

Development of Pavement Condition Index Model Using PAVER 6.5.7 for Flexible Pavement Urban Roads in Kerbala City

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Abstract

The pavement condition index (PCI) is an important factor indicating pavement condition of roads. The pavement is one of the basic parts of the road infrastructure. Accordingly the aim of this paper is to develop a pavement condition index model using PAVER 6.5.7 for a flexible pavement urban roads in the Kerbala city center. The development model is depending on the PCI value of 109 sample sections having 57.8 km length, Data collected for pavement distress (type, dimension, and severity) were used to find PCI. The filtering and outlier analysis was done by using a polynomial (fourth-degree) constrained least squared for statistical process. These processes were done by (PAVER 6.5.7) software.

The result of the prediction model of PCI shows that it is valid to be used in the prediction of the condition of pavement for the same family type.

Key words: Pavement Condition Index (PCI), PAVER 6.5.7 System, Flexible pavement, prediction of pavement condition, Maintenance Model.

الخلاصة

مؤشر حالة التبليط (PCI) هو عامل مهم يشير إلى حالة تبليط الطريق. ويعتبر التبليط واحد من الأجزاء الأساسية للبنية التحتية للطرق. وبناء عليه، فإن الهدف من هذه الورقة هو استحداث نموذج إحصائي لمؤشر حالة التبليط باستخدام برنامج PAVER 6.5.7 للطرق الحضرية ذات التبليط المرن في وسط مدينة كربلاء المقدسة. نموذج التطوير يعتمد على قيمة PCI ل 109 عينة من الأقسام التي يبلغ طولها الكلي 57.8 كم، البيانات التي جمعت لفشل التبليط والتي تمثلت ب(النوع والبعد والشدة) تم استخدامها لإيجاد PCI. تم إجراء تحليل التصفية والحدود باستخدام متعدد الحدود (الدرجة الرابعة) للعمليات الإحصائية. تم تنفيذ هذه العمليات من قبل برنامج (PAVER 6.5.7).

نتيجة لذلك تبين إن نموذج التنبؤ المستحدث ل PCI انه يحقق الغرض و من المفيد استخدامه في التنبؤ بحالة الرصفه لنفس نوع العائلة.

الكلمات المفتاحية: - مؤشر حاله التبليط، نظام بيفر 6.5.7، التبليط المرن، استحداث حاله التبليط، نموذج صيانته.

1. Introduction

Pavement Management System (PMS) is a valuable tool, can save money and maximize benefits for the highway system. It has become increasingly popular among local highway agencies, since many countries have the realized benefits of having a decision-support system that helps them find cost-effective strategies for keeping their pavements in good condition (Fitch *et.al.*, 2001; Zhou, 2011). Pavement condition prediction models are imperative for a complete pavement management system.

Condition prediction models are used at both the network and project levels to analyze the condition and determine maintenance and rehabilitation (M&R) requirements. Prediction models are used at the project level to select specific rehabilitation alternatives to meet expected traffic and climatic conditions. The models provide the major input to perform life-cycle cost (LCC) analysis to compare the economics of various M&R alternatives (Shahin, 2005).

Pavement condition is a generic phrase to describe the ability of a pavement to sustain a certain level of serviceability under given traffic loadings. It is usually represented by various types of condition indices such as Present Serviceability Index (PSI), Present Serviceability Rating (PSR), Mean Panel Rating (MPR), Pavement Condition Index (PCI), Pavement Condition Rating (PCR), Ride Number (RN), Profile Index (PI), and International Roughness Index (IRI) (Huang 1993). In this work Pavement Condition Index (PCI) was used.

A PCI pavement condition is obtained by subtracting the sum of all distresses from 100 (Shahin, 1994). Thus, the PCI is numerical ratings of the pavement condition that range from 0 to 100, with 0 being the worst possible condition and 100 being the best possible condition. The condition ranges from a PCI of 0 "Failed" to 100 "Excellent", with an "Excellent" condition corresponding to a pavement at the beginning of its life cycle, and a "Failed" condition representing a badly deteriorated pavement with virtually no remaining life. Table 1 shows the general description for each pavement condition (Juan, 2012).

Periodic PCI determinations on the same pavement will show the change in performance level with time. Because the PCI procedure is designed to be objective and repeatable, it can also be used to predict pavement condition. PMMS typically employs a pavement rating system known as a pavement condition index (PCI) as the basis for evaluation of current and future pavement conditions.

