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A Review of the Application of Computational-Probabilistic Chain Markov Method in Predicting the Deterioration of Pavement

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Summary

Pavement naturally are deteriorating and eroding due to many traffics and environmental conditions. The prediction of pavement performance has an important role in efficiency of pavement management system. By understanding the process and the manner of reduction of pavement service can predict the necessary resources and arrangements to avoid accelerating process of degradation and deterioration. The deteriorated models are tools for predicting the future failure of pavement based on the current status, the causes of failure and the effect of different techniques of repair and rehabilitation for maintaining the level of performance and the status of its structure. In this paper, after stating the concepts of performance and deterioration of road surface, studies has been done in the past decade researches in the world, about Computational-Probabilistic Markov models, transition probability matrix extraction techniques, predictive models and their application in management of the road surface.

KEYWORDS: computational chain Markov, deterioration of road, probabilistic predicting models, pavement maintenance management, semi-Markov model.

1. INTRODUCTION

Pavement naturally are deteriorating and eroding due to many traffics and environmental conditions. Doubtless, without adequate and timely maintenance, highways and roads in city and suburban severely will be declined and deteriorate. A good pavement management system requires a predictive model, an accurate and effective performance pavement [1]. By understanding the process and the manner of reduction of the pavement service can predict the necessary resources and arrangements to prevent from the accelerate degradation and deterioration. The mean of deterioration can be the type of changes for the status of pavement or changes in surface roughness or an indicator of a particular kind of damages such as during time. After the construction and implementation of the road surface, several factors depending on the type and severity of the effect, began to destroy and to decrease its ability to provide service. These factors can be divided in two general categories: load (loads of traffic) and the environment conditions (weather and

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drainage conditions). The factors related to the design and implementation of road surfaces, including the type of materials, the correct design, methods and quality of implementation, also have considerable effects in accelerated pavement deterioration [2].

2. APPLICATION MODELS OF PAVEMENT DETERIORATION PREDICTION

The most important part of pavement management is the exact prediction of pavement failures during the pavement life cycle analysis; therefore, prediction failure of road procedures is a key factor in pavement management system [3].

The prediction rate of the road surfaces deterioration due to complexity identify the rate of pavement status or difficulty of collecting accurate data, especially in the absence of sophisticated equipment or highly skilled technical force, is very difficult. Various pavement maintenance systems are used around the world but, unfortunately, all these systems do not use a systematic method to determine the rate of pavement condition or determined experimentally the probabilities of transition state pavement [4]. A pavement performance prediction model has the different types which depending on management objectives, the richness of database and ease of use. Three main categories of these models include certain models, probabilistic and easy computational. The deterioration processes of pavement generally result from five parameters: pavement structure, traffic load, weather, modification history and quality construction. Many of these parameters are changed randomly and are not predictable; on the other hand, the interaction between these factors is uncertain, so the deterioration of pavement is completely random phenomenon and the probability [5].

Accurate models of predicted pavement performance and optimization models that properly designed are the key elements in a successful management at the network level. For the proper schedule in maintenance of road surfaces need to identify the behaviour of pavement & it's vanish model and predict the pavement condition. So the level of network management, predictive models of pavement status to schedule inspections, life cycle costing, analysis, benefit / cost and budget planning and optimization are used and requires less accuracy [6].

3. THE APPLICATION OF MARKOV PROBABILITY COMPUTATIONAL MODEL IN THE DECADE 2004-14

Some people related the start discussion of pavement management to tests of Osho, in 1956 to 1960 that led to providing the concept of performance and capability of

serving road surface. Halbrok and Vanhokov in 1974 measure and predict the performance of welded structural concrete pavement performance in the 128 projects with performance more than 15 years in Michigan State, used a variety of techniques such as Markov model. They concluded that the Markov chain approach has the best correlation with field data and in general not only for wide cracks but also for pavement of suture concrete is also a suitable method [7].

