Proceedings of 14th IOE Graduate Conference
Peer Reviewed
Year: 2023 Month: December Volume: 14
ISSN: 2350-8914 (Online), 2350-8906 (Print)

Development of Roughness Evaluation Model Based on Existing Distresses for Asphalt Concrete Pavements

Saurav Shrestha [a], Rojee Pradhananga [b], Nishan Khanal [c]

[a,b] *Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[c] *Department of Computer and Electronics Engineering, Kantipur Engineering College, Nepal*
[a] sauravshrestha00001@gmail.com, [b] rojeepradhananga@gmail.com, [c] nishan.khanal98@gmail.com

Abstract

In order to maintain the functional and operational condition of the road, the deterioration in the pavement's condition must be properly evaluated, maintained, and dealt with before its cost exceeds a desirable limit. In order to suggest maintenance activities, DoR presently employs the SDI measure in general to show the functional performance and condition of the road which is subjective and inadequate pavement performance measure. The IRI, an indicator of perceived road roughness and ride quality is also in practice by DoR in some major national projects as evaluation measure.Therefore, this study develops a model useful to evaluate IRI based on distresses observed on the the asphalt concrete concrete pavement at the location. The distress data was collected for the section in consideration through manual visual inspection survey and quantified as per ASTM 6433. The IRI of the section in consideration was evaluated with the help of RoadRoid application for 28.3 km road section of asphalt concrete pavement after validation using Romdas Z-250 reference profiler. Grouping of distresses were then formed as per the nature of the cracks. The regression models were then developed with the distress density of each severity as independent variable and the IRI as the dependent variable. The linear regression model was chosen as best regression model as it yielded least MSE among regression models of various degree for model development. The final model consisting of relationship between the existing distresses and IRI was concluded as the output of the model with coefficient of determination of 0.541 and 0.515 for training and testing of the model which represents moderate strength of the developed model.

Keywords

Distress, Roughness, International Roughness Index, Surface Distress Index, Distress Density, Regression

1. Introduction

The efficiencies of the road network play an important role for social as well as economic development of a region and in turn the entire nation. For the construction of any road, a huge amount of capital investment is required. However, as time passes by, the constructed road deteriorates due to several factors such as the type and the materials used for the construction of the road, sub grade soil, traffic loading intensity and volume, drainage facilities, climatic conditions and so on. The deterioration seen in the surface of the pavement is to be timely assessed, maintained and taken care of before the cost of maintenance exceeds the desired limit forcing rehabilitation or reconstruction of the pavement. In order to determine which road section is to be prioritized, different computation measures have been developed which includes metric in terms of Pavement Serviceability Rating (PSR), International Roughness Index (IRI), Pavement Condition Index (PCI), Surface Distress Index (SDI), and so on. IRI is the most objective measure among these measures as it is a measure of vehicle response which is caused as a result of interaction between the vehicle and the pavement due to the roughness of the road. [1]

In order to describe the existing pavement surface condition and to categorize the surface of the road an effective tool is desired. DoR currently uses metric of SDI so as to indicate the functional performance and state of the road in order to propose maintenance activities for the selected section. SDI is only a subjective measure and is fairly unsatisfactory and does not give indication of ride quality or roughness of the pavement which is of considerable significance for National Highways of economic importance. For road sections where ride quality and comfort is of paramount importance along with the roads structural condition, IRI can be the most effective and objective indicator of pavement performance.[2] In recent years, IRI based contracts have been also practiced in some major national projects in Nepal including the IRI based contract for improvement project of East- West highway for an extended maintenance period of four years. Despite IRI not being used in Nepal to that extent, it is collected on a yearly basis (IQL III).

IRI; which is a measure of road roughness and ride quality perceived in the road is generally determined with the help of the mounted bump indicator/ Roughometer or calculated using a quarter car vehicle math model [3]. The Android based roughness estimation methods have been getting wide acceptability in the recent present as smartphones can be used (which uses the tri-axis accelerometer sensor present in the smartphone) for the evaluation of the road profile in terms of roughness. RoadRoid Pro 3 and RoadBump Pro are some of the widely used and validated smartphones applications commonly used to measure IRI [4]. The RoadRoid IRI represents the roughness of the pavement section in consideration while also providing with idea about the ride quality in the same section. The IRI which is evaluated with the help of various tools and techniques is directly associated with the nature and the quanitity of distresses in the pavement [5]. Some distresses have very high impact on the change in roughness of the pavement surface directly affecting the ride quality whereas some of the distresses do not contribute to the change in roughness as much. So, the major objective of the research is to develop the relationship of various distresses and their severities with the Roughness of asphalt concrete pavement expressed in terms of IRI.

