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FUNCTIONAL ANALYSIS OF DOUBLE BITUMINOUS SURFACE TREATMENTS

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ABSTRACT

Purpose: The purpose of this study is to assess the performance of double bituminous surface treatment on the Malekhu–Dhading Beshi (MDB) Road in Nepal-Asia.
Design/Methodology/Approach: The descriptive study was conducted to evaluate the compatibility of the road condition assessment method for analysing results and assessing road conditions between 2012 and 2021. The assessment method consists of the International Roughness Index (IRI), the Surface Distress Index (SDI) and the Pavement Serviceability Rating (PSR). The correlation between SDI and IRI, SDI and Average Annual Daily Traffic (AADT), IRI and AADT, SDI and Age of pavement, and IRI and Age of pavement were obtained from the correlation analysis.
Research Limitation: The study lacked adequate data on the quality and availability of the performance of the road projects and the delays in the study area.
Findings: The relation between IRI-Traffic and SDI-IRI is positive, with R2 values of 0.0713 and 0.6831, respectively. The relation between IRI and Traffic is poor, and the relation between SDI and IRI is good. The relation between SDI-Traffic and SDI-Age of pavement is logarithmic, with R2 values of 0.4786 and 0.4319, respectively, which is a moderate relationship. The relation between the Ages of pavement and IRI is polynomial with an R2 value of 0.2676, indicating a poor relationship. Pavements in this category (value of PSR between 1.00 and 2.00) have deteriorated to such an extent that they affect the speed of free-flow traffic.
Practical Implication: Understanding performance characteristics enables the strategic timing of applications, the selection of appropriate treatment types, and the prediction of maintenance cycles. This leads to a more efficient allocation of public resources and extended pavement life cycles.
Social Implication: Enhanced road surfaces facilitate emergency vehicle access, school bus transportation, and agricultural product movement, directly impacting quality of life and social equity.
Originality/Value: This pavement deterioration model can be used for the forecast of future values of IRI. This model is the basis for the assessment of Double Bituminous Surface Treatment pavement.
Keywords: *Forecast. improvement. maintenance. pavement condition. rehabilitation cost*

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INTRODUCTION

Department of Roads (DoR) Nepal has constructed 13,447.62 km of road, including 6,979.33 km of Blacktopped, 2,276.87 km of Gravel and 4,191.42 km of earthen roads (DoR, 2018).

Since 2005, DoR has started to collect data related to surface SDI and IRI of paved roads, though it does not represent the structural conditions. According to available data, the SDI and IRI assessments of Double Bituminous Surface Treatment (DBST) pavements can be conducted. DoR is responsible for the operation and maintenance of highways under the government's planned maintenance strategy. However, in Nepal there is no such precise and reliable maintenance strategy throughout the year, recurrent maintenance (at least twice a year), periodic maintenance (usually 6 to 8 years interval based on periodic maintenance guidelines) and emergency maintenance (during monsoon whenever needed) are being implemented under the planned methodology has been in practice till now except SDI and IRI but improving (Aggarwal et al., 2014). In the prevailing situation, surface condition can be evaluated based on available data, and it will be helpful for the assessment of pavement in one of the major feeder roads of Nepal (DoR, 2005; Adlinge & Gupta, 2012).

The Malekhu-Dhading Beshi Road (MDBR), traced in the late 1960s with the voluntary participation of the people in the concerned area, was financed by a German government-owned development bank Kreditanstalt für Wiederaufbau (KfW), for its upgradation to an all-weather bitumen road along with the construction of a new bridge over Thopal Khola and rehabilitation of the Trishuli River Bridge. It is supposed to be an environmentally friendly Green Road Project. The Swiss Consultancy ITECO carried out a feasibility study to upgrade it and made a cost estimate of Nepalese rupees (NRs·) 650 million for the upgrading-related construction and rehabilitation activities. The maximum speed that the design of the road allows is 25 km/h. Feasibility studies were carried out with the financialassistance of KfW for the road in 1996 and for Trishuli Bridge in 1997. The Government of Nepal (GoN) and KfW signed the first agreement to implement the project on March 9, 1998, in order to upgrade Malekhu Dhading Beshi Road, to rehabilitate Trishuli Bridge andto construct Thopal Khola Bridge. In 1999, the total project cost was estimated to be 16.8 million Deutsche Mark (DM), which was later revised to be 16.44 million DM, equivalent to NRs. 608 million in 2000 (CEDECON, 2003; Gautam, 2018; Gautam et al., 2017).

In this operation, the Roads Board Nepal and DoR could work jointly for a more effective, stable and steady fund flow for the road maintenance.

In Nepal, DBST is widely used in feeder roads, especially hilly roads with moderate traffic and loading. Due to the technical capacity of the client, consultants and contractors, Nepal is now experiencing DBST, but construction quality is to be improved in the coming years to apply it. (CEDECON, 2003) MDB is a road with a pavement life of 16 years, and there is insufficient research on pavement condition and necessary maintenance interventions.This road meets feeder

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road specifications as put forth by DoR, except for a few curves and switchbacks. Assessment of pavement conditions is to be done for the improvement of the road. DBST is used for surfacing roads, streets, parking areas, storage areas and airfield shoulders and overruns. Sufficient research has not been conducted to predict the condition of pavements in Nepal. DBST is an economical maintenance tool that is easy to place with a minimumof personnel and is long-lasting; hence, the study of this road section is selected (Burke, 1994).

Regular and reliable information on road conditions is essential for a proper maintenance management plan. The reliability of data to be collected by an inspection team depends verylargely on the techniques being used. Good techniques will lead to good data and a sound maintenance system for the roadway network in the Palestinian Territories.

Irregular information collection regarding pavement condition, and with limited human resources, it is not being effective. The planning and budgeting of future years' workload are based on the present available SDI and IRI values. It is difficult to predict the deterioration of the pavement and design appropriate maintenance strategies. DoR is notable to develop best practices for the timely planning and programming of preservation and rehabilitation treatments (Gautam et al., 2017).