Dong Yang and Chang in 2004 on the basis of the analysis and data the status pavement highway, Shin-da China, Markov probability predicting techniques and the use of regression analysis was used to predict pavement performance. They concluded that the exponential function, pavement performance decreases with time and Markov's predicting possible model has the range of application and specific limitations [8]. T.John and Pytalka in 2005 with a review of a 1000 km hypothetical networks and predict the future state of pavement base on Markov probability model and solve equation AX = B, with a deviation of 5.5 to 6.10 per cent (Figure 1) was obtained. The following figure shows differences between the values of the current pavement status and the predicted status.

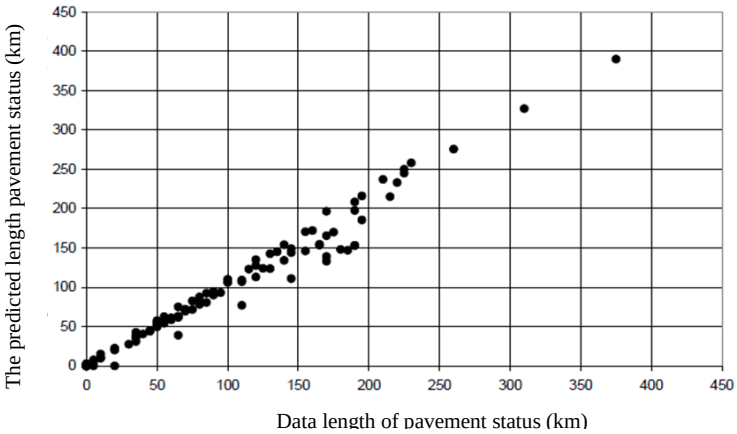

Figure 1. The real length and predicted the pavement status [10]

Ortiz Garcia and Associates extracts the transition probability matrix of the data bank in 2006, proposed three nonlinear optimization problem and they asses by the six special artificial data bases: the first method assumes that the past data of pavement status for each part of the network are readily available [9].

The second methods uses regression curve derived from the original data and a third method assumes that annual distributions of pavement status are available. In this method, the aim of minimizing the difference between the actual distributions of cases derived from the recorded data with predicted modes by possibilities Transfer Matrix.

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Minimize $z = \sum_t \sum_i [a_t(i) - a'_t(i)]^2$ subject to:

$$\begin{cases} 0 \le P_{ij} \le 1 \text{ for } i,j = 1,\dots,n \\ \sum_{j=1}^{n} P_{ij} = 1 \quad \text{for } i = 1,\dots,n \end{cases} \tag{1}$$

where
a_t (i): the predicted state vector by transition probability matrix and
a'_t (i): actual state vector obtained of the recorded data at time t [10].

Chow and colleagues in 2008 compared with predictive models pavement conditions, by comparing the predicted conditions with observed actual conditions for a period of 5 years (2001-05) and use the database Ohio Department of Transportation, they concluded that Markov model has the highest prediction accuracy compared to other assessed models in addition to it can predict the amounts of PCR (the rate of pavement condition), damage road surfaces in the future.

Figure 2 shows the difference between the predicted values of PCR (which is derived from the Markov model) and show real PCR values.

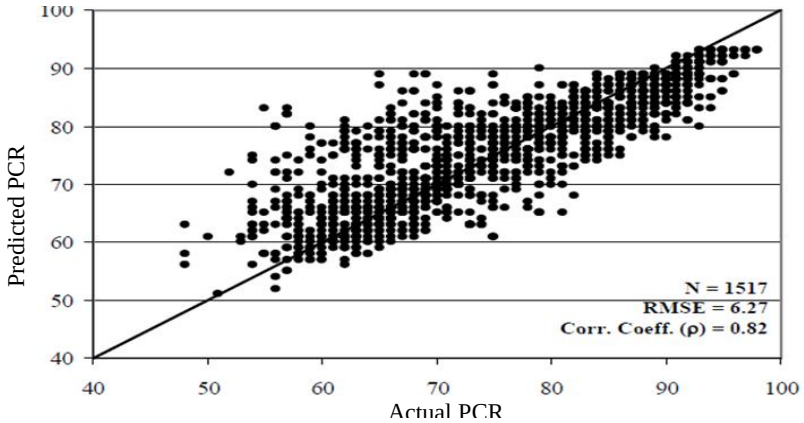

Figure 2. The predicted PCR and PCRA real value (2002-06) [11]

