Highway – 458 to explain the importance of the flexible pavement maintenance and management in the stage of operations and maintenance of the highways. This study help us to understand the types of defects in the flexible road surface and also how to minimize the defects so it the road users can ride without any hindrance. All this study helps to achieve the design life of the road section. For data collection and condition assessment, a Network Survey Vehicle (NSV) was used, which has ability to capturing the road section physical condition very fast and accurate.

Purpose of Examination

The main purpose of examination is to know the produced data by NSV vehicle like roughness, rutting, visual condition and different types of defects of the flexible pavement which lies in the operation and maintenance stage for all national highways to meet the design life of the pavement with cost estimation. So that, the maintenance of the highway is to be done with the minimum amount and the design life of the pavement can be achieved. Major result of the NSV Survey are as follows:

- Visual condition data - Which contains data of ravelling, cracks, potholes, edge break, bleeding, patching and different types of distresses.
- Roughness data - Pavement Profile per kilometer in all lanes.
- Rutting data- Pavement surface depression or Irregularities.

II. FIELD STUDY AND DATA ANALYSIS

Project Highway Section

The Road Condition Survey method is used to evaluate the condition of a road section at National Highway-458. It involves systematic data collection to examine the structural soundness of the pavement, identify various surface distresses, and assess the overall riding quality. In the current study, the selected stretch for conducting the survey is National Highway NH-458 from Lambia to Raipur section.

Condition Survey Carried out for Project Section

The Condition survey play one of the most significant and essential field activities of the project.

Working Method of Network Survey Vehicle (NSV)

The Network Survey Vehicle is mapped using advanced survey technologies that incorporate equipment such as lasers, GPS, distance measuring system and video image processing systems. It is employed for the automated collection of road section inventory data and road pavement condition data. The vehicle plays a significant role in studies related to road asset management, pavement maintenance management systems, and road safety audits by ensuring correct and efficient data acquisition.

Network Survey Vehicle System Key features

- About 80 km/h high survey speeds of vehicle

- ASTM-compliant longitudinal (International Roughness Index) & transverse (Rut Depth) profiling.
- Pavement Textures Mean Profile Depth
- It can measure Curvature Radius, Slope and Cross-fall
- Collect the data of GPS Coordinates (X, Y, Z) which are longitude, latitude, and altitude by DGPS
- (ROMDAS software) for Real-time in-vehicle data acquisition software for the display and gathering of data;
- Video imaging through out the stretch for roadside furniture/road assets;
- Data analysis and report preparation post processing software (DATAVIEW software).

Other some applications for Network Survey Vehicle are given below:

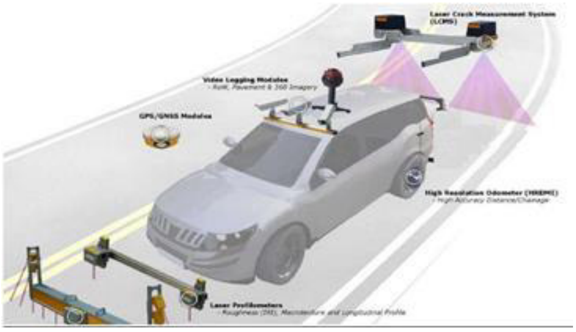
- Road Network and project level road and asset collection surveys
- Quality of road can be controlled by the contractor
- Maintenance of runway in the airport
- Easily management of the asset & road inventory data
- Stretch geometry and mapping surveys & Road safety assessment.

Advantages of Network Survey Vehicle

- Identify the root causes of pavement surface deterioration and related road section problems.
- Identify the correct place and extent of the damage section.
- To address the issue adopt new design techniques.
- Achieve improved road section quality and extended pavement life by adopting proactive maintenance practices.
- Save currency on asset management expenses.

Kinds of Surface defects Measured and Reported

The Network Survey Vehicle (NSV) contains advanced instruments such as the Laser Crack Measurement System (LCMS) for automated crack detection, high-resolution digital cameras for right-of-way (ROW) imaging, high-accuracy DGPS receivers, and ROMDAS (Road Measurement Data Acquisition System) software for in-vehicle data acquisition and processing. These technologies are used to measure correct data and evaluate various pavement surface characteristics and defects.



