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VALIDITY OF GARBER MODEL IN PREDICTING PAVEMENT CONDITION INDEX OF FLEXIBLE PAVEMENT IN KERBALA CITY

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ABSTRACT

Pavement Condition Index (PCI) is one of the important basics in pavement maintenance management system (PMMS), and it is used to evaluate the current and future pavement condition. This importantance in decision making to limit the maintenance needs, types of treatment, and maintenance priority. The aim of this research is to estimate the PCI value for flexible pavement urban roads in the study area (kerbala city) by using Garber et al. developed model.

Based on previous researches, data are collected for variables that have a significant impact on pavement condition. Data for pavement age (AGE), average daily traffic (ADT), and structural number (SN) were collected for 44 sections in the network roads. A field survey (destructive test (core test) and laboratory test (Marshall Test)) were used to determine the capacity of structure layer of pavement (SN). The condition index (CI) output from a developed model was compared with the PCI output of PAVER 6.5.7 by using statistical analysis test.

The developed model overestimates value of CI rather than PCI estimated from PAVER 6.5.7 due to statistical test to a 95% degree of confidence, (R = 0.771) for 44 sections (arterial and collector).

KEYWORDS: Pavement Condition Index (PCI); Garber et al. model; Maintenance model; Flexible pavement; Structural number; Coring test.

1. INTRODCTION

Maintenance of highway pavement is one of the most important components of the entire road system and should be accorded due importance. The work dimension for maintenance is very large, but the funds obtainable are not adequate to identify the needs of maintenance (Shah et al., 2012). Pavement maintenance management systems (PMMS) is part of pavement management system (PMS), as shown in Fig. 1. Management of pavement extend a sensible and cost effective approach to operations of pavement maintenance (Hass et al., 1994). The PMMS process involves the following steps for a given pavement section: (1) assess present pavement condition, (2) predict future conditions, (3) conduct an alternatives analysis, and (4) select an appropriate rehabilitation strategy (Garber et al., 2011).

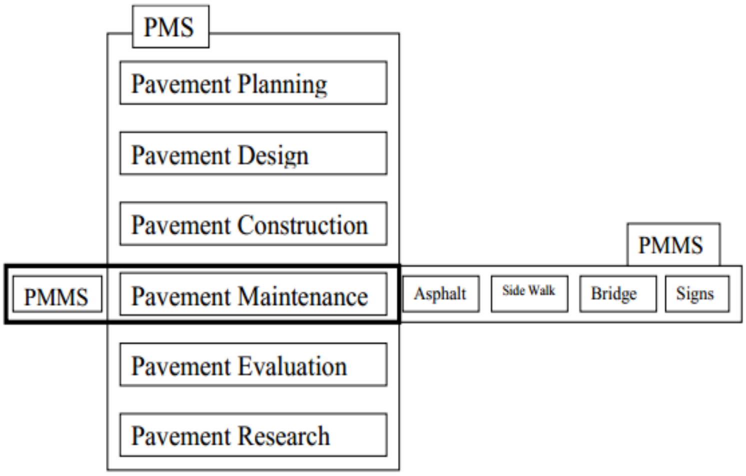

Fig. 1. Pavement Maintenance Management System (PMMS) and Pavement Management System (PMS)(Abo –Hashema et al., 2006).

Pavement Condition is “a generic phrase to describe the ability of a pavement to sustain a certain level of serviceability under given traffic loadings”. The PCI is an evaluation process that is evaluated in correspondence with steps include in ASTM D 5340, Standard Test Method for PCI Survey. This procedure is used worldwide to provide a measurement of the condition of pavements taking into account the functional performance with implications of structural performance. Determinations of periodic PCI on the same pavement will show the differences in level of performance with time. Because the PCI procedure is designed to be objective and repeatable, it can also be used to predict the condition. Table 1 shows the general description for each pavement condition.

Table 1. Pavement condition level (Juan and Martinez, 2012).

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. RELATION AND MODELS OF PCI

Predictions model for maintenance and rehabilitation treatment alternatives are essential for programming of priority (Hass et al., 2015). When developing the condition prediction models should be use a valid statistical approach to store a basis for determining the model accuracy and precision. The most development model uses a regression analysis method, statistical methods that show the precision of the regression equations are often used. Probably the tests widely used are the standard error of estimate, the coefficient of determination, correlation coefficient, the residual analysis, F-test, and other tests are also used (Smith, 1986).

