Predicting of Present Serviceability Rating by International Roughness Index in Jordan

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Abstract

Pavement distress information is usually converted into different condition indices. The condition indices combine information from all of the distress types, severities, and quantities into a single number. The Present Serviceability Rating was one of the earliest pavement condition indices that was developed at the AASHO Road Test. It was a subjective ride quality rating that required a panel of observers to ride in an automobile and assign a pavement condition value that indicated the level of service the pavement provided on the descriptive 0 to 5 scale. This paper presents the Applicability of the International Roughness Index as a Predictor of Present Serviceability Rating. Using the least square method, different regression models were developed to predict pavement conditions in terms of Present Serviceability Rating at any given surface roughness. Further, an analysis of the coefficient of determination and percent stander error confirms the existence of a strong natural exponential model between both variables.

Keywords

International Roughness Index (IRI), Present serviceability Rating (PSR), least square method, Pavement Management System, Surface Roughness, and natural exponential model.

Introduction

Pavement's Distresses are considered as the most significant aspect in the design Process; since each failure criteria should be developed separately to take care of a specific distress. Moreover, an evaluation process of pavement distresses isn't less important than the distresses themselves, because it is a main section in any pavement management system, which is important to decide which is the most effective strategy for the maintenance of the pavement. During the ASSHO Road Test [1], a concept of Pavement Serviceability was developed as a factor in pavement design, and that was considered an outstanding feature of the AASHO design methods.

The pavement management system, as established by the American Association of State Highway and Transportation Officials (AASHTO), is characterized as a compilation of tools or methodologies that aid decision-makers in identifying optimal strategies for the implementation, evaluation, and maintenance of pavement layers within a real-world context and over a designated duration. Maintenance and rehabilitation (M&R) strategies can be included in pavement management systems to cater to the diverse types of roadways. The need for enhancing and maintaining the pavement arises from the detrimental effects of both traffic load and environmental conditions. Consequently, the initial assessment of road conditions is typically conducted by manual measurements, a method that exhibits limited efficacy and necessitates substantial time and work. In addition, contemporary methodologies were employed to assess pavement deterioration, utilizing computerized algorithms to analyze data and examine the condition of the pavement surface. While this approach offers enhanced efficiency and expediency, automating the pavement rating process remains challenging. Numerous metrics are employed in the evaluation of pavement conditions to quantify and assess the various distress present, hence indicating the overall state of the pavement [2,3].

Serviceability is defined as the ability of a specific section of pavement to serve traffic in its existing condition. (1) PSR is a subjective pavement condition index that indicates pavement level of service in a conventional 0-5 scale that represents the mean of the individual ratings made by the members of a specific panel. However, this type of rating is based on car ride dynamics; it is unclear whether such levels are acceptable for trucks. Also, it is not practical for large-scale pavement networks, so it is important to correlate the subjective rating of pavement performance with objective measurements such as the International Roughness Index [4].

To establish the relationship between PSR, and IRI, various studies have concentrated on the pavement management system (PMS)[3,5,6]. According to Dewan and Smith [7], there is a significant relationship between PSR and IRI, which is determined by a high coefficient of determination.

The relation between the International Roughness Index and the given serviceability rating was developed by Al-Omari and Darter [8]. The primary aims of this study are to construct a prognostic framework for Pavement Serviceability Rating based on the profile International Roughness Index for various types of pavements, including composite, flexible, and rigid pavement. The second objective of this study is to ascertain the extent of rehabilitation required by utilizing the International Roughness Index and the specific type of distress identified from the long-term pavement performance (LTPP) database. This study was conducted to examine various pavement types in the states of Louisiana, Michigan, New Jersey, New Mexico, Ohio, and Indiana, as well as the combined analysis of all six states. A statistical analysis system (SAS) data set was utilized to establish a nonlinear correlation (R^2 = 0.97) between the International Roughness Index and Present Serviceability Rating (PSR) across various pavement types. The authors incorporated the variables of the International Roughness Index (IRI), Pavement Structural Rating, and pavement type for each pavement section within every state, as demonstrated in Equation 1.