Schematic Representation of NSV

Engineering Criteria Meet by NSV

The following criteria has been met by the process of defects detection.

- Measuring the 3D road profile via established methods like laser scanning.
- Ability to collect data while operating at varying speeds, ranging from a minimum of 20 km/h to a maximum of 80 km/h.
- Profile depth precision is 0.5mm.
- The capability to monitor lane positioning to minimize driver deviation and ensure consistent, highly repeatable survey data.
- The width of a highway lane should be no less than 3.5 metres.
- A transverse profile is used to determine the widths of the pavement carriageway and shoulder areas. The collected rut depth information conforms to ASTM E1703 / E1703M standards and can be adjusted to various straightedge lengths ranging from 1.8 m to 3.5 m. Additionally, pavement imagery is captured with the capability to automatically detect and evaluate surface distresses.
- Roughness data shall be collected starting at least 100 metres in advance of each Location Reference Post (LRP). This requirement applies to both the unprocessed longitudinal profile data and the calculated International Roughness Index (IRI) values. The roughness measurements conform to ASTM E950 standards for a Class I road profiler. The IRI values are obtained for both wheel paths, and the results are identical for each path.
- Possibility of taking pictures at user-defined intervals (every 5m), for example.
- Minimum picture resolution is 1600x1200
- Standard JPEG image.
- The HRDMI (High Resolution Distance Measurement Instrument) integrated into our Network Survey Vehicle (NSV) is capable of achieving a distance resolution of 1 mm. It provides a measurement accuracy of 0.1%, which corresponds to a maximum deviation of 1 metre over a distance of 1 kilometre.
- All data is provided in open, non-proprietary formats such as .MDB or Excel files, allowing it to be accessed and reviewed without the need for any

specialised software.

Different Modules of Network Survey Vehicle (NSV)

Laser Crack Measurement System (LCMS Module)

- 28800 Hz invisible laser blasts at pavement surface
- Captures whole 4 m width profiles of a road lane
- Record images under both daytime and nighttime lighting situations.
- Automatic identification of certain pavement flaws

Laser Profilometer Module of Network Survey Vehicle

- A Laser Profilometer with two lasers is built within the NSV. Surface Pavement Roughness can be measured with this inertial profiler (one laser in each wheel path).
- The longitudinal profile of the road is calculated using samples taken every 25 mm of longitudinal travel from the outputs of the lasers and accelerometers placed in each wheel path (750 mm on either side of the centerline of the vehicle).
- After the survey, any abnormal spikes observed in the roughness data—caused by features such as rumble strips, speed breakers, expansion joints, cattle grids, railway crossings, bridge abutments, and similar surface irregularities—will be filtered out and excluded from the analysis.

As specified in World Bank Technical Paper No. 46 – Guidelines for Conducting and Calibrating Road Roughness Measurements, the equipment is classified as a Class I Roughness Measuring Device.

It meets International Standards mentioned below:

- World Class 1 Profiler
- ASTM E950
- ASTM E1926
- ISO 13473
- ASTM E1845

Limitations of Laser Profilometers

- Operating the vehicle on roads with an IRI value of 8 or higher is not recommended, as it may lead to potential damage and reduced measurement accuracy.
- Accuracy decreases at speeds below 20 km/h; therefore, surveys should not be conducted on untreated roads under such conditions.

Cracking Data

- Chainage of Crack
- Length, Width & Depth of Crack (in mm)
- Classification of Crack
- Severity of Crack
- Very Weak< 3mm wide

- Weak < 6mm wide
- Medium< 20 mm wide
- Major > 20 mm wide

Reveling Data

Raveling refers to the progressive deterioration of the pavement surface resulting from the dislodgement of aggregate particles and the loss of asphalt binder. It may begin with the removal of fine particles and gradually extend to the loss of coarse aggregates, eventually producing a noticeably rough, uneven, and pitted surface with significant aggregate loss.