Deterioration modeling for long life pavements notation for flexible pavements requires a periodic monitoring of surface distresses (APA, 2010) based on a greater probability of deterioration active in the wearing course than deeper in the structure of pavement, and the fact that deeper failures also reflect to the surface. As a result, when design criteria are satisfied. Therefore, after satisfying design criteria, such as reaching limits of cumulative strain, performance, or deterioration. Then a scheduled maintenance and rehabilitation are needed to yield the required design life. While design methods like MEPDG (AASHTO, 2008) can be used to predict deterioration; there is not much evidence to date on their accuracy, especially over the longer term. There are four basic types of prediction models: purely mechanistic, mechanistic-empirical, regression based, and subjective.

3. GARBER ET AL. MODEL

Garber et al. developed a model depended on a data collected by rating the condition of 20 individual pavement sections. The fitted model describes the deterioration of the pavement sections as follows (Garber et al., 2011):

$$CI=98.87-2.18AGE + 0.02ADT + 0.28SN \quad (1)$$

Where:

CI = condition index.

AGE = number of years since construction.

ADT = average daily traffic in 1000 veh/day.

SN = structural number.

The R^2 of this model is equal to (0.973) (Garber et al., 2011).

4. COLLECTED DATA FOR MODELING

Valid Garber et al. independent variables (AGE, ADT, SN) can be determined by surveying and analyzing the collected data for the study area (Kerbala). 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. Fig. 2 shows the location of the study area and the location of served sections.

4.1. Estimation of Average Daily Traffic (ADT)

The Average Daily Traffic (ADT) value for sections can be determined depending on traffic data collections. The traffic flow data are recorded by using a video camera. Data recorded by video camera tapes and later copied onto solid disk. The traffic data have been collected and classified depending on the type of vehicle, such as passenger car, light truck, heavy truck, and bus. Vehicles of different types require different amount of road space because of variations in size and performance. To allow for this in capacity measurement for roads traffic volumes are expressed in passenger car units (PCU); the weighting for each class of vehicle has to be varied to suit the purpose for which they are to be used. For traffic count and design purposes, conversion factors similar to those of "Road Transport Study, Iraq, 1982" are used by SCRB. These factors are shown in Table 2.