2. Literature Review

The study was conducted by Prasad in order to establish a relationship that existed between the roughness of the pavement and various surface distresses found on PMGSY roads. To achieve this, a total of eight PMGSY roads that were located in Jhunjhunu district and Churu district of Rajasthan, India, were selected as the study sites. Distress data was systematically gathered at 50-meter intervals along these roads. The collection of the roughness data was done using a Bump Integrator after calibrating with MERLIN on selected stretches for the study. Additionally, unevenness data was obtained from a newly constructed road section, and this value was deducted from the unevenness values that were observed of the test stretches. This subtraction helped determine the net impact of distresses on the overall pavement condition. Based on the field-collected data, a regression equation was developed, considering the IRI value as the dependent variable and the and the visible distresses as the independent variables that were present on the roads. [6]

IRI was used for the representation of the roughness and the distresses along the pavement were quantified. 83 sections of flexible pavement were assessed with each section having width of 250 m and the distresses as well as the IRI data was collected for each section in consideration. The IRI data was collected with the help of Dynatest RSP test system and the relationship between the visible pavement distresses and the IRI was developed. The result of the SPSS regression indicated that the model was strong enough for the prediction of IRI with the help of visible pavement distresses.[7]

Statistical correlation analysis was conducted to examine the connection between IRI and pavement distresses. The objective was to assess the extent of distress associated with the quality of the ride. By employing a statistical correlation test, the study determined the relationship between the IRI values and the distress density. The findings revealed a noteworthy correlation between the IRI and depression, patching, cracking, and raveling for both main and secondary street categories, with a confidence level of 95%. However, no significant relationship was found between IRI values and potholes or rutting distress types in either the main or secondary streets. Consequently, the statistical investigation suggests that cracking, patching, depression, and raveling could potentially be classified as distress types related to ride quality. [8]

The highway connecting from Jadan to Jeddah was evaluated in order to assess the IRI and its relationship with distresses including rutting, ravelling, cracking and so on. RST vehicle was used in order to assess the IRI and distresses were calculated manually. two models were developed with cracking, rutting adn ravelling vs IRI and It was found that rutting didnt contribute to IRI which concluded ravelling and cracking to the major influencing factors for IRI. [9]

According to Lars Forslöf and Hans Jones, the build-in vibration sensors of the smartphones could be used to collect the roughness of the road up to class 2 or class 3 in effective way. The roughness value changes significantly with time so frequent measurement were necessary. The cIRI value of the interface indicated the calculated IRI value using the sensor of the smartphone. The correlation was developed in terms of eIRI to further simulate the conditions of quarter car system. Hundreds of Road Link sections were compared between the smartphone measured IRI and class I IRI measurements for 20 m length intervals and 81% correlation was found with the laser measurement systems which indicated that RoadRoid could be used as an alternative to conventional IRI measurement systems. [10]

Donny and Mamok highlighted that the RoadRoid app could be used as a cost effective alternative for the estimation of IRI. A total of 5 road segments were analyzed in the Mageten District road. The PCI was initially evaluated and the road was found to be in good condition. The IRI using RoadRoid showed that the pavement was in medium condition in terms of roughness. The negative correlation with value -0.23 was found.[11]

Arianto, Suprapto and Syafi [12] used Android based application in form of RoadRoid in order to measure the roughness of the road with the help of smartphones vibration and accelerometer sensors. The IRI was the output of the application which was used to indicate the roughness condition of the pavement. The pavement condition evaluation was also evaluated in addition to the roughness measurement of Janderal Sudirman Kalianget road. The thus obtained IRI value was combined with SDI in order to propose suitable maintenance strategy for the road. The pavement condition of Jenderal Sudirman-Kalianget section of length 4.2 kilometers (37.17%) was in good condition and 2.3 kilometers of the same road (20.35%) was in fair that needed routine maintenance. While 2.1 kilometers of the road (18.58%) were in bad condition and 2.7 kilometers (23.89%) were found to be in poor condition which indicated the need of periodical maintenance and reconstruction.