The accuracy of model has expressed by the root mean square error (RMSE) and coefficient expressed. RMSE is defined as follows:

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (PCR_p - PCR_A)^2}{n}} \tag{2}$$

where PCRP the predicted value of PCR, PCRA real value of PCR and *n* is the number of observations. The Smaller values of RMSE indicate more accurately model. The correlation coefficient indicates the rate of compliance between actual and predicted the PCR. Full compliance has the coefficient of correlation [11].

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Abazai in 2011 with a case study on low-traffic roads, use Markov model to predict the failure rate road surfaces in the future as well as predict the required thickness of flexible road surfaces [12]. Lthan and Eddie in 2012 with an experimental study and by using real data in the world, use the hidden Markov models for modelling deterioration hide pavement (deterioration that is not directly measurable) used [13].

Uchwuat and MacLeod, in 2012 with comparisons between regression models and Markov chains in modelling the performance of road surface, achieved the following results:

1. Advantage Markov models are that it can be calculated with a minimum of 2 years of pavement condition data while regression models need more data.
2. Markov models have the possibility that the expert's opinion or Bayesian methods used in the development of pavement performance curves.
3. The predicted data analysis with the actual performance data of pavement during the period of 6, 9, 13, 19 and 23 years showed that Markov models estimate the lower pavement performance. This issue is well shown in the figure (3) [13].

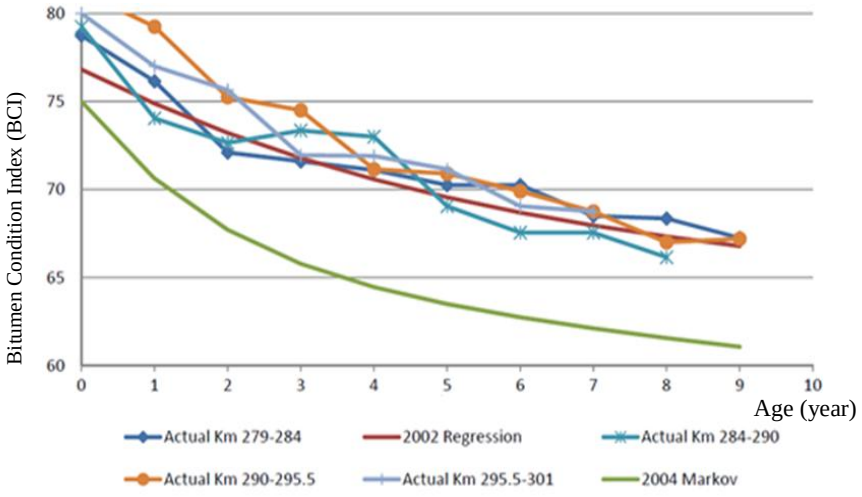

Figure 3. Comparison of Markov models and Regression by real data [13]

Wang and colleagues in 2013 developed and implemented a network-level optimization model into a pavement management data system for the Ohio Department of Transportation as well as they predicted future status pavement based on past data and Markov's transition probability model. This combined the optimized model, linear programming model and Markov's transition probability model and has the following features [14]:

1. Calculating the needed minimum funds to achieve the desired level of network status road surface,

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2. The creation of maximum improvement in the status of pavement network of the allocated budge t, and
3. Identify the relationship between optimized development policy and allocated budget. They concluded that the highway agencies can use this model as a decision support tool used to manage network-level road surface.