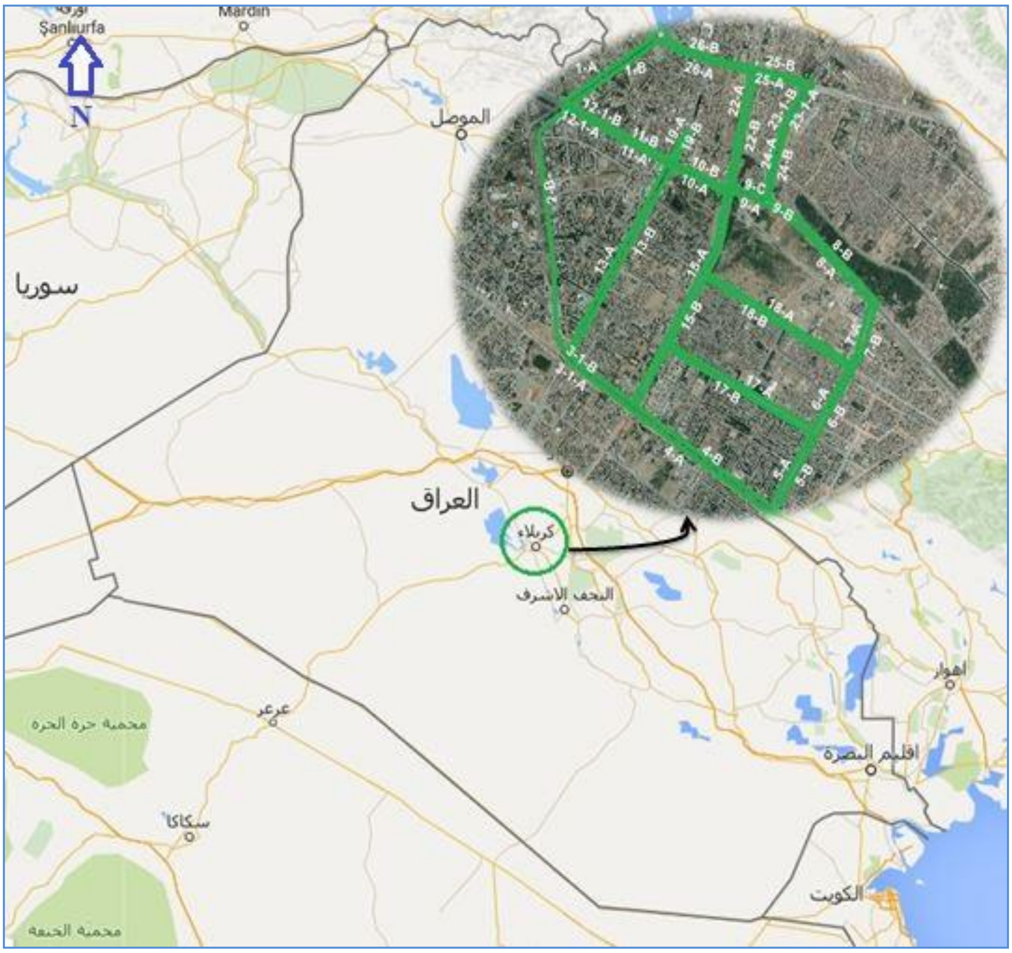

Fig. 2. The Road Network served in Kerbala, Iraq.

Table 2. Conversion Factors of Different Type of Vehicle to PCU.

SCRB- Conversion factors to PCU			
Vehicle Type	Type of Terrain		
	Flat	Hilly	Mount
Passenger cars	1.00	1.00	1.00
Buses up to 24 passengers	1.25	1.75	3.00
Buses above 24 passengers	2.00	3.00	6.00
Truck, and trailer combination	3.00	5.00	10.00

In this research used the Conversion factors of flat case. The traffic volumes data abstracted from video recording for each section of arterial and collector roads. Table 3 shows a typical traffic data that have been collected. Used a federal highway administration charts as shown in Fig. 3 to convert the traffic value from one hour to daily traffic value, and Fig. 4 to convert the daily traffic value to average daily traffic value. Table 4 shows a typical data of average daily traffic (ADT) value for study area.

Table 3. Traffic Data Collected for Each Section in Study Area of kerbala city

Street	Passenger	Light truck	Heavy truck	Bus	Time	Day
1-A	1389	86	10	173	3:59-4:59 PM	Saturday
1-B	1433	118	7	198	3:59-4:59 PM	Saturday
2-B	1207	93	37	73	4:05-5:05 PM	Tuesday
3-1-A	807	133	27	152	9:0-10:0 AM	Saturday
3-1-B	615	183	29	67	9:0-10:0 AM	Saturday
4-A	1512	192	69	185	9:0-10:0 AM	Saturday
4-B	1629	195	70	190	9:0-10:0 AM	Saturday
5-A	507	74	13	18	10:0-11:0 AM	Saturday
5-B	652	62	14	29	10:0-11:0 AM	Saturday
6-A	620	52	11	28	10:0-11:0 AM	Saturday

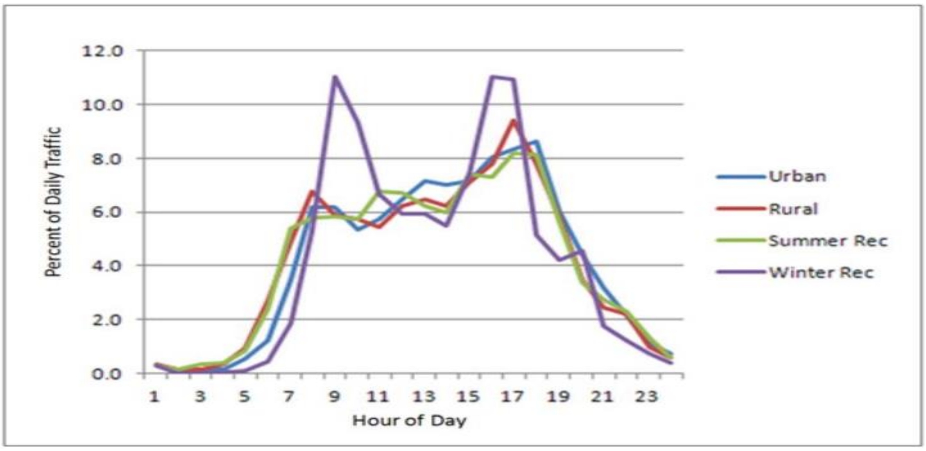

Fig. 3. Daily Traffic Factors (Sucrose: Federal Highway Administration, 2016).

