TRIAL ASSET MANAGEMENT ON ROAD PAVEMENT

Waseda University Fellow Hirokazu Akagi
Waseda University Student ○Reiher Michael
Waseda University Student Hashi Kengo

1.0 Introduction

Due to the growing number of traffic volume and the ever increasing demand for transportation and hence the use of traffic infrastructures, proper management and sustainability of built road pavement has become an extremely important issue being addressed by many research organizations in the world.

The purpose of this study is to develop a Pavement Maintenance Management System (PMMS) to find a quantitative approach for finding the optimal sequence of maintenance that will satisfy certain performance objectives over a planning horizon. The approach consists of (1) a mathematical model for pavement deterioration over a number of years that is specified in terms of a Markov Process; (2) the optimal maintenance decisions that are found by minimizing the Life Cycle Cost (LCC) of the pavement at the budget year.

2.0 Investigation Method

2.1 Data collection

Maintenance Condition Index (MCI) data is used as a condition state for the pavement. It is a measure of the rutting ‘D’, crack width ‘C’ and longitudinal roughness ‘ σ ’of the road and is determined from equation 2.1

$$MCI=\left(10-1.48C^{0.3}-0.29D^{0.7}-0.47\sigma^{0.2};10-1.51C^{0.3}\ 0.3D^{0.7};10-2.23C^{0.3};10-0.54D^{0.7}\right) \quad \textbf{EQ2.1}$$

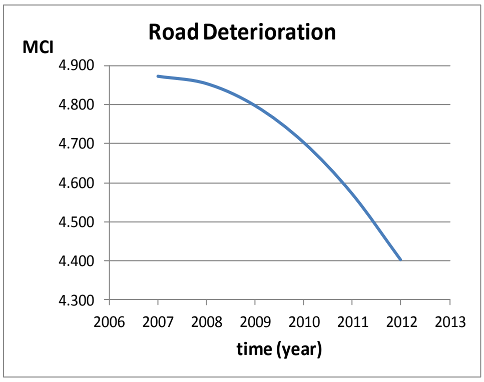

Figure 2.1 MCI parabolic deterioration

2.2 Parabolic deterioration approach

For pavement deterioration, it is assumed here that the emission probability, i.e. MCI decrease behavior over time, will follow a parabolic pattern (EQ 2.2) as depicted in figure 2.1. From actual recorded survey data from 2007 to 2012, applying this method showed a very small difference in the actual and predicted data. In EQ 2.2, t is time from 0 to T.

$$MCI_{t}=MCI_{t=0}-\left[\left(MCI_{t=0}-MCI_{t=T}\right)/T\right]\times t^{2} \quad \textbf{EQ2.2}$$

2.3 Monte-Carlo Simulation

The number of data for each given year (t) collected from actual pavement survey results for 3 road sections, separated into 3 categories – (1) unmaintained road, (2) overlay and (3) sub-grade improvement maintenance; was increased using a Monte-Carlo Simulation as illustrated in the flow diagram figure 2.2. Increasing the number of data is sufficient in order to obtain a reliable Markov Transition Matrix.

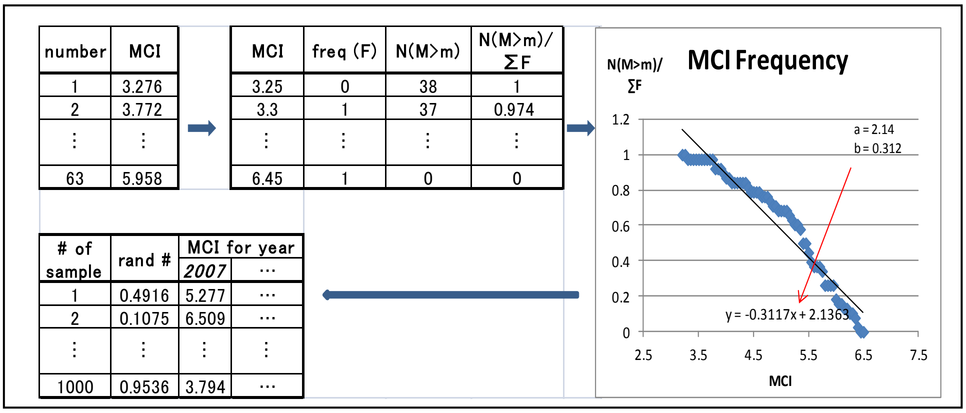

Figure 2.2 Monte Carlo Process for year 2007 data. Increased from 63 to 1000

2.4 Development of Markov Transition Matrix

Data are grouped into different condition states as l = 1 to L. From the pavement condition data for 6 duty cycles (number of year for available data), the first 5 duty cycles are used as inputs and the last 5 duty cycles as outputs. The output matrix is the product of the input matrix and Markov Probability Transition Matrix (see EQ 2.3), where NCS – number of recorded MCI within each Condition State; t – time in years. The algorithm (EQ 2.4) where n – number of input/output cycle; subjected to the following constraints is

$$NCS[1,\dots,L]_{t+1}=NCS[1,\dots,L]_{t}\times\underset{L\times L}{\begin{bmatrix} p_1\ q_1\ \dots\dots 0\\ 0\ \ p_2\ q_2\ ..0\\ 0\ \ 0\ \dots\dots..1\end{bmatrix}} \quad \textbf{EQ 2.3}$$

Key words: Maintenance Control Index (MCI); Pavement Management Maintenance System (PMMS); Markov Transition Matrix; Monte-Carlo Simulation; Life Cycle Cost (LCC)