3. Methodology

This section includes all the details related to the study area under consideration, the detailed process of data collection of IRI using RoadRoid application, the validation of the RoadRoid IRI data with Romdas z-250 reference profiler, analysis of the collected data and the details related to the development of regression model between the distress group and the corresponding IRI. This sections also includes the presets and the corresponding accelerometer sensitivities used for IRI survey using RoadRoid application.

3.1 Study Area

The distress data and the IRI data for the research was collected in Asphalt concrete pavements near Kathmandu, Bhaktapur and Lalitpur districts. The sections were selected based on the criteria of incorporating maximum forms of distresses in the pavement to evaluate its relation with the IRI. All the sections of the roads considered for the collection of the data were feeder roads of similar nature i.e. asphalt concrete pavements. A total of 28.3 km of asphalt concrete pavements were taken in consideration for data collection with the help of manual visual inspection survey. The summary of study area selected for the study is presented in Table 1.

Table 1: Study area for data collection

Link	Designation	Distance Surveyed
Jadibuti-Manohara-Sanothimi	F086	2.4 km
Samakhusi-Grande-Tokha	F082	4.4 km
Lainchaur-Maharajgunj -Bansbari-Budhanilkantha	F021	9.3 km
Hattiban-Harisiddhi-Thaiba-Godawari	F024	5.6 km
Imadol-Sanagau-Mahalaxmi-Biruwa-Lamatar	F072	6.6 km
Total length surveyed		28.3 km

3.2 IRI Data Collection

IRI value is determined for all the selected sections of the road with the help of licensed version of RoadRoid Pro 3. The accelerometer and sensitivity presets that were used throughout the course of data collection is as shown in figure 1 and figure 2.

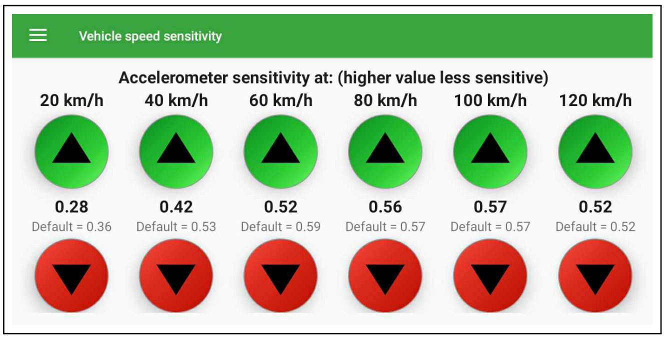

Figure 1: Accelerometer sensitivities for various speeds

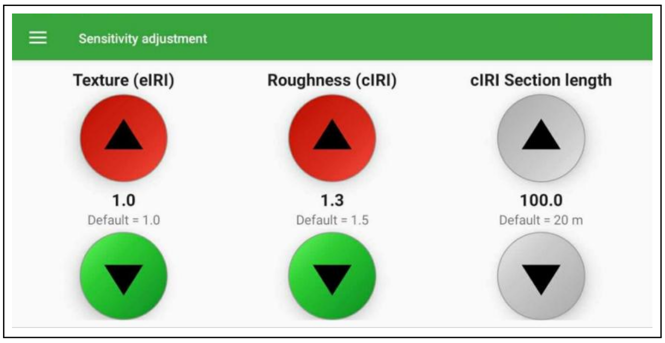

Figure 2: IRI parameter sensitivities for data collection

Following lists out the RoadRoid IRI data collection steps:

1. After setting the presets and sensitivity for the device after validation, the stable car mount, Logitec+ is fixed in the windshield.
2. The mount is connected with the windshield of the vehicle with a suction cup and oriented in direction such that the phone is oriented in landscape mode.
3. The phone is placed in the mount and the Road Roid application is opened. The fitting button is pressed in order to adjust the 3D sensor of the phone. This is done in order to ensure that the accelerometer only picks vertical acceleration (Y direction) and excludes turning (Z direction) and breaking (X direction).
4. The camera is oriented towards the road to take video to set up and identify reference points in order to compare data with distresses obtained in the next phase of the survey.
5. The start survey button is then pressed in order to commence the road quality/roughness estimation survey.
6. The application collects date in form of latitude and longitude of the path, eIRI, cIRI, distance covered, free space remaining and temperature of the phone.

