



ELEMENTS OF PAVEMENT MANAGEMENT SYSTEM: CASE STUDY

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Abstract. This paper presents the elements of a Pavement Management System with a particular focus on the initial effort to create a comprehensive data archive and its further application in four different maintenance strategies. Pavement performance indicators including longitudinal and transverse cracking as well as roughness were investigated with respect to numerous distinct factors which can be grouped into three categories, i.e. climatic, pavement structure, and traffic-related. High-quality climatic data was obtained from the national weather stations in Connecticut. Maintenance and construction data was used to determine the pavement age and structure amongst several other factors. Traffic data was acquired from the state records and accumulated traffic loading was estimated for all segments based on their age. High definition pavement images collected by the Automatic Road Analyzer vehicle in 2010 were used to quantify the longitudinal and transverse cracking with respect to their location within the pavement surface. Elements of the Pavement Management System with stochastic elements were created from this data and analyzed in order to demonstrate the budget implications under four different management scenarios. Scenarios varied by the trigger values of the Pavement Condition Index for considered maintenance treatments. The 20-year projection analysis clearly showed the benefit of repairing pavements that are still in a good condition even without considering related user-delay costs and/or vehicle-operation costs which would only heighten the differences between scenarios.

Keywords: Pavement Management System (PMS), Pavement Condition Index (PCI), International Roughness Index (IRI), pavement treatment scenarios.

1. Introduction

Intensive pavement construction around the world has created a very large road network that needs to be constantly maintained and preserved to fulfill its socio-economic role. Road maintenance is a general term used for the set of activities that has the following overall goals:

1. provide and maintain serviceable roadways to ensure positive social experience,
2. ensure cost-effectiveness by extending pavement life and
3. mitigate environmental footprint.

Road maintenance includes both preventive maintenance and rehabilitation activities. They should be a part of well-defined strategy that comprises appropriate maintenance methods and strategies applied in specific climate conditions in order to address certain distresses under administrative and budgetary constraints (Hicks *et al.* 1997; Moya *et al.* 2011; Shahin, Walther 1990).

One of the crucial aspects of the road maintenance is the proper timing (Peshkin *et al.* 2004). The key is to apply a method/strategy when the pavement is still in relatively sound condition with no structural damage. Numerous research projects show that performing preventive maintenance repairs at the optimal time provides the most sustainable approach to the maintenance of roads. As a consequence, many countries have implemented preventive maintenance programs into their strategies to help them maintain their road network. However, the problem is that the road maintenance process is a multi-objective issue that depends on many factors, such as country development level, labour costs, user-delay costs, vehicle-operation costs, traffic level and vehicle type distribution, climate conditions, present road conditions, construction quality, local experience, etc. There is no single model that would fit in every situation, but that should not prevent agencies from implementing a well-defined road

maintenance system since its already proven benefits far outweigh the implementation costs and obstacles.

In more general terms, Pavement Management System (PMS) can be viewed as a well-defined and transparent process of planning and executing maintenance of a pavement network aimed to minimizing budget expenditures and environmental impact while maximizing pavement life and user safety. While the PMS can be implemented and structured in various ways, it typically comprises the electronic inventory of the existing pavement network together with the corresponding information on its current and historical performance, traffic loadings, as well as construction and maintenance history (Fig. 1). Based on this information, pavement condition prediction models can be created and assigned to the network pavement uniform segments (Braga, Čygas 2002; Saliminejad, Gharaibeh 2012; Sivilevičius, Petkevičius 2002). When these predictions are combined with the specific treatment policies, the PMS optimizes the extend and timing of the repairs using various algorithms, such as prioritization, enumeration, linear-, non-linear- and dynamic programming, genetic algorithm etc. (Abaza, Ashur 1999; Camahan *et al.* 1987; Gao *et al.* 2012; Harvey 2012; Manik *et al.* 2008; Marzouk *et al.* 2012; Mbwana, Turnquist 1996). The constant pavement evaluation improves performance predictions via the feedback loop (Fig. 1) and allows for creating more precise planning scenarios. As mentioned before, the modern and sustainable approach to maintaining a pavement network is to keep as many roads as possible above fair condition, while minimizing the number of roads in a poor condition.