The recent data on the condition of this road under DoR shows that maintenance and rehabilitation (M & R) were not taken care of appropriately and systematically by DoR. One of the primary reasons for poor maintenance is the limited availability of resources for road M & R. Additionally, improper activities or untimely execution of M & R can also contribute to this issue. Investment in new road construction and road improvement is not sufficient; proper maintenance and repair (M&R) is equally important.

Assessments of pavements are helpful for both public and for communications with the public; the results help to increase awareness among road users, decision makers and legislators regarding its importance (Brinson & Ammons, 2011). This result not only educates them but also helps to make appropriate investments in the whole transportation.

The main objective of this research is to assess the performance of the Double Bituminous Surface Treatment (DBST) pavement of the Malekhu-Dhading Beshi Road section.

LITERATURE REVIEW

Reduction in asphalt concrete production and placement temperatures offered by Warm Mix Asphalt (WMA) results in several environmental, economic and social performance and construction benefits in support of sustainable development. The sustainability benefits of WMAs 22 derive from: Low energy use for production and placement (Tutu & Tuffour, 1987), Low emission of greenhouse gases, Conservation of natural resources, and increased reuse of old asphalt in new asphalt mixes. These benefits notwithstanding, it is recognised that cost increases

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may arise from plant modification, the cost of additives and technology licensing fees. However, such costs are likely to be offset by cost reductions due to lower production temperatures and less plant wear (EAPA, 2009).

WMA technologies are comparatively energy-efficient due to their ability to reduce mix production temperatures. This translates to reduced fuel costs and results in savings that may range from 11% to 35%, which correspond to 1.5 – 2.0 litres of fuel per ton of WMA mix (D'Angelo et.al, 2008). Nicholls and James found that a reduction in production temperature by 10˚C results in energy savings of 3% to 4%, which corresponds to about 0.25 kg of fuel per ton of asphalt produced (Nicholls & James, 2013). Mixing temperature of WMA to allow for long haul distance is possible without causing significant premature ageing of the binder (Croteau & Tessier, 2008).

The growing acceptance of WMA is based on confirmation of its economic, environmental and performance benefits relative to conventional HMA, and it is anticipated that WMA will soon become the standard practice within the industry (Nicholls & James, 2013). Reported paving-related benefits of WMA include," ability to pave in cold weather and yet obtain desired densities", "ability to have good workability after long haulage"," reduced compaction effort"," ability to incorporate higher proportions of RAP", and " ability to place multiple lifts within a short time " (UN Press Release, 2014), (Nicholls & James, 2013). It is believed that more uniform compaction is achieved with WMA because its compaction temperature allows the roller train to be better spaced to ensure proper mat coverage (Anderson & May, 2008).

WMA exhibited similar or better performance, including improved compaction, similar stiffness and rutting resistance, improved resistance to fatigue and thermal cracking, similar or less moisture damage and greater durability compared with Hot Mix Asphalt (HMA) (D'Angelo et al., 2008). Due to the relatively low production and placement temperatures, WMA provides comfortable working conditions, both at the asphalt plant and at the paving site, as workers experience cooler working temperatures, a reduction in the emission of fumes and odours. Reduction in the emission of fumes and odour during placement of WMA has been found to range from 30% to 50% (D'Angelo et.al, 2008) and (Anderson & May, 2008) and from 30% to 90% behind the paver (Croteau & Tessier, 2008). According to European Asphalt Pavement Association (EAPA) (2010), as a rule of thumb, the release of fumes is reduced 23 by about half for each 10˚C reduction in placement temperature. The table of factors and references is given in the appendix.

METHODOLOGY

Study Area

MDB road is one of the major feeder roads of Nepal. The road starts from Trishuli Bridge over Trisuli River at Malekhu of Prithivi Highway. It connects the Dhading district with the National Highway.

The road from Malekhu to Dhading Beshi has already been upgraded to all-weather bituminous

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roads, which the government of Nepal implemented with the assistance of the KfW. The implementing agency for the project was the DoR of the Ministry of Physical Infrastructure and Transport. This study covers the section between km 0+000 to km 17+500, which lies within the Dhading district, and the construction of DBST was completed in2002. The terrain in this road is hilly, representing DBST pavement construction on hill roads in Nepal. The road is of strategic importance, i.e., a major feeder road and the age of the road is 16 years, so this road is selected for study. As the age of pavements in this section exceeds 16 years, road deterioration, such as cracking, is visible.

The pavement structure consists of an average of 10 cm thick double bituminous surface treatment surfacing on top of a 20 cm thick crushed stone base and sub-base, ranging from 20-30 cm mixed with aggregate material. Subgrade soil for the road was predominantly soft soil with small sections of bedrock and silty clay soil (CEDECON, 2003).

The study area of this study is 17.5 km of blacktopped. This section of data on road geometry, traffic, and road condition is maintained in HMIS, DoR. According to the division road office's records in Bharatpur, minor maintenance was conducted in 2013 to improve the road surface and enhance traffic safety. This involved providing, mixing, laying, and compaction of premixed bituminous carpet. Additionally, recurrent maintenance was performed in 2016 to repair potholes and address damage to the bituminous surface.