Table 1 Description for Pavement Condition Level.

Condition	PCI Range	Description
Excellent	86 - 100	No significant distress.
Very Good	71 - 85	Little distress, with the exception of utility patches in good condition, or slight hairline cracks; may be slightly weathered.
Good	56 - 70	Slight to moderately weathered, slight distress, possibly patching.
Fair	41 - 55	Severely weathered or slight to moderate levels of distress generally limited to patches and non-load-related cracking.
Poor	26 - 40	Moderate to severe distresses including load-related types, such as alligator cracking.
Very Poor	11 - 25	Severely distressed or large quantities of distortion or alligator cracking.
Failed	0 - 10	Failure of the pavement, distress has surpassed tolerable rehabilitation limits.

2. Study Area Description

Kerbala is located in the central region of Iraq on the edge of the Eastern Plateau Bank, west of the Euphrates River, and specifically between longitudes 43.33 north, Plate 1 show location of the study area. Kerbala is one of the main cities of the Islamic holy shrines, characterized by its standing historical, cultural and specificity urban in Iraq position representative the existence of shrines representing the two major city center shrines of Imam Hussein and Al-Abbas peace be upon them. This means that there is located within the most densely populated geographical regions in Iraq. The importance of not only the city of Kerbala because of the tourist attractions, but also include the land route leading to the pilgrimage back and forth (ICTR, 2007 b). Kerbala city has 1,741.005 km road's length, Directorate mayor's team shows that 999.355 km City Center roads have 59% paved and 41% unpaved, and the Directorate roads and bridges team shows that 741.650 km External roads have 90 % paved and 10 % unpaved.

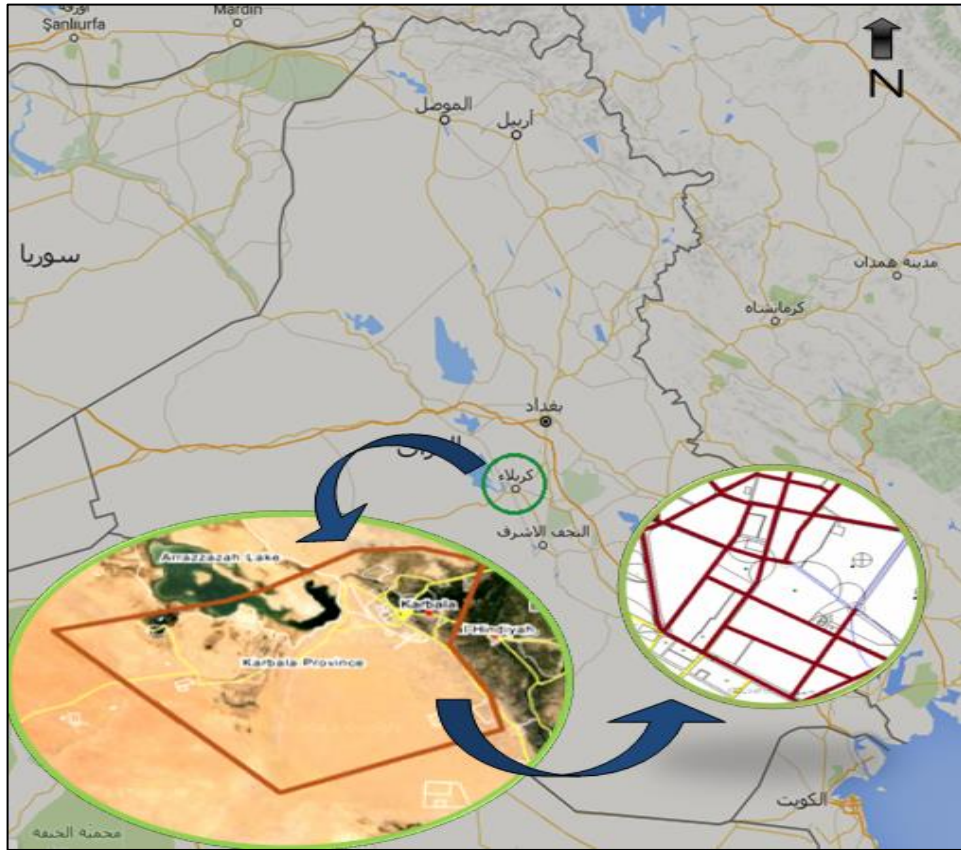


Plate 1 The Road Network in Kerbala, Iraq.