$PSR = 5 * e^{-0.24 * IRI}$, where IRI in km/m ……………………………..… Eq.1

The researchers discovered that there were no statistically significant variations observed among the models when considering different states and pavement types. In their study, Gulen et al. [9]established an additional correlation between the International Roughness Index and the Present Serviceability Index rating (PSI). To measure the IRI, a vehicle equipped with specialized instrumentation was employed. The present study was undertaken to assess the suitability of the International Roughness Index as a measure of pavement performance for Taiwan highways. The analysis employed a backpropagation neural network methodology to evaluate the application of IRI in this context. Furthermore, the International Roughness Index can be estimated based on the assessment of pavement distress using video pictures captured by a camera. This estimation process utilizes a backpropagation neural network. A correlation was established between the average present serviceability index rating and the International Roughness Index using data provided by the Indiana Department of Transportation (INDOT). The data consisted of measurements from 10 randomly selected sections in Indiana, each spanning a distance of 1 mile. The analysis encompassed three different roughness levels for all types of pavement, as outlined in Equations 2-4.

$PSI = 7.21e^{-0.471IRI}$ (R^2 = 0.84) for asphalt pavement …..…………..….Eq.2

$PSI = 14.05e^{-0.74IRI}$ (R^2 = 0.93) for concrete pavement ………………..…..Eq.3

$PSI = 9.0e^{-0.56IRI}$ (R^2 = 0.84) for composite pavement ……………….Eq.4

In this study, Fakhri and Dezfoulian [5] employed artificial neural networks and regression models to establish a correlation between deflection bowl parameters obtained from a falling weight deflectometer (FWD) and two key indicators of pavement performance, namely the international roughness index and the pavement surface evaluation and rating index (PASER). The results demonstrate that our model effectively establishes a satisfactory correlation between the International Roughness Index, Pavement Surface Evaluation and Rating, and structural indices, all of which are derived from deflection measurements. The comparative analysis of the performance of artificial neural networks (ANNs) and non-intelligent models, such as regression models, reveals the higher performance of ANNs. The findings of this study demonstrate that the integration of the IRI and PASER indices yields a heightened level of precision in the assessment of structural pavement conditions.

Barzegaran et al. [10] developed prediction models based on the International Roughness Index to assess pavement distress, presenting it as a potential alternative solution. This study examines a total of 507 kilometers of asphalt pavement located in Kermanshah, Iran. The study utilizes the International Roughness Index and the Pavement Surface Evaluation and Rating as efficient and economical indicators for evaluating the condition of the pavements. The PASER research team created prediction models for the International Roughness Index using regression analysis (R^2 = 0.66) and artificial neural networks (R^2 = 0.69). The results of the model development, with an R^2 value of 0.97, and the validation, with an R2 value of 0.85, indicate that the artificial neural network model exhibited strong performance.

This study studied rehabilitation and maintenance strategies for multilane roads in Jordan. Also, we developed proposed models using a regression model to find the relationship between the parameters (IRI, and PSR) that measure the pavement performance, and this was achieved by using 3411 section samples from different roads in Jordan.

Data Collection Methods

The Data was collected from the Geographic Information System Department in the Ministryof Public Works and Housing for specific parts of the three main highways in Jordan shownbelow in Table 1, It included measurements for both the International Roughness Index and Present Serviceability Rating for flexible pavement sections in three listed highways, in Jordan.Figure 1 shows the selected section of each Highway marked in a yellow double line on the Jordan map.

Table 1: The Number of Sections in Each Road.

No.	Highway	Start and End Station	The Number of Sections
1	Road 10: is the northernmost East-Westhighway in Jordan, which starts at Karameh Border Crossing, from Freeway 1 on Iraq's border in the east and ends at Al-Shuna al-Shomaliya with a junction with Highway 65 in the west after passing through Mafraq and Irbid.	From 10+100 to 10+190 (272.844 m)	2408
2	Road 5: is the easternmost north–south highway in Jordan. It starts at Safawi, from Iraq Highway in the north, and ends at the Saudi Arabian border at Mudawwara in the south.	5+100 (44.573 m)	407
3	Road 15: is also known as the Desert Highway and it runs in Jordan from south to north. It starts in Aqaba going northeast towards Ma'an, passing through the desert to the east of the major settlements in the southern region of Jordan. It then merges into the regional Highway 35 going to Amman.	From 15+420 to 15+480 (87.128 m)	596

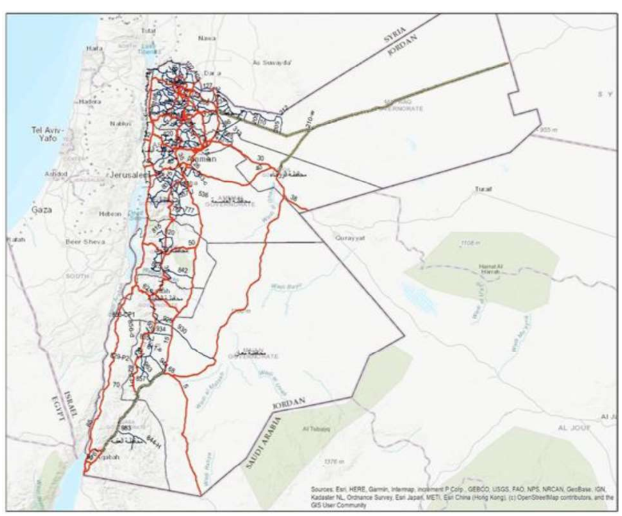

Figure 1: Sections of Highway with Available Data of (IRI and PSR).