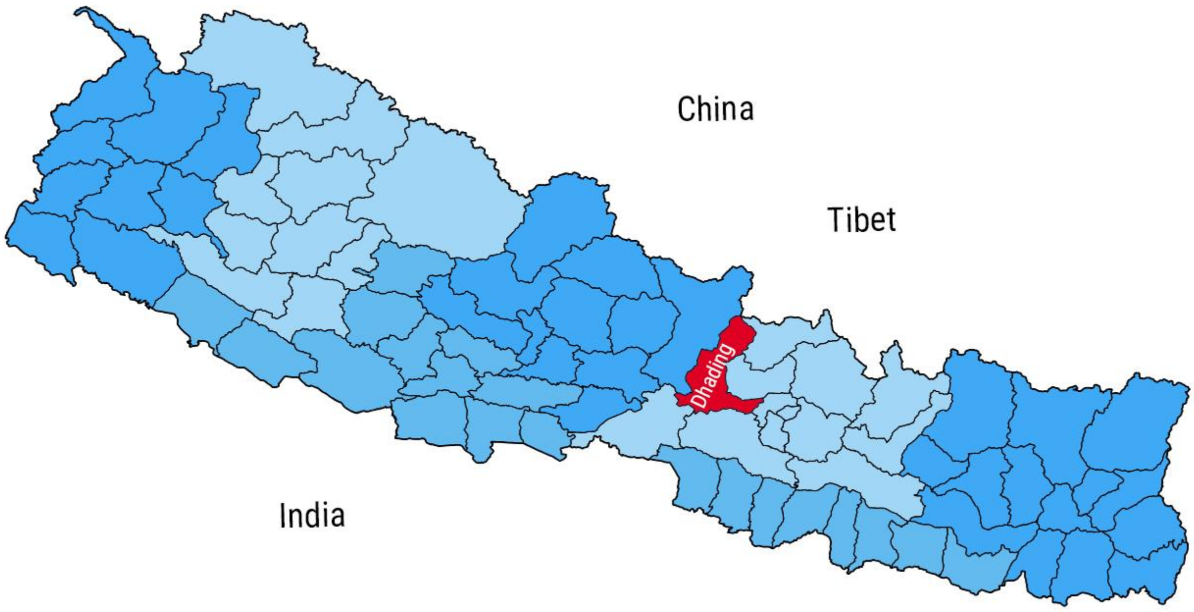

Figure 1: Map of Nepal Showing Dhading District
Source: (http://www.google.com/map) [Accessed on 12 January, 2019]

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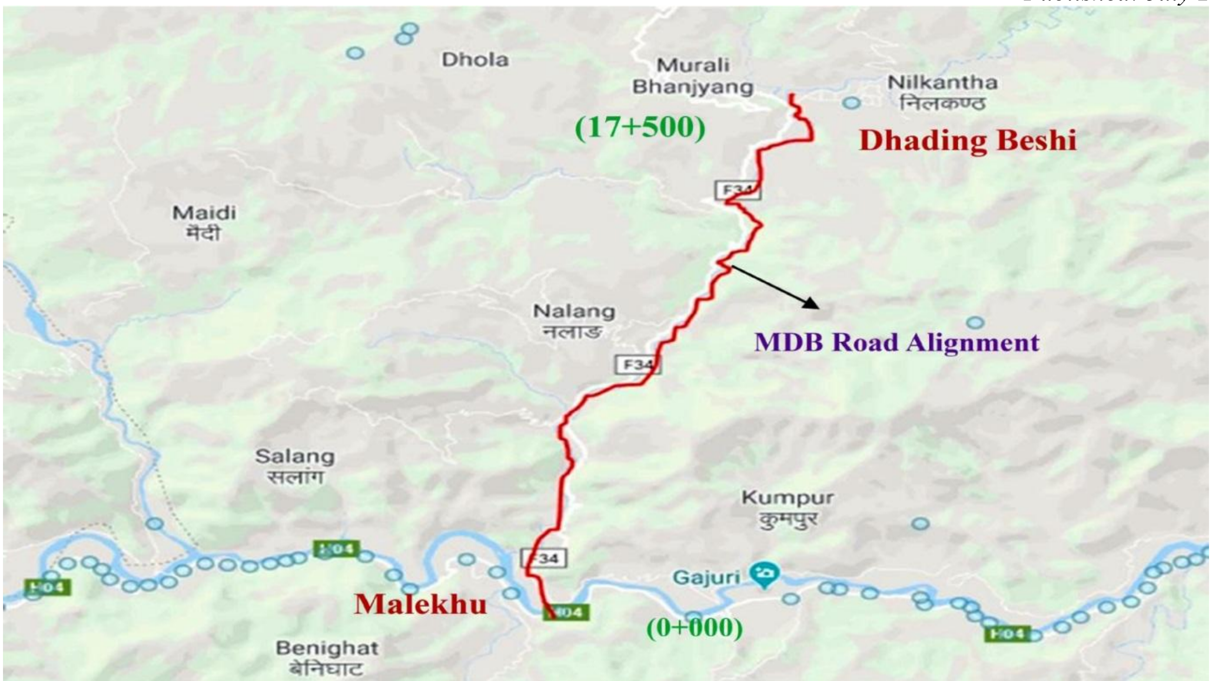

Figure 2: Study Area Map
Source: (http://www.google.com/map) [Accessed on 12 December, 2018]

Data Collection

Secondary Data Collection

A review of the relevant documents and familiarisation with the theory and practice of surface distress and road roughness has been done.

1. **Road Section Basis:** Road section information like link ID, link name, length, speed flow type, traffic flow pattern, road class, climate zone, surface type, road width and shoulder were collected from the DoR-HMIS unit in 2019.
2. **Road Section Condition:** Road section condition data, consisting of IRI and SDI of the last seven years (2012 to 2018) of the MDB road, were collected from the DoR-HMIS unit in 2019.
3. **Road Section Traffic:** Traffic data of MDB was collected from the DoR-HMIS unit in 2019.
4. **Unit Cost: The** Unit cost of road works was collected from recent DoR projects and ARMP of 2018 for the costing purpose. These are simplified rates based on DoR work norms, and the district rate of Dhading District was taken as the base norms and rate for cost estimation of M&R works. The other data related to maintenance was collected from the authorised authority.

Several references were thoroughly analysed to get an idea, such as (Long, 2016; Owolabi et al., 2012; Siswosoebroth et al., 2005; Sinurat, 2014; Muench et al., 2010; Gupta et al., 2014; Gharaiben et al., 2012; Aashto, 2001).

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Primary Data Collection

The distress survey is also a tool for estimating recurrent needs and monitoring recurrent work. Distress surveys and measures of major and minor distresses in the appropriate formats compatible with DoR- Road Network Database System (RNDS) were done. The following primary data were collected.

1. **SDI Data:** During the field survey 100% sampling survey was done, and all pavement distress (potholes/ cracks, etc.) was captured. The formats and methodology for the surveys and distress recording were developed and used. The distresses were taken to suit the HDM database format. The process to create a group from 100% systematic sampling involved identifying the road length and then selecting a starting point for chainage. The procedure comprises a walk-over survey generally covering the last 1000-meter sections of the road on which the current SDI was determined. To represent non-representative sections of the road, additional samples were taken.

