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DETERIORATION OF EGYPTIAN DESERT ROADS IN AL-MINEA DISTRICT

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Abstract

Deterioration of Egyptian desert roads in Upper Egypt (Al-Minea area) were investigated through developing deterioration model. This model requires collecting data related to time periods for different progressive deterioration stages for road surfaces. Ten road segments located in desert roads were studied. Each road segment has an average length of 500 meters. The progressive deterioration stages of road surface were monitored for each segment in term of Pavement Condition Index (PCI) and plotted against time for each road type. Least square regression analysis has shown that a quadratic function represents the best fit for the collected deterioration data with a coefficient of determination (R^2) ranges from 0.95 to 0.96. The developed deterioration prediction model can be used to predict future deterioration of desert roads.

***Keywords*:** Desert Road Deterioration; Prediction Models; Pavement Condition Index.

1. Introduction

The deterioration nature of road surface can be considered a function of time. Therefore providing timely periodic maintenance activities for road surface is a matter of concern, since this has a great impact on the safety, riding comfort, aesthetics and convenience of road users. With that regard, this paper considers developing a deterioration prediction model of Egyptian desert roads in Upper Egypt (Minea area). Ten newly maintained road segments with an average length of 500 meters and almost have the same age of construction or last overlay were selected. The selection of the total ten segments was mainly based on having a similarity in the geometric dimensions, nature of passing traffic as well as the physical properties of the road segment materials.

2. Evaluation of Pavement Condition Index (PCI)

The Pavement Condition Index (PCI) defined in PAVER [1] is an index that reflects the composite effects of various distress types and their severity and density upon the overall condition of the pavement segment. The severity of a distress, in general, represents the various stages of distress development, while the density of the distress is defined in terms of its coverage percent in a given roadway segment. The pavement condition index concept was used within this research to reflect the condition of the road surface for the selected segment. Hence, the different progressive deterioration stages of road surfaces can be estimated by monitoring the successive changes on PCI values with time. Pavement condition index was calculated for each segment based on recorded severity and density of four main distresses that are noticed on the selected roads, namely:

- Block Cracking
- Transverse and Longitudinal Cracking
- Pot holes
- Shoulder drop off

The PCI calculation was made following the procedure stated by Shahin [1] and Sharaf [2]. The procedure is also described in details in the Egyptian Code for Urban and Rural Roads Works, (Part 10: Road Maintenance) [3]. This procedure is simply based upon the summation of deduct points for each type of observable distress and subtracts them from 100 to yield the PCI. The calculated PCI is a numerical indicator ranges from 0 to 100. A PCI value ranging from 0 to 10 represents a failed segment, while a value ranging from 85 to 100 represents a segment that is in an excellent condition. In between the PCI level ranges from very poor to very good. Table (1) presents the PCI scale and associated condition ratings. Measurements, data collection and PCI evaluation for all the selected segments were made every three months for a period of 30 months with the help of road department engineers that are well trained and have more than 10 years experience in roads maintenance. During the data collection phase of this research, no maintenance was applied to the selected segments in order to estimate the natural deterioration behaviour of the segments road surface.

Table 1 PCI Scale and Associated Condition Ratings

Condition	PCI values
Excellent	$\geq 85 - < 100$
Very Good	$\geq 70 - < 85$
Good	$\geq 55 - < 70$
Fair	$\geq 40 - < 55$
Poor	$\geq 25 - < 40$
Very Poor	$\geq 10 - < 25$
Failed	$0 - <10$

Table 2 illustrates an example for PCI calculation for a road segment located on agricultural area at time period 18 months. As early mentioned, evaluation of distresses density and severity as well as PCI calculation were made according to the procedure stated and described in details in the Egyptian Code for Urban and Rural Roads Works (Part 10: Road Maintenance, pages from 11 to 85) [3].

Table 2 Example of PCI Calculation for a Road Segment

Distress Type	Density Percent	Severity	Deduct Value
Block Cracking	5%	Low	4
Transverse and Longitudinal Cracking	1.5%	Medium	11
Pot holes	1.5%	Low	18
Shoulder drop off	2.0%	Medium	7
Total Deduct Values			39
Total Corrected Deduct Values (*q = 3)			21
PCI = 100 - Total Corrected Deduct Values			**79**
Segment Rating Based on PCI Scale			**Very Good**

* q = Number of distresses with a deduct value more than 5

3. Deterioration Prediction Model

Developing deterioration prediction model for road surface can aid in estimating periodic maintenance interval for roads corresponding to a given level of service. Deterioration prediction models in general can be classified into two main types [4] [5], namely; probabilistic models and deterministic models. The first type adapts transition probability technique that is mainly based on the Markov process [6]. Within this type of models, a transition probability matrix is formed to define the probability that a road element in an initial condition will be in some future condition. One of the main disadvantages of the probabilistic models (in addition to its complexity) is that, they can not include road element condition history since the estimate of the future condition is based only on the current condition. The second type (the deterministic models) is mainly based on direct regression where the dependent variable of functional deterioration is related to one or more independent variables [7]. Within this type of models, a set of regression equations are developed based on engineering experience and/or a long-term road performance database. In many occasions, the deterministic models gave reasonably accurate results [7] [8]. For this reason and for its simplicity the deterministic models were adapted within this research.

Table 3 presents the relation between average PCI values for the segments in each road type and time in months based on data collected from the field. By doing least squares regression analysis for the collected data, it was found that a typical deterioration model is represented by a quadratic function in time with the dependent variable, being the PCI at a given time. The deterioration model can be expressed in the following mathematical form;

$$PCI = at^2 + bt + c \qquad (1)$$

Where:

PCI = Pavement Condition Index at time t.
t = time since last maintenance.
a,b,c = unknown coefficients.