RoadRoid calculates roughness in form of cIRI which is calibrated as per the IRI using advanced laser sensing equipment and also calibrated for various operational speeds. The aggregate IRI values are then generated for 100 m section from RoadRoid application itself and the sections are validated with the help of video of the section taken from camera in the survey. The video of the road section taken during IRI survey with rear camera of the phone is later used in order to match the values of IRI with the distresses of the corresponding sections. The sample view of instantaneous eIRI, cIRI and Speed can be shown through graph as in the example given below in figure 3.

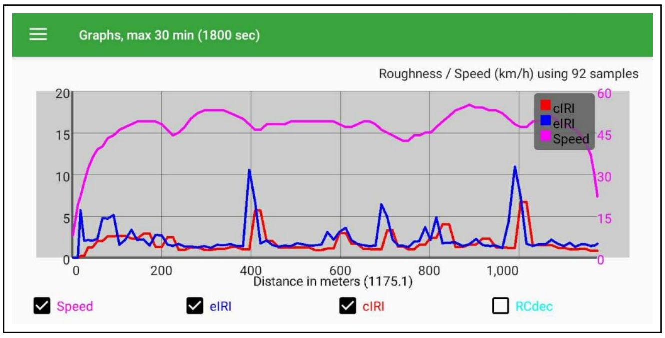

Figure 3: Sample instantaneous eIRI, cIRI and speed

3.3 Distress Data Collection

The distress data are collected for the sections in consideration based on the specifications provided by ASTM 6433. The severities of all the distress in consideration are also noted. Each of the distresses (Alligator Cracking, Bleeding, Rutting, Potholes, Corrugations, Patching and so on) are quantified into three severities as low, medium and high. For the collection of the data, sections are first divided into sub-sections of 100 m length and distresses are noted in terms of area. Each of the sections are marked in order to ensure that the corresponding IRI values could be matched with the respective sections in order to relate the distresses with the IRI which is the main focus of the study. During the collection of the distress data, distresses like railroad crossing are not considered. Polished aggregate distress is not considered where bleeding is considered and vice versa.The distress density of each type of distresses and their corresponding severities are determined by dividing the quantified area of the distresses with the total area of the section. The distress densities are used as input in the development of the model.

4. RoadRoid IRI validation

The IRI obtained from RoadRoid is tested against the roughness data collected for same stretch of road for validation of IRI obtained from RoadRoid. For this, the ROMDAS Z-250 Reference Profiler is used in order to obtain highly accurate data of ride quality in terms of IRI. The Reference profiler is used inside the periphery of Pulchowk Campus and a total length of 100 m is surveyed for IRI. The data is then converted for 5 m intervals using ProVAL 3.1 software because the least interval that could be analyzed from RoadRoid is 5m. The IRI value is again estimated for the same section of the road with the help of RoadRoid application. A total of 4 passes on the same section is carried out and the average of the four values is taken as RoadRoid average IRI. Table 2 shows the RoadRoid IRI in each pass of the section along with the IRI measured for the same section with the help of ROMDAS Z-250 reference profiler.

Table 2: Reference Profiler IRI and RoadRoid IRI for same section

Section (m)	The ROMDAS Z-250 Reference Profiler IRI	RoadRoid IRI 4 passes same section				RoadRoid average IRI
0-5	1.251	1.5	1.45	1.32	1.36	1.408
5-10	1.631	1.85	2.05	2.12	1.9	1.980
10-15	2.777	2.85	2.98	3.01	2.94	2.945
15-20	10.502	5.88	6.18	6.45	5.98	6.123
20-25	7.253	6.45	6.78	6.12	6.23	6.395
25-30	5.123	4.23	4.12	4.57	4.23	4.288
30-35	1.941	2.05	2.33	2.08	2.06	2.130
35-40	2.530	2.8	2.6	2.56	2.48	2.610
40-45	3.794	3.8	3.98	3.77	3.23	3.695
45-50	6.424	5.21	5.23	5.98	5.15	5.393
50-55	7.156	6.15	6.35	6.66	6.39	6.388
55-60	6.471	6.12	6.32	6.89	6.44	6.443
60-65	3.859	3.5	3.26	3.55	3.68	3.498
65-70	3.491	3.5	3.66	3.45	3.54	3.538
70-75	3.318	3.12	3.28	3.18	3.5	3.270
75-80	3.151	3.05	3.5	3.22	3.32	3.273
80-85	3.246	3.44	3.08	3.2	3.22	3.235
85-90	2.748	2.89	2.85	2.98	2.74	2.865
90-95	2.606	2.4	2.56	2.14	2.71	2.453
95-100	2.484	2.56	2.55	2.87	2.49	2.618