- Chainage of Raveling
- Raveling Index Value (Indicator of Raveling)
- Percentage of Raveling (%)
- Area of Raveling (in m^2)
- Severity of Raveling

Potholes Data

For a defect to be classified as a pothole, it must have a minimum diameter of 150 mm, although this threshold can be adjusted as required. The default criterion is based on the Distress Identification Manual, published in 2003 by the Federal Highway Administration.

- Chainage of Pothole
- Area of Pothole (in m^2)
- Maximum Depth (in mm)
- Average Depth (in mm)
- Severity of Crack: Pothole Severity is defined according to IRC:82-2015 as below:

✓ Small: Less than 25 mm deep,
✓ Medium: 25 mm to 50 mm deep.
✓ Large: More than 50mm deep.

Rutting Data

- A rut is defined as a longitudinal surface depression formed along the wheel track of a roadway. Rutting may occur in one or both wheel paths within a traffic lane.
- Rut depth refers to the maximum vertical deformation of the pavement observed in a transverse cross-section, measured relative to a reference line drawn perpendicular (90°) to the edge of the roadway.
- Rutting may develop as a result of traffic loads as well as environmental factors. Repeated wheel loads, especially from heavily loaded trucks, can create longitudinal depressions along the wheel paths due to pavement deformation, surface wear, or a combination of both. In addition, environmental effects such as moisture infiltration can weaken and deform the pavement structure, subgrade, or shoulders. For example, swelling or heaving of the shoulder or pavement edge caused by moisture may lead to longitudinal surface depressions that are identified as rutting.
- Chainage of Road

- Left Wheel Path Rut Depth and Width (in mm)
- Right Wheel Path Rut Depth and Width (in mm)
- Average Lane Rut Depth (in mm)
- Severity of Rut/Condition of Road: Rut Severity is defined according to IRC:82-2015 as below:

✓ No rutting: Less than 4 mm depth.
✓ Low: 4 mm to 10 mm depth.
✓ High: More than 10 mm depth.

Roughness Data from Laser Profilometer

The roughness parameters for the respective project are presented in the RIS template for all six lanes of the main carriageway (L1, L2, L3, R1, R2, and R3). These parameters were derived from LCMS raw data processed using the ROMDAS data acquisition software and further analyzed through the DATAVIEW post-processing software.

- Left Wheel Path IRI in m/km for each lane
- Right Wheel Path IRI in m/km for each lane
- Lane IRI (Average of both wheels IRI) in m/km for each lane
- Roughness Index in mm/km for each lane
- Condition of Road a per IRC: SP:16-2019

Condition Assessment of Existing Pavement

Highway pavements consist of multiple layers composed of different materials, engineered to carry traffic loads under specific climatic conditions over a designated service life. The structural design ensures that stresses induced by wheel loads are adequately distributed and reduced so they do not exceed the load-bearing capacity of the subgrade. At the same time, the pavement must provide a smooth and durable riding surface in all weather conditions while ensuring a high level of safety for road users.

The purpose of pavement condition evaluation is to obtain accurate and timely information on its performance, determine the extent of deterioration, identify the need for maintenance, rehabilitation, or reconstruction, and estimate the associated costs.

Typical Distress types Associated with Performance

Performance Type	Performance Indicator
Functional	1. Riding Quality (Roughness and Rutting) 2. Surface Distress (Cracking, Bleeding, Potholes, Raveling etc.)

Analysis of Network Survey Vehicle (NSV) Data

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This section presents the analysis of the various performance parameters obtained during the NSV survey.