   The percentage area of each distress present in each of the inspected sample units was calculated. Each section was rated as per the Indian Road Congress (IRC) (IRC: 82, 2015) guidelines. The functional condition of the pavement was assessed as good, fair or poor based on this rating. The overall pavement condition was also determined. Direct speed measurement methods measure the running speed of vehicles.

2. **Traffic Volume:** For geometric design and evaluation of economic benefits, the volume, composition and loading for current and future traffic on the road needto be known. All traffic forecasts, except in the case of new roads, require knowledge of existing traffic and a combination of reliable historical traffic information as well as information on local and national traffic growth. Traffic studies were conducted on the studyroad stretches, with axle load surveys on roads identified for deterioration modelling. The data collected includes: Classified traffic volume (direction-wise) count was done for 1 hour on a representative 3 days (December 26, 27 and 28, 2018). The traffic volumes are also a cause for pavement deterioration. With the increase in traffic volume, the roughness of the road also increases. With the increase in traffic volumes, the rutting area will be developed across the wheel path, the cracking area will increase, which will soon develop into potholes, and there will be a loss of materials from the wearing surface of the pavement, since there is no separate lane for heavy vehicles and buses in the study area. A traffic survey was conducted in the exact location as previous surveys conducted by the DOR. A traffic count survey was done near the start of the road section (0+100). Vehicle classification was done as per DoR, 2005.

3. **Vehicle Speed:** To find out the speed, a direct timing procedure was used, for which two points were marked on the pavement at a 200-meter distance apart, and an observer started and stopped an accurate stopwatch as the vehicles crossed these two marks. Location selection was based on the survey team's specific purpose of minimising impact on traffic flow and speed, considering

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both straight, level sections and those in grade with curves. Two sections at chainage 0+100 and 12+000 were selected. From the known distance and measured time intervals, spot speed was calculated. Due to the parallaxeffect, the reaction of an individual observer may affect the result. One observer stands at the firstreference point and gives a signal to the observer standing at the last reference point (with a stopwatch). The speed of public vehicles and private vehicles was measured separately (every fifth vehicle). This speed is important for the regulation and control of traffic operation, analysing the causes of accidents, before and after study of improvement projects,determining the problems of congestion in the road section and level of service (Kassa, 2013; Mishra et al., 2020).

Running Speed (km/hour) = 3.6*Length of Route (m)/ Running Time (second).

Data Analysis

There are two steps of data analysis: first, to identify the current pavement condition, and second, to forecast the pavement condition after three years, considering the M&R cost. The different relationships between independent and dependent variable parameters were analysed to find pavement condition. The average speed was calculated in kilometres/hour (km/hr), and the traffic volume was calculated in vehicles/hour (veh/hr).

The deterioration rate was determined using the data along the road. The condition level was determined regarding pavement condition. These factors were calculated using data based on the values and relationships between IRI, SDI, Traffic, and Age of pavement, and IRI and Age of pavement. SDI and IRI after three years (2021) were forecasted. M&R work was determined, and the cost was estimated, and a comparison was made for the present year (2019) and after 3 years. M&R work was done. There are severalcorrelations between PSR and IRI.

Regression analysis was conducted, and three types of best-fitted curves —power, polynomial, and logarithmic —were identified during the analysis, establishing a relationship.

Different techniques available for developing pavement deterioration models were reviewed. The regression technique is empirical, and it tries to build a relationship between the pavement condition and its causative factors. The reliability of a regression model was measured by its goodness of fit, in terms of the coefficient of determination R^2 value.

The equation for analysis is as follows;

Power $y = \alpha\, x^{\beta} \ldots$ *(I)*
Polynomial $y= \alpha x^2+\beta x+\epsilon \ldots$ *II)*
Logarithmic $y = \alpha\, Ln\, (x)-\epsilon \ldots$ *(III)*

Where x is the independent variable, y is the dependent variable, that is, the condition indices, and α and β are the regression parameters, and ϵ is the prediction error.

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To correlate pavement section responses to traffic and climatic parameters from these methods, two parameters must be combined into a single parameter. These parameters are the Present Serviceability Rating (PSR). Various correlations were established between PSR and IRI. The most used equations are as follows.

Calculation of PSR using the relationship between PRS and IRI given by (Paterson, 1986; Paterson, 2000; Paterson, 2012) was done using the following relation.

$$PSR = 5e^{(-0.00286*IRI)} \ldots (IV)$$

Where,

PSR = present serviceability rating (varying between 5 and 0),

IRI = international roughness index (inches/mile).

PSR ranges from 0 to 5 (very poor to very good). The PSR is also a well-known indicator of pavement condition in the highway community. Not much is currently known about the IRIon the national highways, especially critical levels at which pavements should be rehabilitated.

Forecast of Traffic, IRI and SDI data

The end goal of DoR is "The reduction of total road transport cost". Total transport cost includes construction costs, maintenance costs and road user costs. To achieve its goal, DoR requires regular access to updated road data in a compiled database system and records, which will facilitate network planning. Traffic count and vehicle classificationsurveys on Strategic Road Networks (SRN) have been conducted by DoR. For the future values ofTraffic, IRI and SDI, various relations and models are used, and a forecast of data can be made.

Forecast of Traffic

For design purposes, future year-wise traffic is needed. The future traffic is estimatedusing the following formula;

$$A = P\,(1+ r)^{x}$$

Where,

P is the number of commercial vehicles as per the last traffic count.

x is the number of years between the last traffic count and the year of interest.

If the data for the annual growth rate of commercial vehicles is not available or if it is lessthan 5 percent, a growth rate of 5 percent should be used (IRC:SP:84-2009: Makendran & Murugasan, 2015).

Forecast of IRI

IRI is a worldwide standard for measuring pavement roughness; however, in Nepal, DoR use the SDI as a roughness Index. The IRI index measured pavement roughness in terms of the number of meters per kilometre that a laser, mounted in a specialised Van, jumps as it is driven across the road networks. Forecasting measured IRI is necessary for analysing pavement deterioration trends, which can be achieved by directly using previously measured IRI or by establishing a relationship with other pavement parameters, such as pavement age, SDI, Structural numbers, and AADT

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(Suryoto & Ary, 2017; Suparman, 2017).