58-205, 3-4-1, Ohkubo, Shinjuku, Tokyo 169-8555, JAPAN Tel：+81-3-5286-3405 Fax：+81-3-5272-0695

used to determine the transition matrix entries. This algorithm is programmed in Excel using the 'Solver Function' with the total difference minimized. Tables 2.4 – 2.5 illustrates the process for determining the Markov Transition Matrix for the given year.

$$\min \sum_{t=1}^{n}\sum_{l=1}^{L} abs\left[NCS(l)_{t+1} - NCS(l)_{t}\right] \qquad \textbf{EQ 2.4}$$

Subject to constraints:

$$abs\left[NCS(l)_{t+1} - NCS(l)_{t}\right] / NCS(l)_{t} \le 10\%$$

$$1 \le p\&q \le 1 \qquad p+q=1$$

Table 2.4 NCS Inputs and outputs and % difference

NCS Input							
year/state	1	2	3	4	5	6	7
2010	153	174	188	138	169	153	25
2011	63	176	191	170	153	171	76

NCS Output							
year/state	1	2	3	4	5	6	7
2011	63.8	176.9	189.9	168.5	152.7	171.8	76.5
% difference	1%	1%	1%	1%	0%	0%	1%

×

Table 2.5 Transition Matrix

Transition matrix							
state	1	2	3	4	5	6	7
1	0.41	0.59	0	0	0	0	0
2	0	0.49	0.51	0	0	0	0
3	0	0	0.55	0.45	0	0	0
4	0	0	0	0.61	0.39	0	0
5	0	0	0	0	0.59	0.41	0
6	0	0	0	0	0	0.67	0.33
7	0	0	0	0	0	0	1

2.5 Budget calculation

The optimal maintenance is based on the least Life Cycle Cost (EQ 2.5) out of two maintenance options as presented in figures 2.3 and 2.4 where TNCS – total number of recorded MCI. The two algorithms are programmed in ***Matlab Software*** using the transition matrices previously developed.

$$LCC = \sum_{t=1}^{n}\frac{Mt}{r^{t-1}} + \sum_{t=1}^{n}\frac{Rt}{r^{t-1}} + \sum_{t=1}^{n}\frac{VOCt}{r^{t-1}} + \sum_{t=1}^{n}\frac{TDCt}{r^{t-1}} - SV/r \qquad \textbf{EQ 2.5}$$

In EQ 2.5, n: analysis period; Mt: maintenance costs at t year (Mt = 0 for no maintenance); Rt: Rehabilitation/reconstruction costs at t year (Rt = 0 for no rehabilitation); VOCt: vehicle operating costs at t year; TDCt: time delay cost caused by rehabilitation work at t year; SV: salvage value; r: (1 + discount rate)

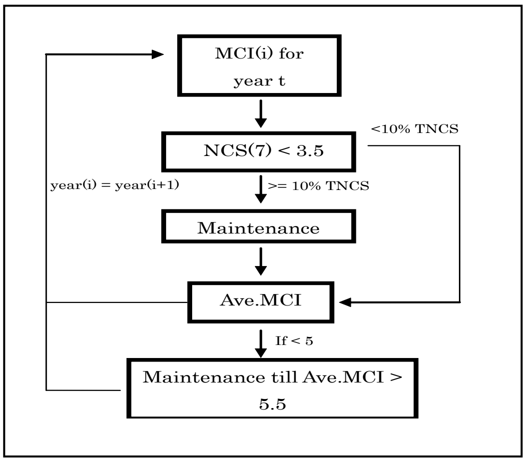

Figure 2.3 Option 1 Maintenance

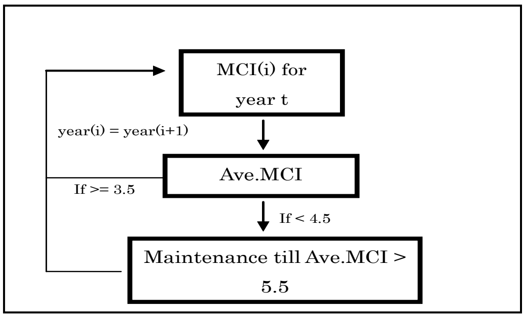

Figure 2.4 Option 2 Maintenance

3.0 Results

The results from the Matlab program for road section 1 is shown in table 3.1 with the graph for option 1 shown in figure 3.1. Budget year is 2007.

Table 3.1 Life Cycle Cost for the two maintenance options

road section	option	year of maintenance	time in years	LCC
1	1	2009	2	¥4,100,635.92
	2	2010	3	¥4,392,037.40

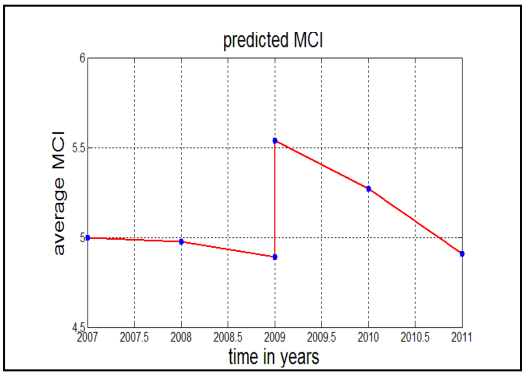

Figure 3.1 Option 1 - deterioration for road section 1

4.0 Conclusion

The optimal maintenance determined is 'option 1' as it produces the lower LCC of ¥4.1m for the designated maintenance year during the 5 year design horizon. However, it should be noted that this approach does not take into account other deciding factors that could alter the decision making. Such factors could include driver satisfaction, environmental aspects and so forth. This requires a more comprehensive study which is not covered in this research and one to be taken into consideration in future researches.

5.0 Acknowledgement

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6.0 References

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