3. Relation And Models Of Pci

A prediction model for maintenance and rehabilitation treatment alternatives are essential for priority programming (Hass *et.al.*,2015). When the maintenance budget was limited, the prediction PCI can help in making a priority for network maintenance. **Figure 1** (Hass *et.al.*, 1994) illustrates how deterioration prediction would be applied to an existing pavement section to estimate the rate of future deterioration and rehabilitation alternatives. The basic requirements for any prediction model are represented in the figure.

Many techniques are available for developing pavement deterioration models. The techniques include straight line extrapolation, regression (empirical), mechanistic empirical, polynomial constrained least square, S-shaped curve, probability distribution, and Markovian. The degree of accuracy required of a prediction model is a function of its intended use. Models for project level analysis need to be more accurate than those for network level analysis (Shahin, 1994).

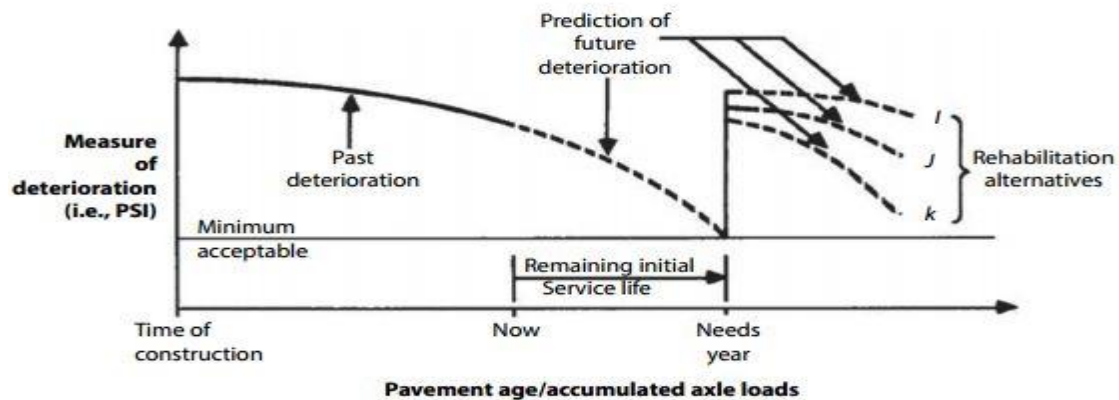


Fig. 1 prediction model of future deterioration of an existing pavement (Hass *et.al.*, 1994).

4. Prediction Models Using Micro Paver

An extensive research program conducted at the U.S. Army CERL resulted in the development of what is called the Family Method (Nunez and Shahin1986, Shahin and Walther1990). The method consists of the following steps:

1. Define the pavement family: a pavement family is defined as a group of pavement sections with similar deterioration characteristics. The Micro PAVER system allows the user to define a family based on several factors, including use, rank, surface type, zone, section category, last construction date, and PCI. For each defined family, a data file is automatically created by Micro PAVER containing pavement section identification, age, and PCI.
2. Filter the data: check on suspicious data is done using a set of boundaries defined by a maximum and minimum envelope expected over the life of the pavements. The program includes a default envelope developed by reviewing many databases; however, the user can easily modify these values. If are cord falls outside the envelope boundaries, the record is moved to the "errors "file.
3. Conduct data outlier analysis: The data-filtering procedure is used to remove obvious errors in the data as described above. Further examination of the data for statistical removal of extreme points is performed in the outlier analysis. This step is important because pavements with unusual performance can have a substantial impact on the way family behavior is modeled
4. Develop the family model: a fourth-degree polynomial constrained least squared error is developed using data after being processed through the filtering and outlier analysis. This polynomial is constrained in that it is not allowed to have a positive slope because the PCI cannot increase with age. In there quest of the user, an unconstrained best fit can be viewed if appositive PCI vs. age slope is detected. This is a useful feature because it may imply a non homogeneous family.