Roughness Analysis

- Roughness is a key parameter used to evaluate the functional performance of pavements. According to ASTM International (American Society for Testing and Materials), roughness is described as the irregularities or deviations of a pavement surface from an ideal flat plane, with characteristic dimensions that influence vehicle response, ride comfort, dynamic loading, and surface drainage.
- The International Roughness Index (IRI) and Bump Integrator Roughness (BI) are commonly used to describe the characteristics of a road's longitudinal profile and serve as standardized indicators of pavement roughness. IRI is expressed in meters per kilometer (m/km), whereas BI is reported in millimeters per kilometer (mm/km).
- IRI represents the cumulative relative movement between the sprung and unsprung masses of a vehicle model, standardized over a unit length of the road profile.
- The fundamental IRI model is based on a set of differential equations that describe the response of a simulated quarter-car system to variations in the road profile.

Characteristics of IRI

- Reproducible
- Portable
- Stable with time
- IRI summarizes the impact vehicle response, and is therefore appropriate when a roughness measure is desired that relates to
- Overall vehicle operating costs
- Ride quality
- Dynamic wheel loads
- Surface condition

Correlation between Bump Integrator Roughness (BI)/ Unevenness Index (UI) and International Roughness Index (IRI) (As per IRC: SP:16-2019)

The accepted world standard for Roughness is the International Roughness Index (IRI). The IRI was an outcome of the International Road Roughness Experiment conducted in Brazil (Sayers et al., 1986a) and is reproducible, portable and stable with time. The equipment is equipped with software capable of computing and generating detailed profile

statistics, including IRI values, individual point elevations, and localized surface curvatures. For the purpose of correlating with BI/UI values, the relationship provided in

Roughness Range(m/km)	Severity	Length in Km	
		L1	R1
Less than 2.55	Good	7	6
2.55 – 3.30	Fair	5	1
More than 3.30	Poor	42.245	47.245
Total		**54.245**	**54.245**

$$\boxed{BI = 630(IRI)^{1.12}}$$

Roughness results of the project road

Maximum Permissible Roughness Values for different pavement surface

S. No.	Type of Surface	Condition of Road Surface					
		Good		Fair		Poor	
		RI	IRI	RI	IRI	RI	IRI
1	Bituminous (BC, SMA, SDBC)	<1800	<2.55	1800-2400	2.55-3.30	>2400	>3.30
2	Cemented	<2000	<2.81	2000-2400	2.81-3.30	>2400	>3.30

Note: In case of four lane divided and above corridors, roughness measurements shall be carried out using Class 1 equipment. For other corridors, the roughness measurements shall be carried out using Class 1/Class 2 or Class 3 equipment depending upon survey speed/geometric suitability.

Newly constructed surface is expected to give roughness values corresponding to GOOD category while the value under AVERAGE and POOR category indicates level-of-service and intervention level for maintenance.

Rutting Analysis

Rutting is a significant parameter used to assess the functional condition of a pavement. It is identified as a permanent deformation occurring along the wheel paths, primarily caused by repeated loading from heavy vehicles. Rutting is considered one of the principal distress mechanisms in asphalt pavements. The detailed rut depth measurements are provided in the RIS Template. A length-wise summary of rut depth conditions for both traffic directions is presented in the table below :

Standard Rutting Depth Range and Severity

Rut Depth Range (mm)	Severity
Less than 5 mm	Good
Between 5mm & 10 mm	Fair
Greater than 10 mm	Poor

Flexible Pavement Distress

Fatigue (Alligator) Cracking

Fatigue cracking consists of a series of interconnected cracks that develop due to repeated traffic loading, leading to fatigue failure of the HMA surface or stabilized base layer. In thin pavements, cracking typically initiates at the bottom of the HMA layer—where tensile stresses are highest—and gradually propagates upward to the surface. This type of distress is commonly known as "classical" or "bottom-up" fatigue cracking.

Bleeding

A film of asphalt binder that coats the pavement surface, often creating a shiny, glassy appearance and sometimes becoming tacky or sticky to the touch.

Block Cracking

Rectangle-shaped sections pavement are separated by connecting fissures. The sizes of blocks range from roughly 0.1 m^2 (1 ft^2) to 9 m^2 (100 ft^2). Block cracking typically affects a large area of the pavement.