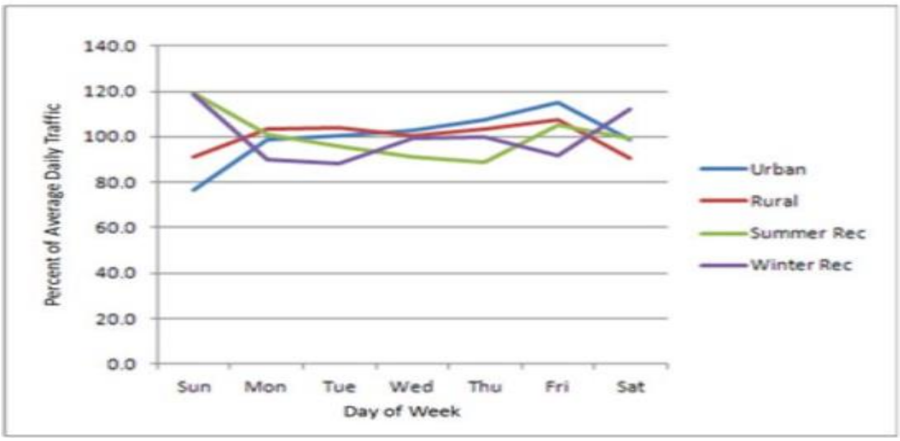

Fig. 4. Average Daily Traffic Factors (Sucrose: Federal Highway Administration, 2016).

4.2. Estimation of Structural Number

Structural evaluation of pavement depends on nondestructive or destructive tests (DT). The data obtained is primary to determine the pavement structural capacity for sections and networks (Hass et al., 2015). Destructive testing techniques include coring in bound layers, boring in soft layers, and dynamic cone penetrometer (DCP) testing in subgrade soils (Uddin, 2002).

Table 4. The Average Daily Traffic (ADT) Value.

Section	ADT veh/h	C(hr)	C(day)	ADT veh/day
1-A	1873	0.08	1.01	23181
1-B	1998	0.08	1.01	24728
2-B	1580	0.0815	1	19387
3-1-A	1358	0.061	1.01	22042
3-1-B	1065	0.061	1.01	17286
4-A	2329	0.061	1.01	37802
4-B	2463	0.061	1.01	39977
5-A	675	0.057	1.01	11725
5-B	830	0.057	1.01	14417
6-A	774	0.057	1.01	13445

During destructive tests, each core was numbered and transferred safely to the Laboratory. However, cores serve one or more of the three general purposes in forensic investigations (i.e., for thickness, for cause of distress, and for laboratory testing).

Core test is usually conducted information about the pavement from the surface down to the subgrade. Coring provide a very detailed picture of how the roadway structure exists at the point cored. The core samples were taken for surface and base layer for each arterial and collector section in the studied area (44 sections). Fig. 5 shows core test for a specific section in the study area.

Steps followed throughout current study:

1. Choose places of core samples for each section, and take the coordinates of them.
2. Use core device to cut a samples.
3. Cut cores at an angle of 90° to the surface in order to ensure recovery of straight.
4. Numbering and mark the core and record number and location on the core log.
5. Photograph the core and record the photograph number on the core log.

Fig. 5. Core Test for Study Area.

4.2.1. Laboratory Testing of Samples

The Marshall Stability Test procedure was used to prepare test specimens using (ASTM D 1559, 1989). Based on the requirements for Marshall to find each of (strength, bulk density, air voids, VMA, and flow). To determine layer coefficient and structural number for each layer (binder, surface, and base).

Steps of test:

1. Separate each pavement layer (binder, surface, base).
2. Take the average high for each core, the dry weight also should be taken and to determine bulk density.
3. Before testing of the core samples leave it in a water bath having a temperature of 60^{o}C for half an hour and test it after that.

The cores were tested in a pine press Marshall device which applies load via a motor driven by mechanical jack at a speed rate of 2 in/min (5.08 cm/min) (AASHTO 90-5, 1993).

The structural number was determined depending on data collected from marshal test results (marshal stability). Average thickness of core samples was used to determine stability correlation factors by using ASTM D6927- 15 for Marshal Stability to correct the stability values. The corrected stability values were used to find structural layer coefficient (a) for each surface and base layer by using the charts presented in NCHRP-128, 1972. These correlation charts are used for estimating resilient modulus of asphalt concrete. Table 5 shows a typical value of structural number for the different sections in the area under study.

To determine structural number for both the surface and base course in each section, equation (2) was used as follows. The SN is calculated as below:

$$SN= a_1 D_1+a_2 D_2 m_2 + a_3 D_3 m_3 \quad (2)$$

Where:

SN: Pavement structural number.

a_1, a_2, a_3 : Layer coefficients representative of surface, base, and subbase course, respectively.

D_1, D_2, D_3: Actual thickness in inches of surface, base, and subbase courses, respectively.

m_2, m_3: Drainage coefficient for untreated layer (2 & 3).

Table 5. Structural Number of the Different Sections in the Area under Study.