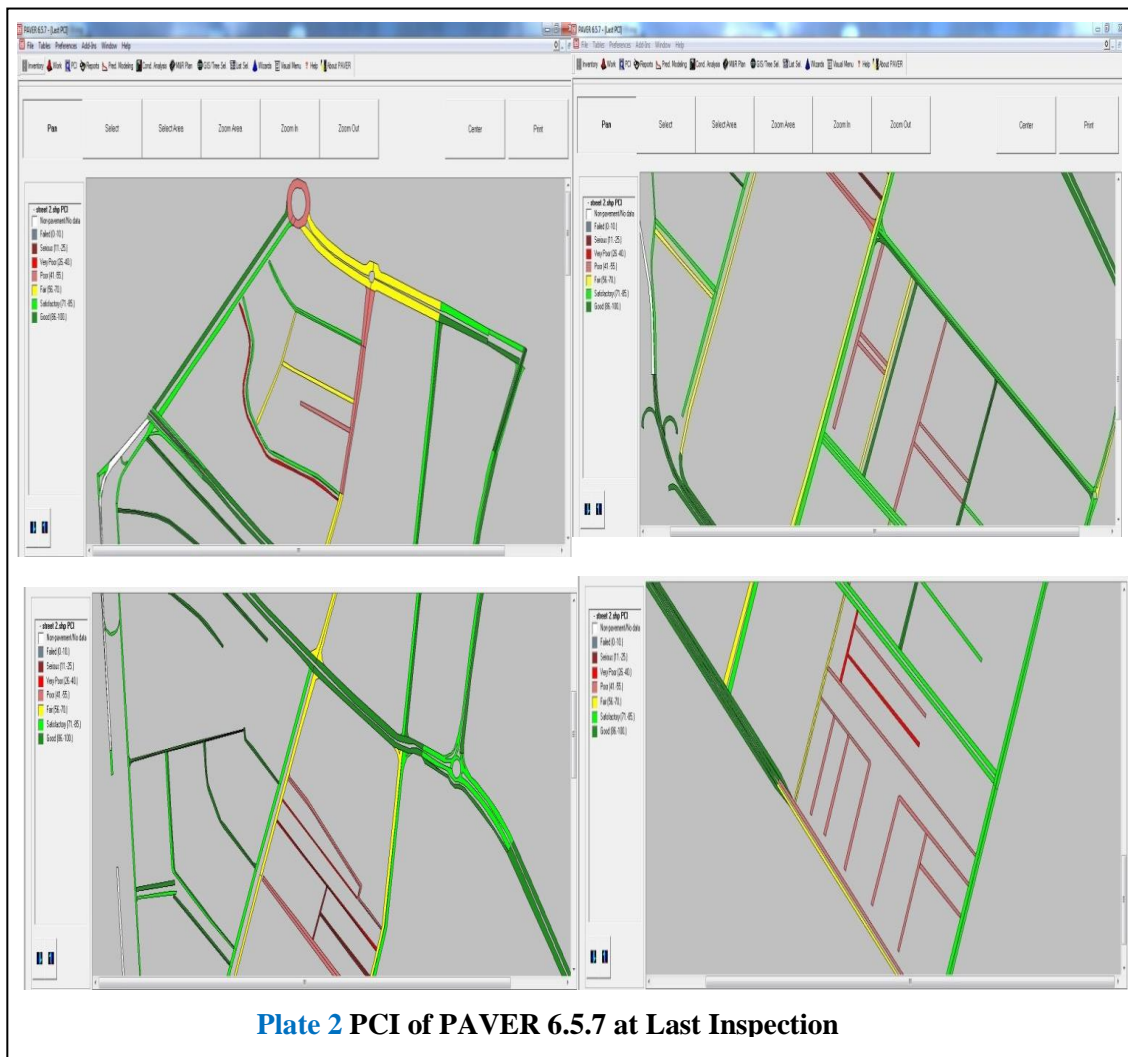
It also helps the user view where the problem is occurring. This best-fit curve for the family analysis extends only as far as the available data. To predict future conditions, the curve is extrapolated by extending a tangent of the same slope as that of the curve in the last few years (currently set to 3 years).

5. Predict the pavement section condition: PCI prediction at the section level uses the curve of the pavement family prediction model. The prediction function for a pavement family represents the average behavior of all the sections of that family .The prediction for each section is done by defining its Position relative to the family prediction curve. It is assumed that the deterioration of all pavement sections in a family is similar and is a function of only their present condition, regardless of age.