Gulen has developed a relationship, and the IRI of road pavement can be forecasted for futureyears. A relation was developed considering IRI as a dependent variable, and Age of pavement in years and AADT were considered as independent variables.

Using the Relationships

IRI = 43+1.8*AGE+0.0004*AADT for flexible pavements on road future IRI can be forecast, R^2 =0.70 (Gulen et al., 2001; Prasada et al., 2013).

Forecast of SDI

Hamdi has developed a prediction correlation of SDI and IRI ($y=48.091x^{0.6914}$) with $R^2 = 0.9697$. Using the correlation equation between SDI and IRI established from the existing data analysis, future years' SDI can be forecasted and used for finding deterioration and pavement conditions (Vidya et al., 2013; Susanna et al., 2017).

RESULTS AND DISCUSSION

The section describes research findings and analysis based on tests, observations, literature and perceptions of respondents.

The road section basis was taken from DoR-HMIS, 2019. IRI, SDI and traffic data of the MDB road were collected from DoR-HMIS.

The IRI, SDI and AADT collected from DoR-HMIS are shown in Table 1.

Table 1:Summary of year-wise IRI, SDI and AADT data of MDB Road

SN	Year	IRI (mm/m)	SDI	Age of pavementin Year	AADT (PCUs)
1	2018	6.80	2.11	16	1668
2	2016	6.60	2.81	14	1614
3	2015	7.86	2.22	13	786
4	2014	6.31	2.66	12	989
5	2013	4.86	1.25	11	735
6	2012	6.34	1.13	10	650

Source: (DoR, 2019)

Due to a technical problem, the Traffic, IRI and SDI data for 2017 were not measured by DoR. Minor maintenance work in 2013 and recurrent maintenance work in 2016 were done. Hence, the value of IRI is decreased in the corresponding years. Traffic data are increasing from 650 in 2012 to 1668 in 2018.

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The evaluation of the functional assessment of the national roadway using IRI and SDI data from 2011 to 2013 was done (Suryoto & Ary, 2017). Hence, in this research, data from 2012 to 2018 are substantial in this study.

a) Relationship between SDI and IRI, SDI and Traffic, IRI and AADT, SDI and Ageof pavement, and IRI and Age of pavement.

Roughness has been universally accepted as a measure of the functional condition of a pavement. It constitutes the smoothness and frictional properties of the pavement surface and, in turn, is related to the safety and ease of the driving path. It is determined using the international roughness index (IRI), which is a measure for the texture of the pavement surface, and also depends on the amount of other functional distresses like potholes, cracking, etc., present on the road surface (Prasada et al., 2013; Sreedevi, 2014).

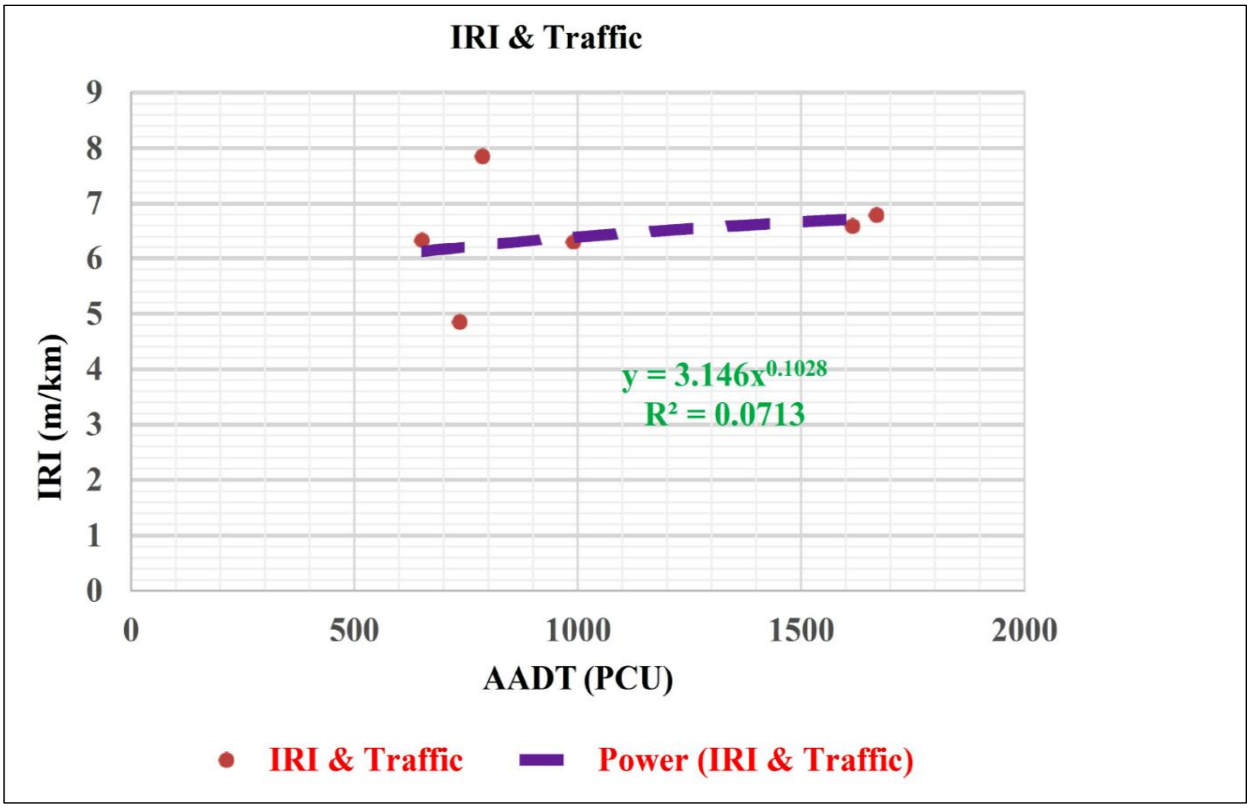

Figure 3: Relationship between IRI and Traffic

A regression equation was developed to find the relationship between IRI and AADT usingExcel with the best-fitted curve. In this equation, IRI was taken as a dependent variable, and AADT was taken as an independent variable. The developed relationship with the corresponding coefficient of determination is presented in Figure 3.