There are three pavement performance indicators which are typically used in the PMS at a network level. The first and most simple method involves driving a van at a constant speed over network roads to calculate and obtain the roughness (IRI) of the pavement. Based on how the suspension of the vehicle behaves with respect to the distortions of the road, a certain roughness value is calculated and stored in very short incremental lengths. Although this value does not give a road agency any exact distress which may be occurring, it does provide the agency with

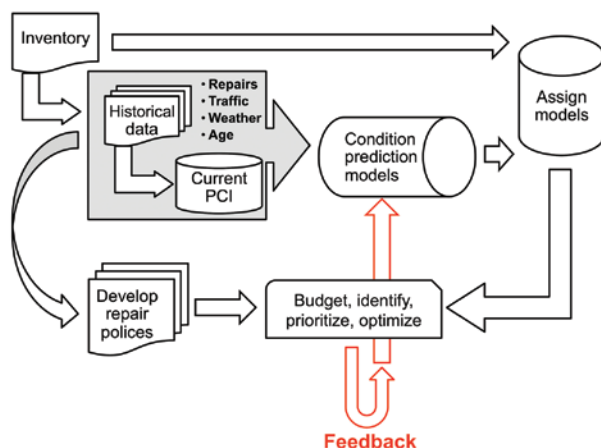


Fig. 1. Implementation steps of the PMS

the estimate of the ride quality currently being experienced by citizens on the network. This is also one of the most universal measurements currently, since most agencies worldwide can use the same technology and get comparable results. On the other spectrum of the performance indicators are the deflection measurements, nowadays obtained in an automated fashion either by the Falling Weight Deflectometer (FWD) or Traffic Speed Deflectometer (TSD). These measurements allows for the non-destructive evaluation of the bearing capacity of a pavement structure. Deflections can be implemented into the PMS through standardized measured deflections or they can be a part of a standalone or combined condition index, for example the Structural Adequacy Index (SAI) and the Pavement Quality Index (PQI), respectively. Deflections can be also included in the maintenance and rehabilitation (M&R) decision process, for example as a screening tool for homogenous pavement segments or they can be implemented into deterioration models in order to increase their prediction accuracy. Lastly, pavement performance distresses are obtained by the specialized equipment mounted on vehicles as they travel over the network. This method typically allows determining physical surface distresses, such as rutting or cracking. This information when properly stored and processed allows agencies to have very detailed pavement condition understanding throughout the network.

In this paper, aforementioned elements of the PMS were developed and presented. Subsequently they led to the development of the performance models at a network-level based on three pavement performance indicators: longitudinal cracking, transverse cracking, and the IRI combined into a Pavement Condition Index (PCI). Next, pavement families were created which had similar characteristics with respect to their pavement type, traffic, climate, and structure. For the entire network, 32 different performance families were created. A decay function was then created to quantify the different rates at which each family is deteriorating. Once this was finalized, different sequences of treatment options were created and different management scenarios were applied to all segments in the network. In the final step, the simulation was conducted for the 20-year period and different scenarios were compared in terms of their net present values (NPV).

2. Elements of Pavement Management System

Due to several data sources with different data formats, a great effort was made to merge different records correctly and to check the quality of the processed data before the analysis. Processed data which constitutes the fundamental elements of every PMS can be grouped in three main categories, i.e. pavement inventory and related historical data, traffic data and finally historical climatic data (Fig. 2).

2.1. Inventory

Several units within the Connecticut Department of Transportation (ConnDOT) provided pavement-related data.

The data is comprised of five main elements: traffic, pavement type and structure, pavement age since last resurfacing project, and pavement performance data. Average Daily Traffic (ADT) was obtained as geospatial vector data with respect to state routes. This format allowed for geospatial manipulation of climate and traffic data which was a key step in the initial phase of this study. Age of the top asphalt layer since the last resurfacing project as well as pavement type (flexible vs. composite) was determined by exploring historical maintenance and construction project files.

Transverse and longitudinal cracking at 5 m increments throughout the entire state was collected in 2010 by the Automatic Road ANalyzer (ARAN) van. The van provided high-quality laser-scan images that were next processed by Wisecrux© software by ConnDOT personnel. This software outputs linear meters of transverse and longitudinal cracking at three severity levels with respect to five different zones across the width of the pavement lane to allow for more in depth analysis.