5. Paver 6.5.7 Software

PAVER 6.5.7 software has been utilized to determine the current PCI and to predict future pavement condition, used to select maintenance and rehabilitation needs at the optimal time and priorities. PAVER 6.5.7 provides many important capabilities, including: pavement network inventory, Pavement condition rating, Development of PCI models (Family Curves), determination of current and future pavement condition (Condition Analysis), determination of (M&R) needs and analyzing the consequence of different budget scenarios (Work Planning), project formulation (U.S Army Corps of Engineers, 2014).

Output of PAVER software includes PCI values and quantity of distress of all sample sections surveyed, as well as PCI of the all roads networks (shahin, 2005). [Plate 2](#) shows the output of PCI for the study area (57.8 km) after integration PAVER with GIS, which estimated depended on the distress data survey (type, dimension, severity level).



6. Paver Pci Model Developing

The Prediction Model and Condition Analysis model of Micro PAVER can be used for modeling and predicting future pavement condition. Pavement sections with the same surface type, pavement use, and pavement rank can be grouped into families. A curve is fit through the pavement condition index versus age data for each family group, and section condition prediction is performed assuming that the behavior of a section is similar to the behavior of its family (ART-045, 2002). However, such factors such as original construction, maintenance, weather, traffic, etc. will greatly affect the life of a pavement. This pavement condition prediction method is very useful in situations where limited historical data are available. Depending on PAVER PCI output data which estimated depending on the data collected from a survey of 109 sections with different classification types (arterial, collector, local) for the study area (Kerbala city center). PAVER View/ Edit condition prediction model tool is used to develop a PCI model with independent variable (Age). Using the outlier boundary 95% (1.960) for data, as a result, 8 sections have out of bound state. [Table 2](#) shows the review model data for 45 out of 109 sections used in the prediction model.

Table 2 PAVER Review Model Data.

Age at Inspection	PCI	Model	Difference	Status	Network ID	Branch ID	Section ID	Surface	Rank
0.25	100	100	0		Kerbala	2	1B	APC	A
6.01	48	70	22		Kerbala	14	1A	AC	C
7.01	71	67	-4		Kerbala	17	1A	AC	C
8	66	66	0		Kerbala	26	1A	APC	A
6.01	50	70	20		Kerbala	27	1A	AC	C
7.79	55	66	11		Kerbala	1	1	AC	A
8.29	86	66	-20		Kerbala	1	A	AC	A
8.29	85	66	-19		Kerbala	1	B	AC	A
2.21	97	91	-6		Kerbala	10	1A	AC	A
2.21	91	91	0		Kerbala	10	1B	AC	A
2.21	93	91	-2		Kerbala	11	1A	AC	A
2.21	87	91	4		Kerbala	11	1B	AC	A
6	94	70	-24		Kerbala	12	1A	APC	A
6	95	70	-25	Out of Bounds	Kerbala	12	1B	APC	A
6.21	80	69	-11		Kerbala	12_1	1A	AC	A
6.17	80	69	-11		Kerbala	12_1	1B	AC	A
7.54	76	67	-9		Kerbala	13	1A	AC	B
7.5	68	67	-1		Kerbala	13	1B	AC	B
9.01	66	66	0		Kerbala	15	1A	AC	B
9.01	74	66	-8		Kerbala	15	1B	AC	B
4.01	63	79	16		Kerbala	16	1A	AC	C
7.01	76	67	-9		Kerbala	17	1B	AC	C
4.01	87	79	-8		Kerbala	18	1A	AC	C
4.01	84	79	-5		Kerbala	18	1B	AC	C
10.01	70	66	-4		Kerbala	19	1A	AC	B
10.01	60	66	6		Kerbala	19	1B	AC	B
3.28	72	83	11		Kerbala	2	1B	APC	A
10.01	47	66	19		Kerbala	20	1A	AC	B
10.01	55	66	11		Kerbala	20	1B	AC	B
10.01	54	66	12		Kerbala	21	1A	AC	B
10.01	52	66	14		Kerbala	21	1B	AC	B
10.01	81	66	-15		Kerbala	22	1A	AC	B
10.01	88	66	-22		Kerbala	22	1B	AC	B

AC: Asphalt Concrete; APC: Asphalt Concrete Over Portland Cement Concrete;
A:major arterial; B: minor arterial ;C:major collector ;E:local.

Table 2 PAVER Review Model Data (continued).