Results and Discussion

Because Road (10) had the largest number of tested sections as well as the longest total length, the models were built based on its data and were tested on the other two roads; R5 andR15. The Relationship between IRI and PSR was analyzed using four different regression models using a least square method, as shown in Table 2. The coefficient of determination (R^2) and percent stander error (PSEE) were calculated to evaluate each regression type and to givean indication of the goodness of fit of each model. That was accomplished using SPSS software and Excel Spreadsheet.

Table 2: Predictive Models for each Road.

Highway	Regression	R^2	PSEE
R10	Linear Regression (**PSR=4.0832-0.51*IRI)**	0.899	8.2%
	Natural Exponential Regression ($\mathbf{PSR = 4.8088 . e^{-0.2272 \cdot IRI}}$)	**0.943**	**7%**
	Logarithmic Regression (**PSR = -3.5016*log (IRI)+4.0702)**	0.931	6.8%
	Power Regression ($\mathbf{PSR = 4.6475 * IRI^{-0.6455}}$)	0.874	9.1%
R15	Linear Regression (**PSR=4.0832-0.51*IRI)**	0.838	12%
	Natural Exponential Regression ($\mathbf{PSR = 4.8088 . e^{-0.2272 \cdot IRI}}$)	**0.952**	**5%**
	Logarithmic Regression (**PSR = -3.5016*log (IRI)+4.0702)**	.848	6%
	Power Regression ($\mathbf{PSR = 4.6475 * IRI^{-0.6455}}$)	.748	9%
R5	Linear Regression (**PSR=4.0832-0.51*IRI)**	0.898	5%
	Natural Exponential Regression ($\mathbf{PSR = 4.8088 . e^{-0.2272 \cdot IRI}}$)	**0.945**	**4%**
	Logarithmic Regression (**PSR = -3.5016*log (IRI)+4.0702)**	0.867	5%
	Power Regression ($\mathbf{PSR = 4.6475 * IRI^{-0.6455}}$)	0.818	7%

Data, including IRI, and PSR, for the previously mentioned roads were entered into an Excel Spreadsheet, which was made for statistical analysis. Also, SPSS Softwarewas used to check the Regression Validity. Several linear and nonlinear regression models were considered. The following nonlinear model was found to best fit the boundary conditions and the actual data:

($\mathbf{PSR = 4.8088 . e^{-0.2272 \cdot IRI}}$); where IRI is in m/Km or mm/m. ……………. Eq.5

For Equations in Table 2, all (R^2) values were very high (above 0.90) and the (PSSE) values did not exceed 7%. That denotes a strong nonlinear model between both variables. Figures 2, 3, and 4 plot the natural exponential model in Equation as well as show that there is not much deviation between the predictions for each Road.