The Chi-square test of goodness of fit is then carried out in order to test the goodness of fit of the frequencies of observed IRI values (data obtained from RoadRoid) with the estimated IRI values (Data obtained from ROMDAS Z-250 Reference Profiler). The test of goodness of fit is presented along with hypothesis testing. The sensitivity of various parameters and speed is then changed in order to provide better fit of IRI with Romdas Profilometer IRI.

Since the data for 5 m internal is not enough to generate adequate number of frequencies, the IRI from Romdas profiler is determined for 2.5 m section intervals to generate 40 data of IRI. Hypothesis testing is carried out to perform this test in which the null hypothesis and the alternative hypothesis are defined.

Null hypothesis (H0): There is no significant difference between the expected frequencies and the observed frequencies.

Alternative Hypothesis (H1): There is significant difference between the expected frequencies and the observed frequencies.

The level of significance is set as 0.05.

Table 3: Chi square test table

IRI interval	Observed frequency	Expected frequency	O-E	(O-E)^2/E
0-1.5	4	5	-1	0.2
1.5-3	12	14	-2	0.285714286
3-4.5	12	9	3	1
4.5-6	4	5	-1	0.2
6-7.5	8	7	1	0.142857143
Sum	40	40		1.828571429

Chi Square = 1.8285

Degree of freedom = 5-1 =4

The P value corresponding to Chi square value of 1.8285 and DOF 4 is 0.7672 which is greater than0.05, therefore there is no significant difference between the observed values and the expected values and the null hypothesis is accepted. Therefore, we can say that, the IRI obtained from RoadRoid can be used for IRI evaluation in this research.

5. Distress Grouping

There are variety of distresses occurring in asphalt concrete pavements due to variety of causes. These distresses are responsible for causing the increase in the roughness of the pavement and subsequantly decreasing the ride quality. However, various distresses are similar in nature, for example, block cracking, longitudinal and transverse cracking, slippage cracking are of similar nature and their effect in the change in pavement roughness is also comparable[8]. So, they can be commonly grouped into single reference in terms of cracking. Similarly bleeding, polished aggregate, weathering and ravelling are associated with distresses related to wearing of the pavement surface so they are grouped together. In this way, grouping of 20 number of distresses and their corresponding severities is carried out based on the nature of the distresses as per the specifications provided by ASTM 6433 after extensive review of literature. Distresses like railroad crossing are not considered during the course of this study because they are only seen in areas with railroads which is not predominantly available in Nepal. Similarly, joint reflection cracking is also not considered in this study as flexible over rigid pavements are not taken for the collection of data. Distresses with similar nature are placed in same group and the distress density (distress percentage in terms of area) was determined for each of the distress group. Rutting and Potholes are taken as isolated distresses as they are of entirely different nature in occurrence with other distresses.The distress grouping table is as presented in table 4 which includes the distresses, the nature of the distress groups and the designation used to indicate the distress group in terms of alphabet.

Table 4: Distress grouping according to nature of crack

Designation	Distress Type	Nature
AC	Alligator Cracking + Block Cracking+ Edge cracking + Long and Trans cracking + Lane shoulder drop off+ Slippage cracking	Cracking
D	Bumps + corrugation+ Swell+ Shoving + Depression	Visco Elastic Deformations
BE	Bleeding+ Polished Aggregate + Raveling + Weathering	Surface Wear
F	Potholes	Potholes
G	Rutting	Rutting
H	Patch + Utility cut patch	Patching and Others

The severities of each grouping of distresses are designated with numerals 1,2 and 3 as low, medium and high respectively.