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It can be seen that when AADT increases, the IRI deterioration rate increases slightly. The correlation between the IRI and Traffic is presented by the power fit of the curve y=a xb, where y=3.146x0.1028, with y representing the value of IRI, a and b being constant values, and x representing the value of AADT. Pearson correlation analysis of the curve indicates the value of R=0.0713. Basedon the correlation equation, the correlation is poor. The fitted line plots display a regression model that has regression equations, but the model has a low R-squared value. The low R-squared graph shows that noisy, high-variability data can have a significant trend, even when R-squared is low; low P values still indicate a real relationship between the significantpredictors and the response variable. Data range for IRI is 0 to 8 m/km, and AADT is 650 to 1668; the best fit power curve seems a straight line. The findings seem to be in line with Nicholls & James (2013), as the focus was on increased AADT impact on deterioration.

The initial road roughness values were taken every 100 meters at each point. IRI values, on average, at the MDB road from 2012 to 2018 are available. The IRI value of the road in 2018, on average, was 6.8 m/km, indicating a poor road condition. These values could be usedfor the recommendation or assessment of road condition, so that the proper treatment could be defined accordingly.

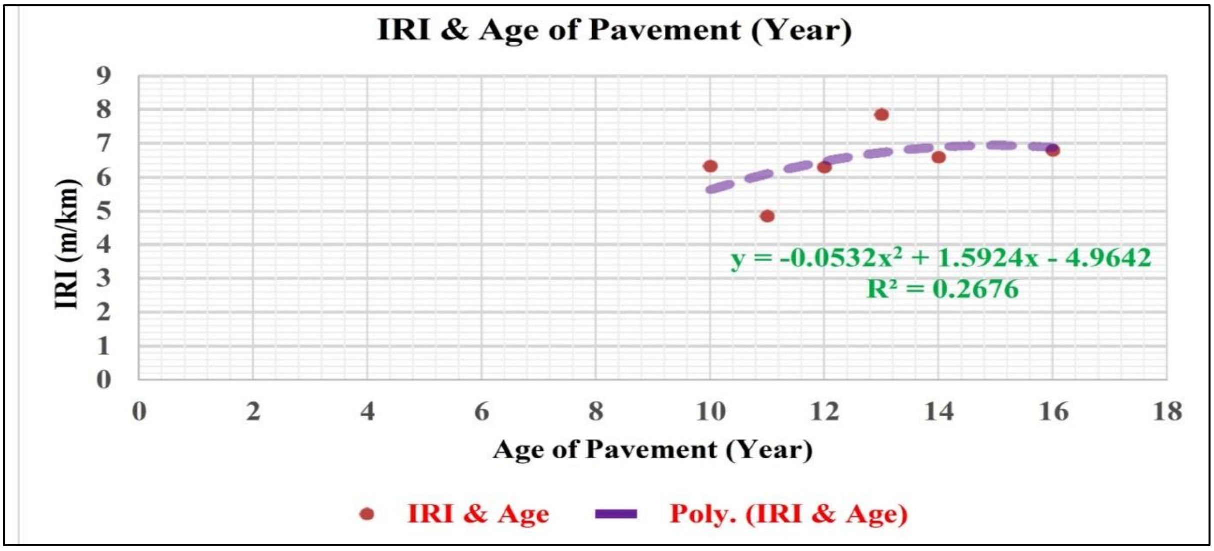

Figure 4: Relationship between IRI and Age of Pavement

From Figure 4, the relationship between IRI and Age is polynomial. It is observed that the value of IRI increases with the age of the pavement. In MDB, the road value of IRI was decreased due to maintenance interventions in 2013 and 2016. The relationship between IRI and Age is poor, with an R^2 value of 0.2676.

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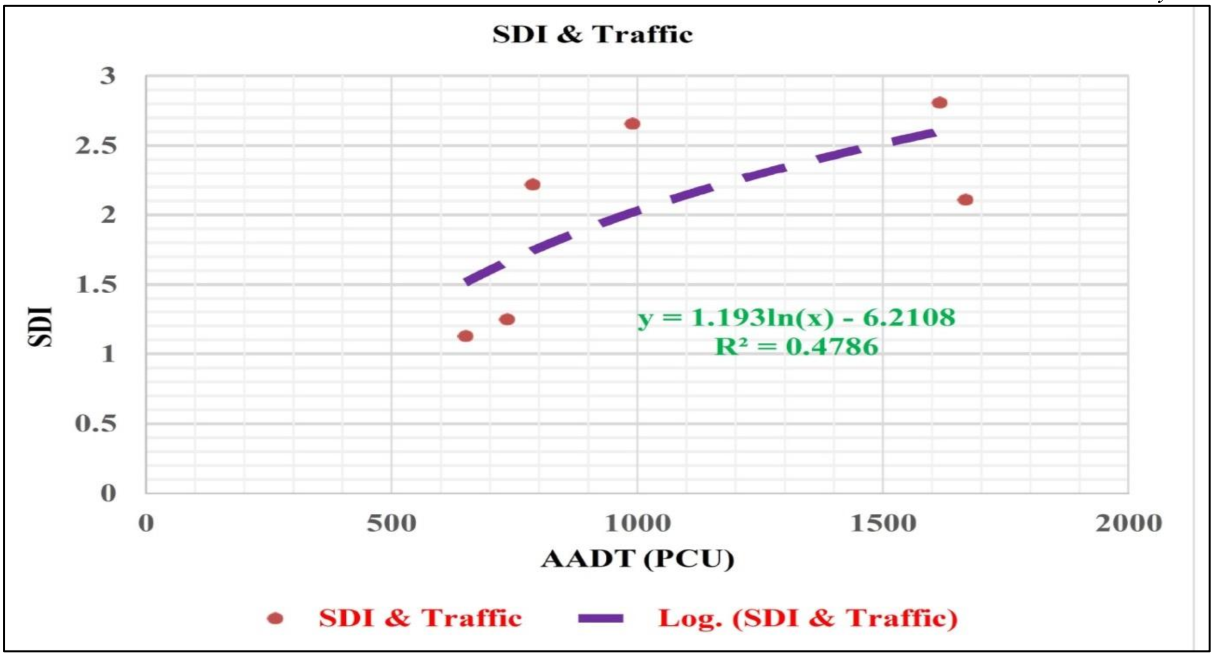

Figure 5: Relationship between SDI and Traffic

From Figure 5, the relationship between SDI and Traffic is logarithmic. It is seen that with an increase in AADT value, the SDI increases. The relationship between SDI and Traffic ismoderate, with an R^2 value of 0.4786.