Age at Inspection	PCI	Model	Difference	Status	Network ID	Branch ID	Section ID	Surface	Rank
3.01	100	85	-15	Out of Bounds	Kerbala	23	1A	APC	B
4.01	97	79	-18		Kerbala	23	1B	APC	B
3.84	85	80	-5		Kerbala	23_1	1A	APC	B
4.01	80	79	-1		Kerbala	23_1	1B	APC	B
4.01	80	79	-1		Kerbala	24	1A	APC	B
4.01	87	79	-8		Kerbala	24	1B	APC	B
8.05	76	66	-10		Kerbala	25	1A	APC	A
8.01	86	66	-20		Kerbala	25	1B	APC	A
7.84	69	66	-3		Kerbala	26	1B	APC	A
3.01	98	85	-13		Kerbala	28_1	1A	AC	E
3.01	97	85	-12		Kerbala	28_1	1B	AC	E
3.01	94	85	-9		Kerbala	28_2	1A	AC	E

AC: Asphalt Concrete; APC: Asphalt Concrete Over Portland Cement Concrete;
A:major arterial; B: minor arterial ;C:major collector ;E:local.

Table 3 shows PAVER statistical analysis output. The fitted PAVER model describes the deterioration of the pavement sections with age (x) as follows:

$$PCI = 100 - 0.00003X - 2.91331X^2 + 0.5204X^3 - 0.03361X^4 + 0.00073X^5$$

Table 3 Statistical Analysis of PAVER Prediction Model

Coefficient of correlation (R)	Approximate (R ²)	Standard deviation of error	Absolute mean of error	Arithmetic mean of error
0.772	0.596	12.59	9.59	0.341

Plate 3 shows the Pavement Life Prediction Curve for Kerbala City Center. PAVER statistical test shows that 60% of variation in the dependent variable (PCI) is explained by the independent variable (age) in the developed model. The remaining percentage of variation (40%) is not explained due to many factors can also affect on the PCI of pavement, such as traffic volume, structure of the pavement, mixing design used in paving, environment affect and human bad use.. etc.

7. Conclusions

- Pavement age factor has the largest effect on the pavement condition.
- This work shows the validity of the PCI prediction model to be used to predict the condition of pavement for the same family type.
- The family deterioration prediction model provides important information about the level of needs for Maintenance & Rehabilitation.
- The prediction model gives a guide for the designer to limit the pavement thickness.
- Using PAVER 6.5.7 software will facilitate the development of a new model by just updating the existing database.

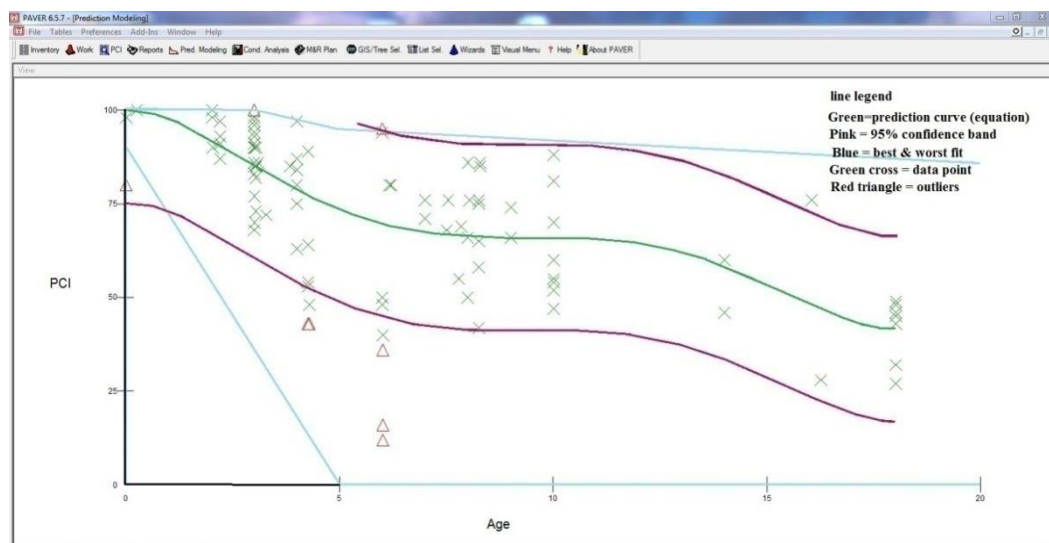


Plate 3 Pavement Life Prediction Curve for Study Area.

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