For example,

AC1- Low severity Cracking
AC2- Medium severity Cracking
AC3- High severity Cracking and so on

6. Regression Based Roughness Evaluation Model

In order to develop the relationship between the dependent variable with one or a number of independent variables, multiple regression model is generally used. Regression models are easier to interpret and construct. The regression models may take linear form known as linear regression models whereas, the degree of the independent variable may be increased in order to best fit the model with the data in concern and such regression models are known as polynomial regression models. The degree of variable is increased in iterations to check for the Validation Mean Square Error for each degree of polynomial and the degree of variable for which the validation MSE is minimum is taken as the best fit regression model for PCI.

The multiple linear regression in which y represents the dependent variable modeled with x as an independent variable, β as the regression coefficient, and ε as the residual error can be expressed with the help of equation 1 as follows.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon \quad (1)$$

Where, y: Dependent variable
$x_1, x_2, \ldots, x_n$: Independent variables
$\beta_0, \beta_1, \beta_2, \ldots, \beta_n$: Regression coefficients
ε: Residual error

To initiate the development of regression model, it is necessary to derive and estimate the relationship between the independent variables (distresses) which can be checked by developing the correlation matrix. 283 data is used for the development of the IRI evaluation model due to constraints in collection of IRI data in the same area where the distress data is collected. Out of this data, 90 % is used for the regression model development and 10 % of the data is used for testing purpose. The correlation between each of the independent variables for IRI determination was checked with the help of Python 3.9.

7. Performance of Roughness Evaluation models

The coefficient of correlation for the individual variables was weak indicating that there was no multi-colinearity between the selected numbers of independent variables in the respective cases. Therefore, all the input variables could be used for the development of regression models for IRI.

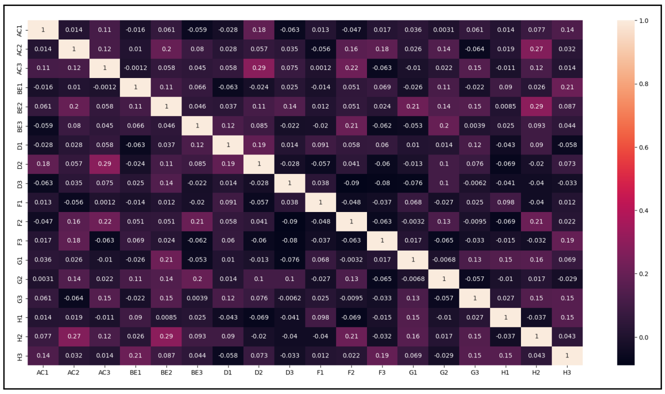

Figure 4: Correlation matrix for independent variables for IRI

Initially, the Multiple Linear Regression model is carried out in Python 3.9 with the help of the linear regression function imported from the `sklearn.linear_model` library. After that, the degree of the variable is increased one by one to check for the Validation Mean Square Error (MSE) for each degree of the polynomial. The degree of the variable for which the validation MSE is minimum is considered the best-fit regression model for IRI. Based on the comparison of the validation MSE, it can be observed that the log MSE is minimum for the regression model with degree one, and the log MSE increases significantly with the increase in the degree of the variable. Therefore, it can be concluded that the regression model with degree one, i.e. the Multiple Linear Regression model, is the best regression model among regression models of all degrees.

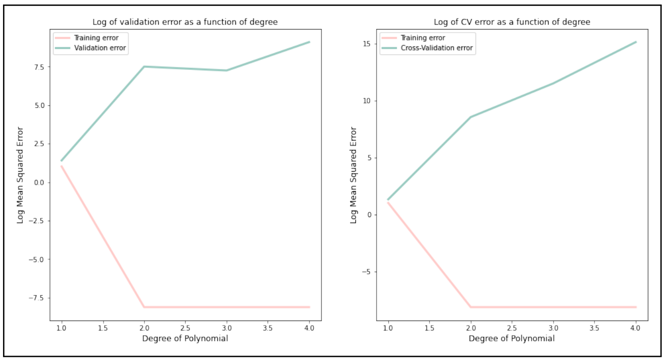

Figure 5: log MSE vs degree of polynomial for training and validation

For the data set using the regression model, R2 is found to be 0.541 and 0.515 for training and testing when the training:testing set is split as 90:10. the model represents moderate fit with the actual values.

The t-test is performed to evaluate the P value for each coefficient of regression equation. In data set 1 the P value of coefficients of AC2, BE1 D2, G1, G2 and H1 are found to be greater than 0.05. This indicates that, the mentioned parameters are insignificant to bring substantial change in the output(IRI) with the change in these variables so, can be omitted from the equation.Therefore, the regression model is prepared using the remaining coefficients. The test statistics with coefficients, standard error and P-value is presented in table 5 whereas the overall summary of results of regression for the evaluation of IRI based on distresses is as presented in table 6.