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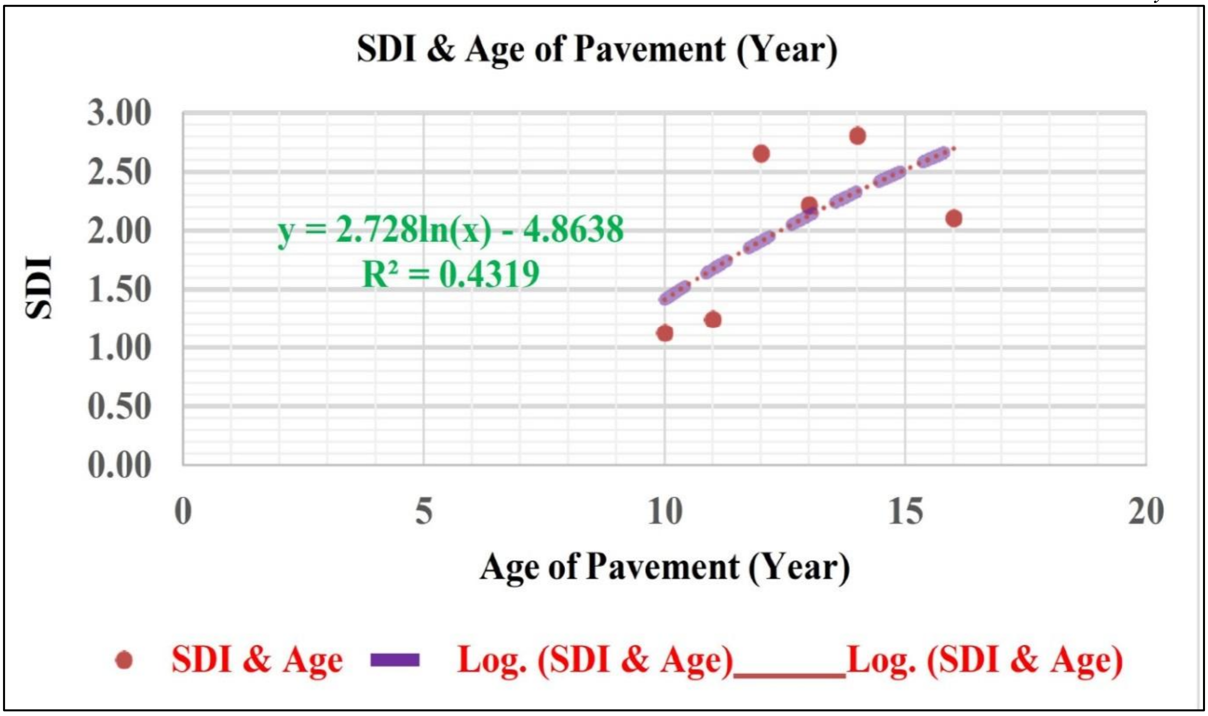

Figure 6: Relationship between SDI and Age

The correlation between the SDI and Age is presented by the logarithmic fit curve of y = a ln(x) - b, where y = 2.728 ln(x) - 4.8638, with y representing the value of SDI, a and b being constant values, and x representing the value of Age in years. From Figure 6, Pearson correlation analysis of the curve indicates the value of R^2=0.4319. Based on the correlation equation, the relation between SDI and the Age of the pavement is a moderate correlation.

Development of Pavement Assessment Prediction Model

From regression analysis IRI as a dependent variable and age of pavement and AADT as dependent variables, the following relation exists;

Table 2: Summary of Regression Analysis (IRI, AGE and AADT)

Regression Statistics	
Multiple R	0.632
R Square	0.399
Adjusted R Square	-0.002
Standard Error	61.433
Observations	6.000

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ANOVA								
	df	SS	MS	F	Significance F			
Regression	2.000	7514.304	3757.152	0.996	0.466			
Residual	3.000	11322.016	3774.005					
Total	5.000	18836.320						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	79.113	236.036	0.335	0.760	-672.059	830.285	-672.059	830.285
X Variable 1	36.755	27.764	1.324	0.277	-51.602	125.113	-51.602	125.113
X Variable 2	-0.126	0.132	-0.953	0.411	-0.547	0.295	-0.547	0.295

From the regression analysis, it is found that the coefficients for AGE of pavement and AADT are 36.755 and -0.126, respectively, with an intercept value.

79.113. Value of R^2 =0.399 and adjusted R^2 = -0.002. From the regression analysis model, IRI = 79.113 + 36.755 AGE-0.126 AADT.

Speed of Vehicles
The speed of vehicles is needed to find the Level of Service (LoS). LoS indicates adequate travel time or speed of public or private vehicles by taking into account indications of congestion or traffic density. This LoS along road corridors is not indicative of the overall level of service from origin to destination. LoS may be measured along key locations and then aggregated for the road. Mishra and Aithal(2022) argue that LoS, being a service efficiency measure, must be taken care of in transport planning right from the municipality.

Level of Service is defined in terms of the average travel speed of all through vehicles at the key locations. It is strongly influenced by the number of vehicles along the corridor, the number of signals per kilometre and the average intersection delay. The speed of motorised vehicles can be improved by segregating public transport and non-motorised vehicles through dedicated lanes or lane demarcation wherever possible. D'Angelo et.al (2008) also found similar results.

