Prediction of Pavement Condition Index for the highway road between Ba'Quba and Tuz Khurmatu of Iraq: A new model suggestion.

Khalid A M,
Dept. Chem. Eng., Col. Eng., Univ. Al-Anbar, Iraq
Khalid_awad10@uoanbar.edu.iq

Abstract

Pavement condition index is an important indication for road performance and safety driving. Abuse of highway roads always resulted in may difficulties like improper driving, long time of trips, travelers discomfort and many other problems. Uncontrolled traffic of heavy loaded trucks together with high temperatures and absence of road maintenance will certainly cause huge damages to asphalt pavement and as a result reduced road lifetime. In this paper an attempt was made to assess the necessary parameters that used to model pavement condition index by the use of bootstrapping via the SPSS ver. 23. The estimated parameters showed a reasonably reliable predictions when compared to actual data.

Keywords: Pavement Condition Index, Estimation, Prediction, performance degradation

Introduction

No doubts, Iraq was confronted with different political issues during the period 1980-2003 and the critical situations after that, evolved very weak economy and shortages of almost everything. As a result many essential infrastructure services was not managed properly. One of these important issue is the maintenance of highway roads which a lot of damages were noticed and ignored due to different reasons.

Prediction of the potential damages for asphalt pavement will help giving an idea about how urgent maintenance is required. In this instance the exponential model that used to predict pavement condition index PCI, was used according to the following equation:

\[ PPCI = P_0 - \Delta P \cdot e^{-\left(\frac{\beta}{A GE}\right)^\beta} \] ...Model 1
The model above is actually used by Lukanen and Han\(^2\), and it is used to predict the performance degradation of asphalt pavement based on PCI. This model allows prediction of pavement condition indices based on previous data.

Mathematically, this model known as a nonlinear regression model that is thought to give better estimates for the model's parameters. Nonlinear regression is a kind of regression technique in which data is fit to a model and then expressed as a mathematical function. Nonlinear regression uses different mathematical formulas like logarithmic functions, trigonometric functions, exponential functions, and many others. Nonlinear models are usually created through a series of approximations (iterations) that come up from trial-and-error\(^3\).

**Data collection**

The driving road between Tuz Khurmatu city that is fall within the official borders for Salahuddin Province, and Ba'Quba city that is fall within the official borders for Diala Province, was considered in this study. The main reason behind considering this road is the huge damage that can be easily realized. Of course different causes contributed to this damage of them the crowded traffic flow on the road with enormous number of heavy trucks which shipped different materials from Turkey and Iran to mid and south Iraq, military operations also contributed to a remarkable proportion of damage and also ignorance.

Figure 1 shows the map of the considered driving road as found by the use of an online software prepared for such purposes\(^4\). According to distance calculator\(^4\), the driving distance was estimated by 88 miles (140.8 km).
Fig.1. Route map showing driving road between Tuz Khurmatu of Salahuddin Province and Ba’Quba of Diala Province.

Traffic experts were asked to assess their ideas about when and how the damage progressed. Table 1 shows the estimates of the experts according to the successive years.

Table 1. Assessment of PCI as declared by experts.

| Year | PCI | Age | Estimated PCI |
|------|-----|-----|---------------|
| 2003 | 92  | 16  | 94.3          |
| 2010 | 60  | 23  | 50.81         |
| 2016 | 43  | 29  | 38.02         |
| 2020 | 20  | 33  | 33.25         |

Data analysis

The SPSS ver. 23 was used to handle the data and find the estimates of the parameters of the first model (Model1). In this context, the nonlinear regression technique was used with the option of bootstrap. Bootstrapping is a statistical technique that can be considered as a sampling procedure. Bootstrapping use iterations with a particular criteria to estimate a population parameter5.

The use of the nonlinear regression technique on the SPSS ver.23 revealed the following estimates for the parameters of Model1.

\[ P_0 = 1 \]
\[ \Delta P = -11.867\rho = 8.563\beta = -3.853 \]

Figure 2 showed the graph of the estimated and predicted readings of the pavement condition indices.

![Graph showing the plot of the estimated and predicted PCI versus time.](image)

Fig. 2. Graph showing the plot of the estimated and predicted PCI versus time.

According the coefficient of determination \( R^2 \) which used to evaluate the property of the regression model and calculated by the use of the following formula\(^6\):

\[ R^2 = \frac{SS_R}{SS_T} \]

Where

- \( SS_R = \text{Sum of Squares for the Regression} \)
- \( SS_T = \text{Sum of Squares for the total} \)

the value of this coefficient 84.18% indicated that this model is quite good to be used to predict performance degradation of asphalt pavement.

This research work suggested another model which found to give a remarkably better estimates of the performance degradation by considering the value of the coefficient of determination as an index for the suitability of the model. In this context
the value of $R^2$ was found to be 95.1% which is extremely better than the previous model. This model is:

$$PPCI = a + b (1 + e^{(-c/\text{AGE})}) \ldots \text{Model 2}$$

Where

$$PPCI = \text{Prediction Pavement Condition Indexa}, b, c$$

$$= \text{Regression coefficients} \text{AGE}$$

$$= \text{AGE of pavement structure since last reconstruction}$$

The estimates of model parameters were:

$$a = -12657.815 \quad b = 6312.017 \quad c = -0.322$$

The predicted values from both models together with the estimated readings were listed in table 2.

Table 2. Predicted readings of PCI from the two models according to the time.

| PCI | Age | Estimated PCI Model 1 | Estimated PCI Model 2 |
|-----|-----|-----------------------|-----------------------|
| 92  | 16  | 94.3                  | 94.54                 |
| 60  | 23  | 50.81                 | 55.21                 |
| 43  | 29  | 38.02                 | 36.69                 |
| 20  | 33  | 33.25                 | 28.11                 |

Figure 3 showed clearly that Model2 gave better estimates than Model1.
Fig.3. The PCI predicted from Model2 is more closely to PCI estimates.

**Conclusion**

According to the data analysis and parameters estimation, it should be clear that there is no unique nonlinear model used to give an optimal prediction for the model’ parameters. Rather, trial and error should always be used to find better results. Scattering plots are very useful when used to assess how the first model should be arranged. Bootstrapping is a very useful sampling technique that help providing more samples that initiate better predictions.

**References**

1. W. James Wilde, P. E.(2014) Assessing the effects of heavy vehicles on local roadways. Minnesota State University, August 2014.
2. Lukenen E. O. and Han C. (1992). Pavement performance prediction models. Minnesota Department of Transportation, St. Paul, MN.
3. Douglas M.B. and Donald G.W. Nonlinear regression analysis and its applications. 1st edit, John Wiley & Sons, 2007, Canada.
4. www.distancebetweencities.net
5. Davison A.C. and Hinkley D.V. Bootstrap methods and their application (Cambridge series in statistical and probabilistic methods). 1st edit., Cambridge University Press, UK, 1997.
6. Marko Sarstedt and Erik Mooi (2014). Regression Analysis in: A concise Guide to market Research. Springer-Verlag Berlin Heidelberg, pp.193-233.