Corrugation and Shoving

This distress involves plastic deformation of the pavement surface, resulting in ripples (known as corrugation) or wave-like displacements (referred to as shoving). The deformation generally occurs parallel to the direction of traffic flow.

Depression

These are localized areas of the pavement surface that are slightly lower than the adjacent sections. They become particularly noticeable after rainfall, as water tends to accumulate in these depressed areas.

Joint Reflection Cracking

These cracks occur directly above the joints of the underlying rigid pavement. Cracks that form away from an existing joint or those not associated with joints in stabilized bases (such as cement- or lime-treated layers) are not classified as joint reflection cracking.

Longitudinal Cracking

Cracks that run parallel to the laydown or centerline of the pavement. It is the variety of fatigue cracking.

Patching

A portion of the pavement surface that has been repaired by placing new paving material over a damaged area.

Polished Aggregate

Portions of the HMA pavement surface where rough or angular aggregate particles are absent, or only a minimal amount of aggregate extends above the asphalt binder.

Potholes

Shallow, bowl-shaped cavities on the pavement surface that penetrate through the entire HMA layer and reach down to the base course.

Raveling

The gradual breakdown of an HMA layer caused by the displacement of aggregate particles, starting at the surface and working its way down.

Rutting

Wheel-path depression on the road surface. Along the sidewalls of the rut, pavement rise (shearing) may take place.

Slippage Cracking

Cracks shaped like a crescent or half-moon, usually with both ends oriented in the direction of traffic movement.

Stripping

The progressive loss of bond between the asphalt binder and the aggregates, typically initiating at the bottom of the HMA layer and advancing upward.

Transverse (Thermal) Cracking

Cracks that develop at right angles to the pavement centerline or direction of placement, most commonly associated with thermal (temperature-related) cracking.

Water Bleeding and Pumping

"Water bleeding" refers to the seepage of water through an excessively porous HMA layer, joints, or existing cracks. Pumping occurs when water along with fine particles from the underlying layers is forced upward through cracks in the HMA surface under the action of moving traffic loads.

III. RESULTS AND DISCUSSIONS

Road Type

Roads are categorized into different types according to their characteristics, purpose, and traffic capacity, such as two-lane, four-lane, six-lane, and eight-lane configurations. The table below indicates that NH-458 is a Two-lane road.

Pavement Type

Pavement types are defined by the materials used for road construction. The selection of a suitable pavement type depends on several factors, including traffic intensity, climatic conditions, subgrade characteristics, available budget, and the required service life. Pavements are generally classified as either flexible or rigid. The table below shows that NH-458 consists of flexible pavement.

Roughness

Highway roughness denotes the surface irregularities or unevenness present on a roadway that may cause riding discomfort, raise vehicle operating costs, and adversely affect safety. It is a key indicator of pavement performance and is routinely measured to assess overall road quality.

Higher roughness values signify a more uneven and deteriorated road surface, whereas lower values reflect a smoother pavement condition. When roughness levels surpass the specified threshold limits, maintenance or rehabilitation measures are planned and implemented to improve ride quality and restore surface smoothness.

The NH-458, data is collected for every 1 km in increasing as well as in decreasing directions and the vehicle captured the IRI for L1 and R1.

Rutting

Rutting is a common surface defect observed on paved roads, particularly in asphalt pavements. It is characterized by the development of continuous longitudinal depressions along the wheel tracks, resulting from the repeated application of traffic loads over time. The NH-458, we got data in terms of average Rutting for Increasing (L1) and Decreasing (R1).

Visual Condition

Visual condition assessment forms a vital component of road surveys and inspections, aimed at determining the overall condition of the pavement surface. It involves systematically examining the roadway to identify and record different types of defects, deterioration, and surface damage. During a visual condition survey, distresses such as cracking, ravelling, potholes, shoving, patch repairs, settlement and depressions, rutting, and edge breaks are evaluated and documented. In given table, the visual data is being collected for above distresses, the distress is being rated from 1 to 5.