In order to create a Pavement Management System in this study, the network needed to be well defined and organized. All road segments were initially split into uniform sections based on similar characteristics on pavement type, total thickness, and traffic volumes, resulting in 13 505 segments which cover a length of 5250 km of state roads. All segments which had pavement types which were not either asphalt concrete or composite were removed. Since two separate ARAN vans with different imaging technologies were used in the collection process, only data from the newer van was used in this study. Furthermore, a filter was used to eliminate all segments which were less than 150 m. At the end, a total of 5581 segments were eliminated translating to 2208 km that had been filmed by the older van, and 3854 segments totalling 216 km were eliminated for being less than 150 m. This left the usable dataset to be 4070 segments totalling 2816 km, or approx 54% of the entire state network. The segments lengths ranged from 151 m to 7500 m with the average value of 687 m and the median value of 452 m (Fig. 3). Fig. 4 below shows a spatial representation of segments used in the study (darker in red), as well as segments which were eliminated (lighter in grey).

2.2. Climatic data

Climatic data was providing several factors potentially affecting the considered pavement segments. In order to obtain detailed yet accurate data, three high quality sources were queried: National Climatic Data Center (NCDC), Quality Controlled Local Climatological Data (QCLCD) and Local Climatological Data (LCD). These services allow for selection of specific climatic elements from stations around Connecticut. In total, 19 stations across Connecticut were identified with daily weather data going back a minimum of 10 years. Based on the collected data, specific weather indices were calculated as shown in Table 1. A weighted surface interpolation was applied to weather indices from surrounding weather stations to each individual segment. This was done by locating the three closest weather stations to the segment’s midpoint and interpolating the