Table 5: Test statistics and regression coefficients for IRI estimation

	Coefficient	Standard Error	t-statistics	P- value	Remarks
Const	2.7089	0.235	11.534	0.000	
AC1	0.6121	0.255	2.402	0.017	
AC2	0.1251	0.122	1.029	0.305	P>0.05
AC3	0.5198	0.126	4.123	0.000	
BE1	0.2089	0.354	0.590	0.556	P>0.05
BE2	0.2607	0.205	1.269	0.020	
BE3	0.4210	0.193	2.181	0.030	
D1	0.8127	0.488	1.666	0.009	
D2	0.1263	0.332	0.380	0.704	P>0.05
D3	1.7199	0.318	5.415	0.000	
F1	3.3087	0.958	3.454	0.001	
F2	8.9494	2.056	4.352	0.000	
F3	10.0175	1.335	7.503	0.000	
G1	-0.3125	1.019	-0.307	0.759	P>0.05
G2	0.1005	0.630	0.159	0.873	P>0.05
G3	1.8102	0.603	3.000	0.003	
H1	0.0948	0.663	0.143	0.886	P>0.05
H2	0.3711	0.264	1.408	0.01	
H3	0.6923	0.371	1.866	0.043	

The IRI regression equation generated in python is as per equation 2.

$$IRI = 2.708 + 0.612 \cdot AC1 + 0.519 \cdot AC3 + 0.260 \cdot BE2 + 0.420 \cdot BE3 + 0.810 \cdot D1 + 1.719 \cdot D3 + 3.308 \cdot F1 + 8.949 \cdot F2 + 10.017 \cdot F3 + 1.810 \cdot G3 + 0.37 \cdot H2 + 0.692 \cdot H3 \quad (2)$$

Table 6: Summary of Regression Results for IRI estimation

Dependent variable	IRI
R-squared:	0.541
Adj. R-squared:	0.502
F-statistic:	13.58
P- value	3.28e-26
Degree of freedom	18

The plot of predicted IRI with the target IRI for training based on regression model in Python is as shown in Figure 6 and is presented in form of equation 3.

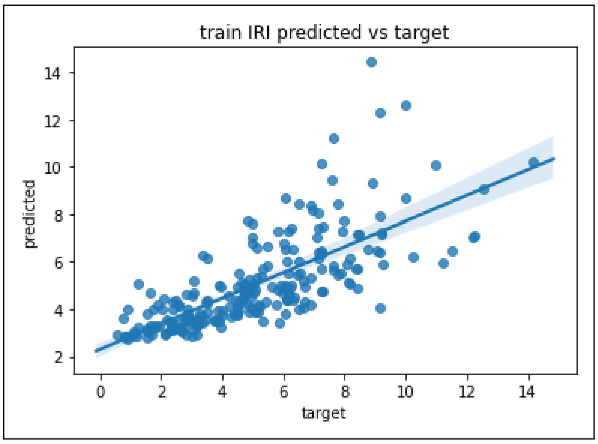

Figure 6: Plot of Predicted vs Target IRI for training set

$$IRI_{\text{predicted\_train}} = 0.54140 \cdot IRI_{\text{target\_train}} + 2.3002 \quad (3)$$

The plot of predicted IRI with the target IRI for training based on regression model in Python is as shown in Figure 7 and is presented in form of equation 4.

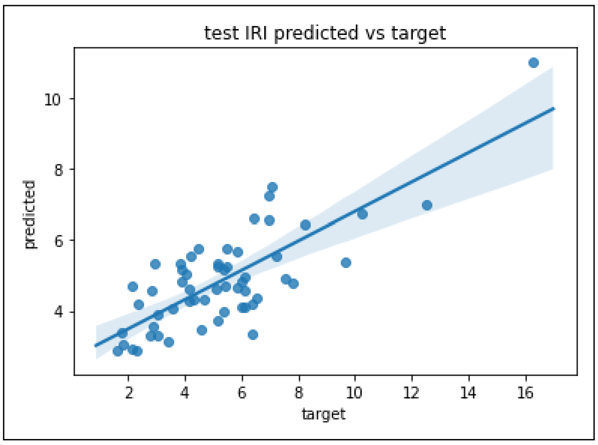

Figure 7: Plot of Predicted vs Target IRI for testing set

$$IRI_{\text{predicted\_test}} = 0.41506 \cdot IRI_{\text{target\_test}} + 2.6508 \quad (4)$$