- Rating 5 indicates - Very Good
- Rating 4 indicates - Good
- Rating 3 indicates - Fair
- Rating 2 indicates - Poor
- Rating 1 indicates - Very Poor

Output Analysis

The collected data are classified into two main categories: roughness and distress. All visual condition details are included under the distress category. The distress results are further grouped according to defined rating levels, as illustrated below.

- Rating 5 indicates - Very Good
- Rating 4 indicates - Good
- Rating 3 indicates - Fair
- Rating 2 indicates - Poor
- Rating 1 indicates - Very Poor

When all the distress data is been categorized in respective levels and weightage factor is multiplied as shown below.

Weightage Factors

Parameter	Weightage
Cracking(%)	1.21
Ravelling(%)	0.91
Potholes(%)	0.61
Shoving(%)	0
Patching(%)	0.91
Settlement & Depression(%)	0.91
Rutting(mm)	1.21

Additionally, the roughness category is determined based on the corresponding IRI values, and the associated levels and ratings are presented in the table below.

Level and Rating

Min - Range	Max-range	Level	Rating
0	1600	Very Good	5
1600	1800	Good	4
1800	2400	Fair	3
2400	3500	Poor	2
3500	20000	Very Poor	1

After, assigning the level and ratings to the Roughness we need distribute the weightage factor in Distress and Roughness equally to achieve Road quality parameter. Here, the roughness and distress shares equally 50%. of weightage.

Maintenance Category based on Distress Score and Roughness Score can be achieved by (Distress + Roughness) x 0.5, whose value will come in between 0 -5, for scoring the achieved value and rating we follow the below table. As per the scorings the maintenance take place.

IV. FUTURE SCOPE OF WORK AND CONCLUSIONS

Future Scope of Work

- India possesses an extensive road network, which continues to expand steadily to support the efficient, safe, and rapid movement of goods and passengers across the country.
- In addition to constructing new roads, it is essential to maintain the existing road

network in good condition to ensure safe, smooth, and convenient movement of traffic for all users.

- Assessing the condition of a road is essential to understand its current serviceability and distress levels, which helps in identifying and planning suitable maintenance and rehabilitation measures to ensure improved and sustained road performance.
- Network survey vehicles play a vital role in supporting the development, maintenance, and safety management of highways across India.
- **Infrastructure Assessment:** Network survey vehicles are fitted with advanced sensors and technology to assess the condition of the highway infrastructure. These systems are capable of detect and record various parameters such as road surface quality, potholes, cracks, rutting, and pavement distress. The information collected helps authorities analyze road conditions, prioritize maintenance and rehabilitation works, and ultimately enhance safety and riding quality for road users.
- **Safety Improvement:** By detecting potential hazard locations such as sharp curves, blind spots, and insufficient signage, survey vehicles contribute significantly to improving road safety. The data gathered enables authorities to implement appropriate corrective actions, thereby minimizing accidents and reducing risks for both motorists and pedestrians.
- **Traffic Management:** Network survey vehicles are capable of observing traffic flow patterns, congestion levels, and driver behavior along highways. The information obtained is useful for planning and improving traffic management strategies, introducing suitable control measures, and enhancing the overall efficiency of traffic operations.
- **Asset Management:** Highways are important assets that require substantial investment for their upkeep. Network survey vehicles support the systematic inventory of road elements such as traffic signs, signals, guardrails, and pavement markings. The collected data facilitates effective asset management and helps in proper planning and allocation of funds for maintenance and improvement works.
- **Planning and Design:** The information gathered by survey vehicles plays a crucial role in the planning and design of new highways or the expansion of existing roads. It provides engineers and planners with a clear understanding of current road conditions, traffic behavior, and possible constraints, enabling the development of more efficient and well-structured roadway projects.