Sample	Layer Name	Average Thickness of Layer (inches)	Marshall Stability (Ib)	Correction Factor of Thickness	Correction Stability (Ib)	Layer Coff. (a)	SN
3	Base (1A)	4.429	4372.140	0.685	2994.916	0.398	3.3825
4	Binder (1A)	4.331	1656.333	0.91	1507.263	0.374	
5	Base (1B)	4.724	4409.244	0.647	2852.781	0.381	3.201
6	Binder (1B)	3.858	991.639	1.4366	1424.589	0.363	
9	Binder (2B)	2.165	1800.294	1.4	2520.412	0.487	2.243
10	Base (2B)	3.622	4365.152	0.647	2824.253	0.386	
11	Binder(3-1-A)	2.827	3187.002	0.938	2989.407	0.531	2.493
12	Base (3-1-A)	2.661	2150.829	1.06	2279.879	0.359	
13	Binder(3-1-B)	2.697	1688.740	1.4366	2426.045	0.475	2.694
14	Base (3-1-B)	3.268	2892.464	0.775	2241.660	0.352	
15	Binder (4A)	2.559	3010.632	0.9875	2972.999	0.524	2.2091
16	Base (4A)	2.480	2003.120	1.0375	2078.237	0.35	
17	Binder (4B)	1.929	1688.740	1.6425	2773.756	0.503	2.0727
18	Base (4B)	3.150	2892.464	0.736	2128.854	0.35	
19	Binder (5-A)	3.008	2223.582	0.95	2112.403	0.438	2.15163
20	Base (5-A)	3.083	2234.759	0.858	1917.423	0.325	

5. RESULTS OF GARBER ET AL. MODEL

Pavement conditions index (CI) is calculated for 44 sections (34 major and minor arterial sections and 10 collector sections) from all network of Kerbala city using Garber et al. model. Table 6 includes typical input data and the results of CI from developed model and the PCI of PAVER 6.5.7 which are estimated depending on the collected data of distress for the same sections in kerbala city.

Table 6. Typical Input Data and Pavement Condition Index of Kerbala City by Using Garber et al. Model.

Input data					Results	PCI of
Street	Type	ADT*1000	Age year	SN	CI	PAVER
1-A	minor arterial	23.181	8	3.382	81.91	86
1-B	minor arterial	24.728	8	3.201	81.83	85
2-B	major arterial	19.387	3.3	2.243	91.92	72
3-1-A	major arterial	22.042	2	2.493	94.77	90
3-1-B	major arterial	17.286	2	2.694	94.92	98
4-A	major arterial	37.802	14	2.209	68.21	60
4-B	major arterial	39.977	14	2.073	68.13	46
5-A	collector	11.725	4	2.152	90.52	80
5-B	collector	14.417	4	2.074	90.44	77
6-A	collector	13.445	4.3	2.359	89.89	85

PCI: PAVER 6.5.7 pavement condition index output, CI: condition index of Garber et al.

Further, CI values obtained from the method are compared with PCI values for these sections which represent the output of PAVER 6.5.7 application. SPSS two paired test tools are used to analysis data and compare them, as shown in Tables 7 and 8. The Garber et al. model overestimated value of CI rather than PCI estimated from PAVER due to statistical test to a 95% degree of confidence, ($R = 0.771$) for 44 sections (arterial and collector). According to the results in Tables 7& 8, it can be concluded that there is a significant difference between value CI and PCI for each it ($0.000 < 0.05$) it is reject null hypothesis. It can be calculated that there is a need to develop a new model or modeling calibration for model of Garber et al. A new model is performed with the same independent variable to achieves a hole calibration for each variable rather than the hole model.

Table 7. Paired Samples Statistics for Pavement Condition Index of PAVER and Condition Index of Garber Model.

Sample	Mean	N	Std. Deviation	Std. Error Mean
Pavement condition index (PCI) due to PAVER	79.5000	44	10.51798	1.58565
Pavement Condition Index (CI) due to Garber et al. Model	87.0416	44	6.79316	1.02411

Table 8. Paired t Test Results for Pavement Condition Index of PAVER and Condition Index of Garber Model.

Sample	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pavement condition index (PCI) due to PAVER Pavement Condition Index (CI) due to Garber et al. Model	-7.5415	6.82875	1.02947	-9.61772	-5.4654	-7.326	43	0.000

6. CONCLUSIONS

- Garber et al. developed a model that cannot be used to predict PCI values for the study area (Kerbala city center), because there is a significant difference between this value and PCI obtained from PAVER 6.5.7 for the sections.
- The clear different in PCI values between Garber et al. model and PAVER 6.5.7 results may be due to the different environmental condition where the data come from (loading type, materials used, and layer thickness). Low structural number value compares with age for many sections cases a large effect on the different between these two values also.

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