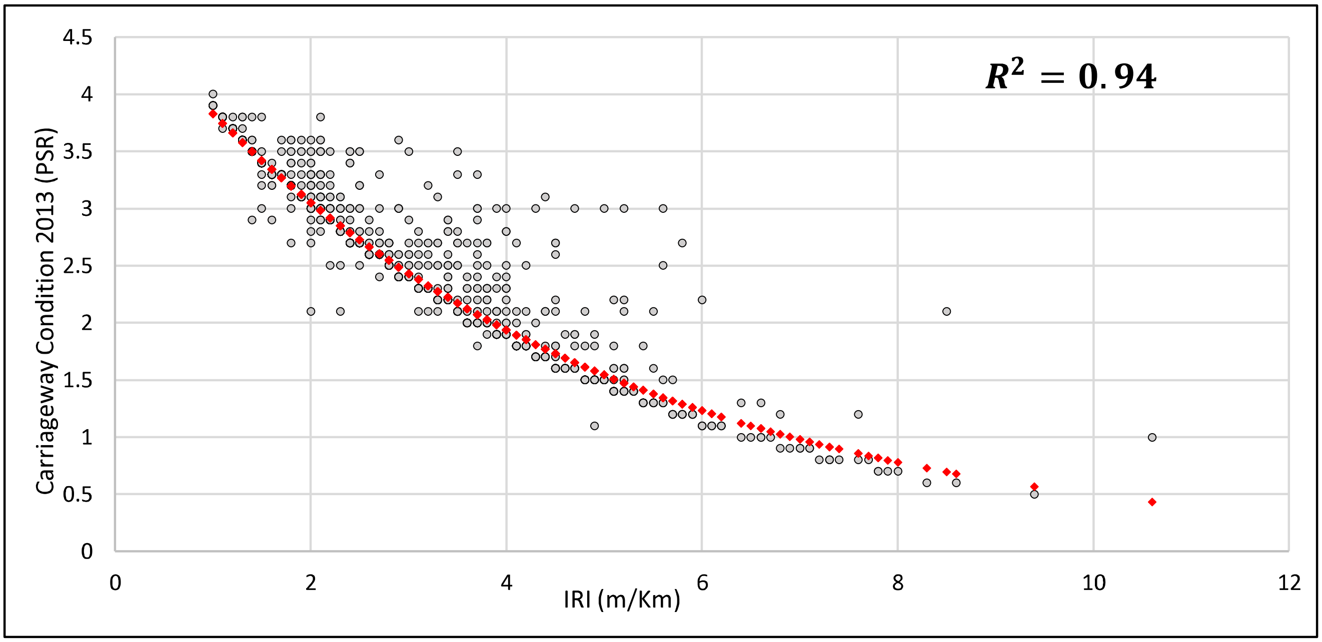

Figure 2: The PSR plot versus IRI for R10.

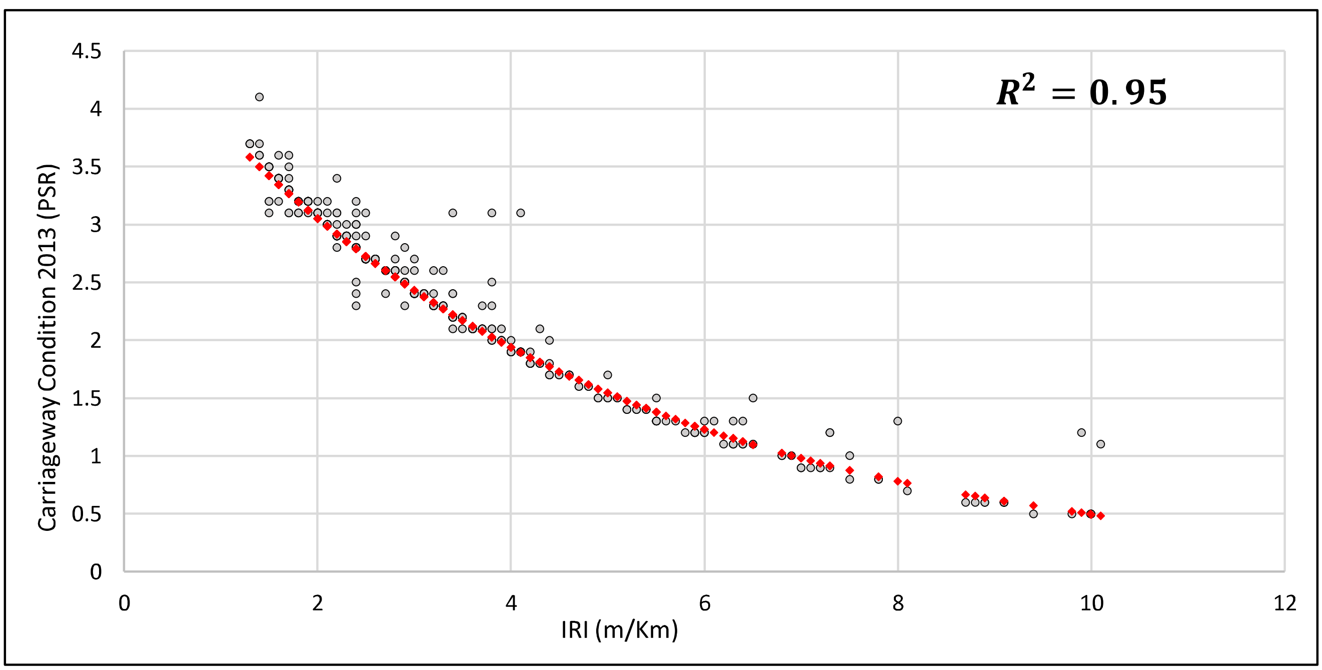

Figure 3: The PSR plot versus IRI for R15.