Table 3: Relation between Average PCI Values and Time in Months

Time of Surveying in Months	Desert Roads
0	90
3	89.1
6	90.2
9	89.5
12	87.9
15	87.5
18	79.3
21	78.9
24	77.4
27	70.5
30	69.7

The coefficients a, b, and c were obtained using the regression analysis. Once the coefficients of the quadratic function have been established, there becomes a one-to-one correspondence between time and pavement condition index. By selecting the required level of service and the related allowable pavement condition index, value for each road type from Table (3), maintenance interval can be obtained using Equation (1). It has to be mentioned that selecting the desired level of service is mainly a management decision and it mostly depends on the budget level available.

4. Results and Analysis

Based on the data illustrated on Table (3), average values of PCI are plotted as a function of time in the Figure (1). It is noticed from the figure, that the PCI values in general decrease with time indicating the increase of road surface deterioration. In general, the deterioration rate is relatively slow at the beginning and then it accelerates with the increase of time. This finding agrees with the typical deterioration behaviour of road segments [9].

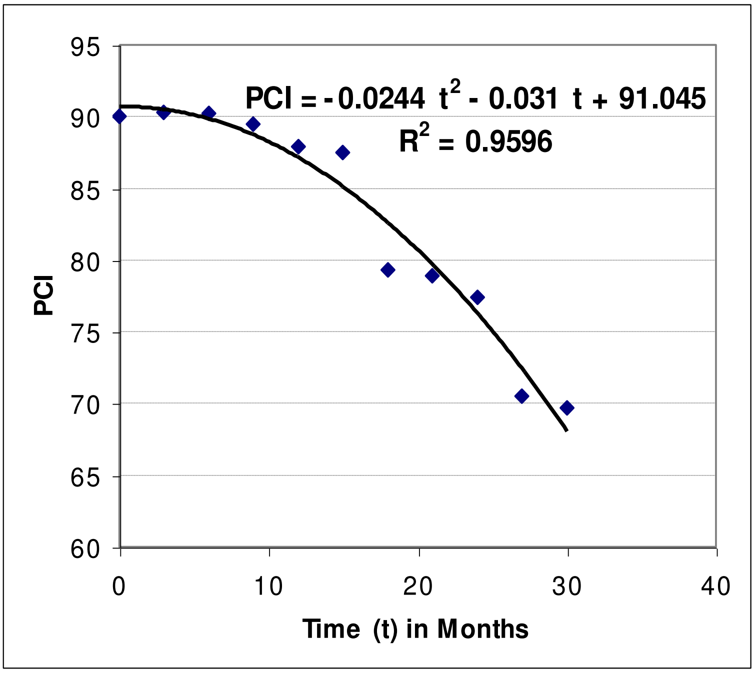

Figure 1 Road Surface Deterioration Function for Roads Located on Desert Roads

Applying the least squares regression equation (Equation (1)) on the data given in Table (3), the coefficients a, b, and c were obtained. It can be noticed that Equation (1) represents the collected data reasonably well with a coefficient of determination (R^2) equals 0.95 . Values of coefficients a, b, and c as well as the coefficient of determination (R^2) are listed in Table 4.

Table 4 List of coefficients a, b, c and R^2 values

Road Type	$PCI = at^2 + bt + c$			R^2
	A	**B**	**C**	
Roads Located on Desert Areas	**- 0.024**	**- 0.031**	**91.05**	**0.95**

5. Conclusions

Deterministic deterioration prediction model for desert road surface in Mniea area was successfully developed. Least square regression analysis has shown that the quadratic function represents the best fit for the collected deterioration data with a coefficient of determination (R^2) equals 0.95. In general the deterioration rate is relatively slow at the beginning and then it accelerates with the increase of time. Since the developed model was mainly based on data collected in Minea area, it would be useful to test this model against data collected elsewhere. Also, it is recommended to extent the data collection program to cover the late stages of the deterioration of the studied segments.

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نموذج تنبؤ لانهيار الطرق الصحراوية المصرية
" في منطقة المنيا"

يرتبط انهيار سطح الإسفلت ارتباطا وثيقا بالعوامل البيئية ، كما أن التقادم له أيضا العامل الرئيسي في معدل انهيار الطبقات الإسفلتية ، وقد تم خلال هذا البحث دراسة عدة قطاعات لاستنباط معدل انهيار الطبقات الإسفلتية للطرق المصرية الصحراوية في منطقة المنيا بصعيد مصر.

حيث تم تحديد عشرة قطاعات طولية بطول كل قطاع 500 متر ، حيث روعي في الاختيار التماثل في القطاع الإنشائي للطبقات الإسفلتية كما روعي توحد الأحمال المرورية للقطاعات التي تمت الدراسة عليها.

ولكل قطاع من القطاعات تم عمل مسح شامل لتحديد الإنهيارت المختلفة التى ظهرت على السطح وفى فترات محددة وتم تقييم معدل الانهيار للطبقات الإسفلتية وذلك تحديد حالة السطح عن طريق حساب معدل أداء الرصف (PCI) وتم رسم العلاقة مع هذا المعامل ومدى ارتباطه مع التقادم (الزمن) وبطريقة اقل مربعات(R^2) لتحديد انسب طرقة إحصائية لتحليل معدل انهيار حيث تبين أن معامل الارتباط يتراوح بين 95% إلى 96%.

ونموذج التنبؤ المستنبط يمكن استخدامه في تحديد معدل الانهيارات المحتملة مستقبلا في سطح الرصف وذلك يفيد في وضع خطة لأعمال الصيانة المستقبلية لتجديد الحالة السطحية للإسفلت، كما يفيد ايضا فى تصميم القطاع الإنشائي الأمثل في مثل ظروف الطرق التي تمت دراستها .