8. Conclusion and Discussion

The relationship between the roughness index and the major pavement distresses and their corresponding severities was successfully developed with the help of regression technique in this research. During the course of data collection, distress data was collected with the help of visual inspection survey and quantified as per specifications provided by ASTM 6433. The grouping of these distresses was carried out according to the nature of these cracks based on literature. The IRI data for all the sections in consideration was evaluated with the help of licensed version of RoadRoid application after validation using ROMDAS z-250 reference profiler. Using the assessed values of distress in form of distress density (percentage of area of section) as independent variables and the value of RoadRoid IRI as the dependent variable. The multi linear relationship between these variables was developed with the help of Python 3.9. The model was concluded to have a moderate fit with the distresses with coefficient of determination of 0.541 and 0.515 for training and testing respectively.

9. Recommendations

The following recommendations may help to further improve the reliability and accuracy of the model.

1. AI based techniques such as ANN could be used and compared with the proposed multiple linear regression model.
2. The IRI could be modelled for various groups of distresses other than based on nature which may yield better results.
3. The data could be collected in more reference sections which will improve the model.

Acknowledgments

The authors are thakful to Dr. Muskan Shrestha and Er. Nischal Kayastha for assisting in collection of data. The authors are also obliged to thank Society of Transport Engineers Nepal for assisting us with SOTEN research grant 2080. Furthermore, the authors are also thankful towards Millennium Challenge Account Nepal for allowing them to use Romdas Z-250 that was useful for validation process of RoadRoid IRI.

References

[1] Turki Al-Suleiman (Obaidat), Subhi Bazlamit, Mahmoud Azzama, and Hesham Rabayah. Pavement deterioration rate and maintenance cost for low-volume roads. *MATEC Web of Conferences*, 312:06002, 01 2020.

[2] Muhammad Mubaraki. Study the relationship between pavement surface distress and roughness data. volume 81, page 02012, 01 2016.

[3] John Smith and Alice Johnson. An interesting study on mathematical equations. *Mathematical Proceedings*, 10:123–145, 2014.

[4] Mohammad Imran Hossain, Erol Tutumluer, null Nikita, and Cole Grimm. Evaluation of android-based cell phone applications to measure international roughness index of rural roads. pages 359–370.

[5] Harinder, D, Anusha, P, Ramesh, A, and Mehaboo, K. Evaluation of flexible pavement performance based on hdm-4 and international roughness index. *E3S Web of Conferences 391*, 391, 2023.

[6] J. Prasad, Shalini Kanuganti, Pooja Bhanegaonkar, Ashoke Sarkar, and Shriniwas Arkatkar. Development of relationship between roughness (iri) and visible surface distresses: A study on pmgsy roads. *Procedia - Social and Behavioral Sciences*, 104, 12 2013.

[7] Hasan H Joni, Miami M Hilal, and Muataz S Abed. Developing international roughness index (iri) model from visible pavement distresses. *IOP Conference Series: Materials Science and Engineering*, 737(1):012119, feb 2020.

[8] Abdullah I. Al-Mansour and Amr A. Shokri. Correlation of pavement distress and roughness measurement. *Applied Sciences*, 12(8), 2022.

[9] Mubaraki, Muhammad. Study the relationship between pavement surface distress and roughness data. *MATEC Web Conf.*, 81:02012, 2016.

[10] Lars Forslöf and H Jones. Roadroid: Continuous road condition monitoring withsmart phones. *Journal of Civil Engineering and Architectures*, 9:485–496, 01 2015.

[11] Donny Putra and Mamok Suprapto. Assessment of the road based on pci and iri roadroid measurement. *MATEC Web of Conferences*, 195:04006, 01 2018.

[12] T Arianto, M Suprapto, and Syafi'I Syafi'i. Pavement condition assessment using iri from roadroid and surface distress index method on national road in sumenep regency. *IOP Conference Series: Materials Science and Engineering*, 333:012091, 03 2018.