Suman and Sinha in 2013, Markov chains and application of pavement quality index (OPQI) were used to predict the future state of road surfaces. The index is obtained based on a theoretical concept that includes all conditions process of the road surface:

$$OPQI_k = 10 \sum_{i=1}^{i=n} \left[1 - (1 - \frac{CI_i}{10}) * W_{i,k}\right] \quad (3)$$

where $OPQI_k$ - indicator of the overall quality of the pavement with a scale of 1 to 10, CI - status indicator or malfunction indicator with a scale of 1 to 10, K -index of the pavement performance, k mi,- index of status or failure of I, Out of the total number. n -Status Indicator = the total number of different types of failures or status indicators which is on the performance index, and W_i, k - the weight of any damage or index of status.

Comparing the observed rate of status in 2011, with the predicted status rate in the same year was used for validating the model which is obtained by the developed failure model. The figure (4) demonstrates this problem.

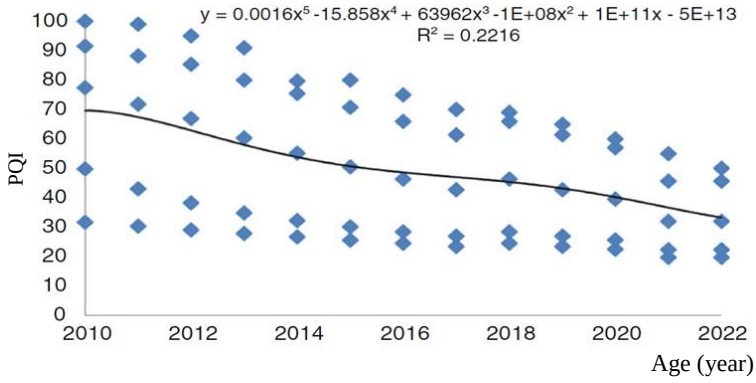

Figure 4. A performance of pavement predictive model [15]

In 2011, the rate of pavement status was 8.6 that the observed value is 1.6 for the same year. This result shows that the developed model has the ability to predict the rate of future state of the pavement with an acceptable degree of accuracy [15].
Surendra Kumar & assoc. use the Markov possible process to develop a decision support system to predict future situation of pavement in 2013. They use Poisson method to calculate consecutive transition matrices and x2 inference test to assess

the rate of compliance. Finally they conclude that the possible process of Markov is a tool for finding the manners of future pavement conditions in any given year, and it will help to find the optimal maintenance policy (due to budget constraints and the current state of the road surface) [4].

4. CONCLUSIONS

A good pavement management system requires a predictive model and accurate & effective performance of road surface. By understanding the process and the manner of reduction the pavement service can predict the necessary arrangements and resources to prevent the accelerated process of degradation and deterioration. The deteriorated models are tool for predicting future pavement failure base on the present status, the cause of failure and the effect of different techniques of repair and maintenance to maintain the performance level of structural condition the road surface. By reducing forecast error of deteriorate road surface, organizations can save the cost of a lifetime with intervention and careful planning. So the accurate models to predict deteriorate are very valuable tool for the road departments and organizations related to pavement maintenance. Some of results of this research are presented as below:

- Since many researchers are interested in predicting the status of piece and to acquire the deteriorate process of special piece, in addition to innovation in the network should be analysed the length of road including many pieces of different indices, and the prediction process by Forecasting the desired length lead in the future. Accordingly, the analysis of cost of future repair and maintenance is also easily done.
- Markov transition probability matrix is assumed to be constant over time that the assumption on the pavement does not conform to reality (homogeneous matrix). Therefore it is suggested to use the heterogeneous matrix with the ability to change over time due to the limitations of homogeneous Markov method, offered by the network is divided into different parts and defines the time zone for each of these segments and time intervals (period), extract matrix separately and combine them together to use to remove this limitation of the homogenization Markov method. Since the semi-Markov model, pavement repair operations also considered that it would be more compatible with the actual situation of road surfaces, the use of this model is recommended for future research.

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