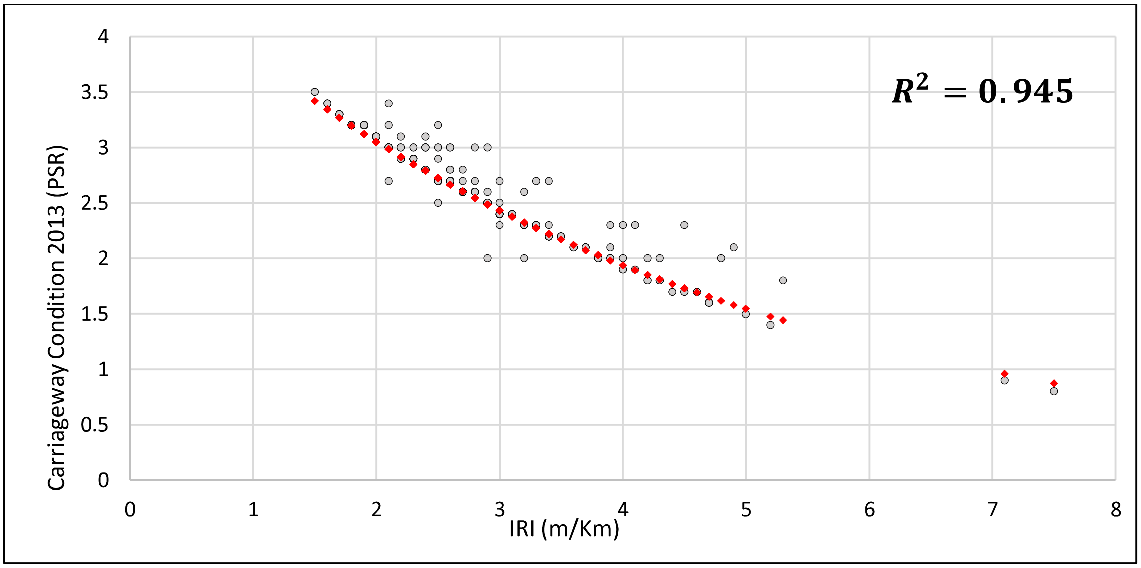

Figure 4: The PSR plot versus IRI for R5.

Figure 5 shows pavement quality for (PSR) and the corresponding approximate (IRI) value. The following Nonlinear Relation between the independent variable (PSR) and the dependent variable (IRI) is recommended to be used for flexible Pavement as represented in Equation 5.

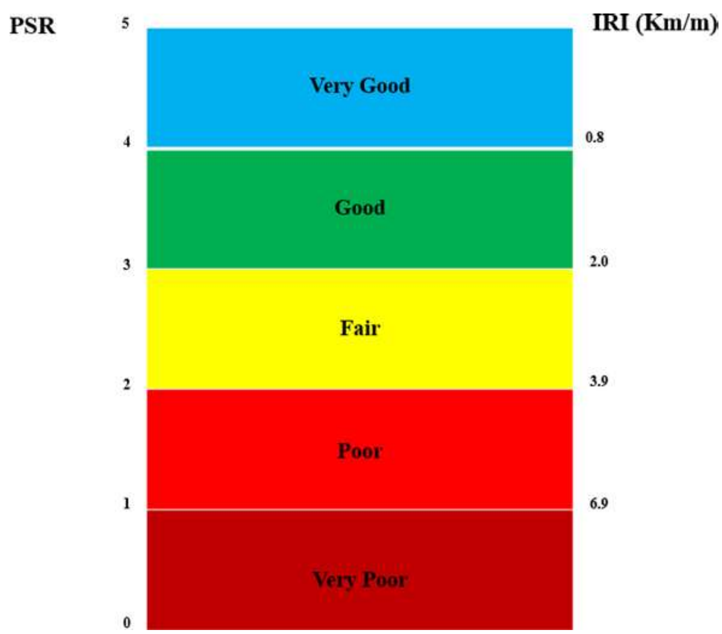

Figure 5: Pavement Quality for a given PSR and IRI values.

Conclusion

This study proposed innovative methods to predict the pavement performance indices PSR, and IRI. Regression models were used to evaluate the pavement performance conditions. And to predict PSR and IRI values. The following Nonlinear Relation between the independent variable (PSR) and the dependent variable (IRI) is recommended to be used for flexible Pavement. The model was simulated in SPSS software to decide their confidence; the coefficient of determination value was our standard in the diagnosis of the model performance. the value of PSR obtained by SPSS software for the first model was 0.94 and 0.95. Moreover, a thorough examination of the coefficient of determination and the percentage standard error provides evidence supporting the presence of a strong natural exponential relationship between the two variables.

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