Speed of Vehicles at 0+100 to 0+300
Table 3: Average Speed of Vehicles

Vehicles	Distance (m)	Malekhu-Dhading		Dhading-Malekhu		Average Speed
		Time	Running	Time	Running	
Public	200	28.2	25.53	24.2	29.75	27.64
Personal	200	24.3	29.62	22.4	32.14	30.88
Motorcycle	200	20.4	35.29	20.2	35.64	35.46

The average traffic running speeds of public, personnel, and motorcycles are 27.64, 30.88, and 35. 46

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km/hour, which is greater than the design speed of 25 km/hour. RAs the road section from chainage 0+100 to 0+300 is straight, level, and the condition of pavement in this section is fair, the level of service is found to be 1.

Speed of Vehicles at 12+000 to 12+200

Table 4: Average Speed of Vehicles

Vehicles	Distance (m)	Malekhu-Dhading		Dhading-Malekhu		Average Speed (km/hour)
		Time (S)	Running Speed	Time (S)	Running Speed	
Public	200	36.4	19.78	35.9	20.05	19.91
Personal	200	28.6	25.17	27.1	26.56	25.86
Motorcycle	200	26.4	27.27	27.2	26.47	26.87

The average public Traffic running speed is 19.91 km/hour, which is lower than the design speed of 25 km/hour. The average of personal Traffic speed is 25.86 and 26.87, which are slightly higher than the design speed.

Cost Estimation

According to the field survey for pavement distress SDI, the road section has 7.00% of minor distress area and 3.66% of central distress area (i.e., 11% of total area), indicating a need for maintenance to maintain the pavement surface in good condition and prevent deterioration. The cost estimates are based on applicable DoR norms. Theunit item rates for each item have been calculated based on the approved district rate for fiscal year 2019. While calculating item rates, it is assumed thata qualified contractor will undertake construction following a mechanised approach for roadworks. Fromthe field survey, all types of surface distress except gravel loss were found probable causes, and treatment procedures as per pavement interactive were observed. The quantity calculation for road resealing and rehabilitation was done. The base cost of resealing with local patching works has been estimated to be NRs 2.34 million for the year 2019. The total cost for rehabilitation of pavement to DBST standard, as per previous pavement work, has been estimated, including contingencies consisting of small miscellaneous items, work charge staff and 13% VAT as per GoN rules, and is calculated to be NRs. 212.15 million for the year 2021. The per km cost, including contingencies, Work charge staff and miscellaneous expenses, and 13% VAT, is NRs. 12.12 million. Mishra and Magar (2017) findings also support similar trends in Tanahu district-based research.

Traffic Volume

A traffic volume survey was conducted over three days, yielding an average AADT of 2413 PCU per day.

The factors are directly proportional to the distress parameters of the pavements. Based on the pavement deterioration trends, the predicted values of SDI, IRI and PSR for the year 2021 are 3.16 m/km, 7.15 and 1.27, respectively. On these values, the condition of the pavement is poor.

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Pavement in these categories (PSR values of 1.27) has deteriorated to such an extent that it affects the speed of free-flow traffic. The flexible pavement may have significant potholes and deep cracks. Distress includes revealing, cracking, and rutting (D'Angelo et al., 2008). This research would draw the attention of policymakers to transport planning.

CONCLUSION

The values of SDI, IRI and PSR are 2.11 m/km, 6.80 and 1.45, respectively. Based on thesevalues, the current pavement condition of this road section is Poor. Due to maintenance intervention in 2013, the condition of the pavement is fair. Maintenance works in this road section decreased the value of SDI, but the IRI value did not decrease significantly.The existence of high gradients, loops, and sharp bends near chainage 12+000 results in a reduced LoS for this section, which is now 2.

The relation between IRI-Traffic and SDI-IRI is powerful, with R^2 values of 0.0713 and 0.6831, respectively. The relation between IRI –Traffic is poor, and the relation between SDI – IRI is moderate. The relation between SDI-Traffic and SDI-Age of pavement is logarithmicwith R^2 values of 0.4786 and 0.4319, respectively; the correlation is a moderate relationship.The relation between IRI and Age of pavement is polynomial, with an R^2 value of 0.2259, which shows a poor relationship.

The deterioration model of pavement was established considering IRI as a dependent variable and the Age of pavement in years and AADT as independent variables. From the deterioration model equation (IRI= 79.113+36.775 AGE-0.126 AADT), the deterioration trend of pavement was forecasted. This pavement deterioration model can be used for the forecast of future values of IRI. This model is the basis for the assessment of DBST pavement.

Pavement improvement measures were identified for M & R through the distress survey data. Based on the values of SDI, IRI and PSR for the year 2019, resealing with local patching is to be done, and for the year 2021, rehabilitation is to be done. The total cost required for resealing with local patching for the year 2019 is 2.34 million, and the price needed for rehabilitation work is 212.15million. Maintenance works should not be delayed, as the delay of M&R work results in a deterioration of the pavement, which increases the cost significantly. M&R can be done by 2.34 million, which decreases the deterioration rate. Without proper M&R work, the rehabilitation cost after three years (2021) will be 212.15 million, which is very high and a challenge to the country. Special consideration is required for moist, shaded, and landslide areas, as well as for hairpin bends, high gradients (>7%), and sharp turnings, to enhance performance.

Practical Implications

Functional analysis provides data-driven insights for transportation agencies to optimise their limited infrastructure budgets. Understanding performance characteristics enables the strategic

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timing of applications, the selection of appropriate treatment types, and the prediction of maintenance cycles. This leads to a more efficient allocation of public resources and extended pavement life cycles.

Social Implication

Understanding DBST performance helps balance environmental concerns with infrastructure needs. Proper functional analysis ensures treatments are applied efficiently, reducing material waste and environmental impact while maintaining community access to essential services. This is particularly relevant for communities that have historically borne disproportionate environmental burdens.

An improved understanding of DBST performance enables cost-effective road maintenance solutions that connect isolated communities to essential services, including healthcare, education, and economic opportunities. Enhanced road surfaces facilitate emergency vehicle access, school bus transportation, and the movement of agricultural products, directly impacting the quality of life and social equity.

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