- **Regular Monitoring:** Conducting regular surveys with network survey vehicles enables ongoing assessment of highway conditions over time. The data obtained supports the adoption of preventive maintenance practices, helps prolong the service life of pavements, and minimizes long-term repair and rehabilitation costs.
- **Quality Assurance:** Network survey vehicles can also be utilized to assess the quality of construction on newly built roads or during rehabilitation works. This helps verify compliance with specified standards and technical requirements, thereby reducing the likelihood of premature failures and repeated maintenance.
- **Data-Driven Decision Making:** The deployment of network survey vehicles encourages data-driven decision-making in highway management and maintenance activities. Reliable and up-to-date information helps authorities set priorities, utilize resources effectively, and respond to issues in a timely manner.
- **Enhanced Automation:** In the future, network survey vehicles are likely to become increasingly automated and autonomous, minimizing reliance on human operators and enhancing operational efficiency. With the integration of advanced sensors, high-resolution cameras, and AI algorithms, these vehicles could independently navigate roadways and capture data with limited manual involvement. This advancement would contribute to greater accuracy, improved productivity, and reduced operational costs.
- **Integration of Advanced Sensors:** The incorporation of cutting-edge sensors, such as LiDAR (Light Detection and Ranging), high-definition cameras, and advanced radar systems, will provide more comprehensive and detailed data about the road infrastructure.
- **Real-time Data Analysis:** With the increasing availability of high-speed internet and data processing capabilities, network survey vehicles could analyze data in real-time.
- **Integration with Smart Infrastructure:** Network survey vehicles could be integrated with smart infrastructure technologies such as Intelligent Transportation Systems (ITS), enabling effective communication between vehicles and roadway infrastructure. Such integration would support better traffic management, improve operational efficiency, and significantly enhance overall road safety.
- **Use of Artificial Intelligence:** Artificial intelligence algorithms can be utilized to process and interpret the extensive data gathered by network survey vehicles with greater speed and accuracy. These systems can detect trends, forecast pavement

deterioration, and suggest suitable maintenance interventions

- **Sustainability and Environmental Considerations:** In the future, network survey vehicles may emphasize sustainability by integrating environmentally friendly technologies and minimizing their carbon emissions. They could also be designed to evaluate the environmental impacts of highways, enabling authorities to plan, construct, and maintain road projects in a more sustainable and eco-conscious manner.
- **Collaboration and Data Sharing:** With growing significance of data in highway management, increased collaboration and data sharing among stakeholders such as government agencies, private organizations, and research institutions may become more common. This collective approach to data exchange can result in more detailed, reliable, and comprehensive evaluations of road networks.

Conclusion

- Road Asset Management through the use of Network Survey Vehicles emphasizes the significant contribution of these advanced systems in transforming the assessment, maintenance, and overall management of road infrastructure. These vehicles have become essential tools for enhancing the safety, operational efficiency, and long-term sustainability of road networks.
- The thesis examines the importance of network survey vehicles in evaluating infrastructure conditions, enhancing road safety, improving traffic management, and supporting effective asset management. Based on the results obtained from the survey of the Lambia–Raipur road section, also designated as National Highway 458 (NH-0458), the study corridor is a two-lane roadway with a total length of approximately 54.245 km. In view of the results the Average Road Condition Index for NH00458 is approx. 3.19 and the Road Condition seems to be "Good". However, in s such areas where the conditions are Good or Fair in those areas Maintenance treatment is to be provided.
- By collecting comprehensive information on road condition, surface characteristics, pavement distresses, and traffic flow, these vehicles support evidence-based decision-making and efficient allocation of resources. This approach allows maintenance activities to be properly prioritized, resulting in reduced costs and enhanced riding quality and safety for road users.
- Furthermore, the thesis highlights emerging trends that are likely to influence the evolution of network survey vehicles, such as increased automation, incorporation of advanced sensing technologies, real-time

data processing, and the application of artificial intelligence. With ongoing technological advancements, these vehicles are anticipated to achieve higher levels of efficiency, precision, and environmental sustainability, thereby strengthening their role in effective road asset management.

- In summary, the thesis reinforces the vital role of network survey vehicles as transformative tools in road asset management. With continuous technological advancements and the integration of innovative systems, these vehicles, expected to assume even greater role in preserving & improving quality, safety, and sustainability of road networks, ultimately benefiting both road users and the environment.

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