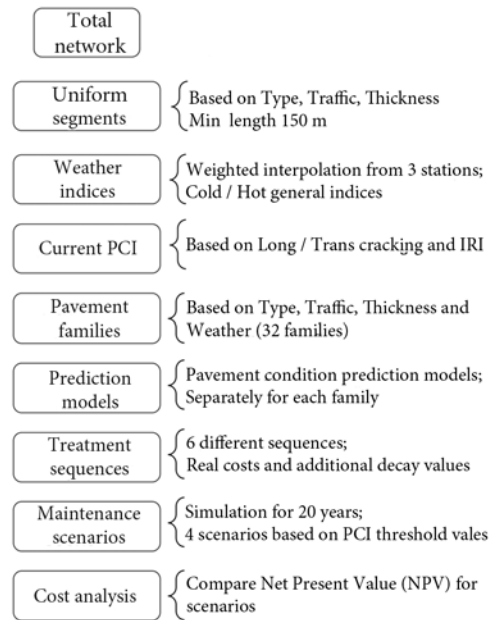


Fig. 2. Study flowchart

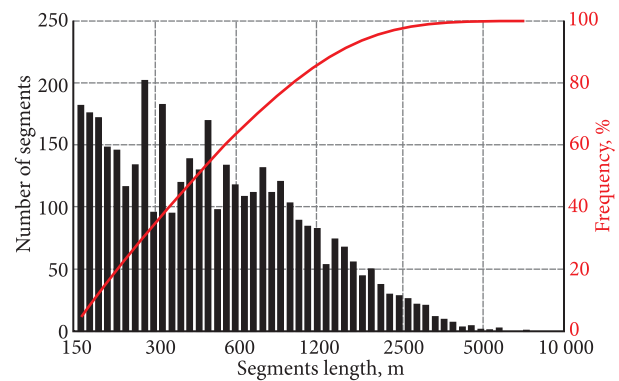


Fig. 3. Distribution of 4070 segment lengths

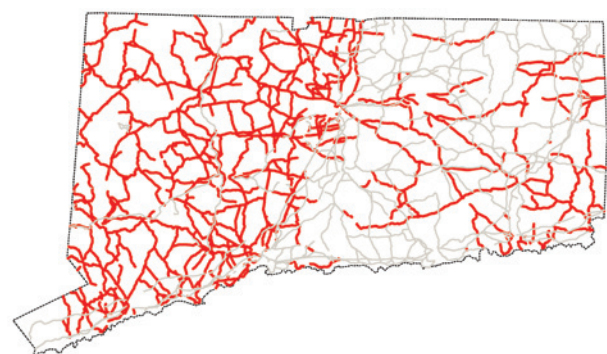
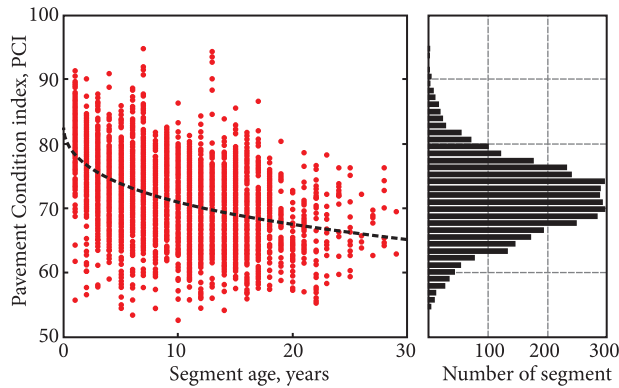


Fig. 4. Network dataset elimination

index value from all three, giving the closest weather station the most weight. Two overall climatic indices, each with three levels, were created in order to assess the impact of cold and hot temperatures in the analysis. Table 1 shows the indices used with regard to both climates. It should be noted that climatic indices were determined for each segment individually taking into consideration only the period since the last resurfacing project.

Table 1. Index ranges used for interpolating cold and hot climate regions

| Cold Climate | | | | Hot Climate | | | |
|-----------------------|------------|------------|------------|-----------------------|-----------|----------|-----------|
| Index | Level 1 | Level 2 | Level 3 | Index | Level 1 | Level 2 | Level 3 |
| Absolute Min Temp. °C | <-20, ...> | (-23, -20) | <..., -23> | Absolute Max Temp. °C | <..., 36> | (36, 38) | <38, ...> |
| No. of Days < -18 °C | <0, 4> | (4, 10) | <10, ...> | No. of Days > 95 °F | <0, 5> | (5, 10) | <15, ...> |
| Avg. Winter Temp. °C | <-5, ...> | (-7, -5) | <..., -7> | Avg. Summer Temp. °C | <..., 26> | (26, 28) | <28, ...> |

**Fig. 5.** Baseline pavement condition of network (as of 2010)

All indices have been arranged so that the higher the level is, the more significantly the region is considered either cold or hot. Histograms were then created of the averaged levels for both hot and cold climate index averages for all segments. For example, if a segment was in Level 1 for Absolute Min Temp., Level 2 for No. of Days < -18 °C, and Level 1 for Avg. Winter Temp., its overall cold climate average index would be 1.33 which is an average of those three levels. Once the histograms were completed for each climate, two groups were created based off the histogram to distinguish segments which experienced more significant climatic impact. After creating the two groups from the histograms, it was seen that the western part of the state experienced less cold weather and more hot weather, whereas the central part of the state experienced colder and less hot climates. It should be also mentioned that other weather-related composite indices can be created, e.g. the number of passes through zero 0 °C.

3. Current PCI

A vital step for any PMS is to construct a way to index the condition of all pavements within the network. In this case, a PCI was created incorporating the three pavement

performance indicators used in the study: longitudinal and transverse cracking as well as IRI. For both longitudinal and transverse cracking, *ASTM D6433-11 "Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys"* was employed to calculate the number of deduct points to use based on cracking density in meters using the medium severity level. Since IRI is not a distress and therefore not listed in the *ASTM D6433-11* standard, deduct points were computed using a correlation equation developed in the study by Park *et al.* (2007). Once deduct points were computed for all three indicators, they were summed and used with the *ASTM D6433-11* total deduct point chart for $n = 3$, which outputs a single PCI deduction value based on the considered distresses. This procedure was repeated for all 4070 segments and a resultant histogram of the PCI for all segments considered in this network is shown in Fig. 5. It should be mentioned that these values represent the baseline network condition as of 2010.

4. Categorical family grouping and model assignment

All 4070 segments were categorized into families which shared attributes. Since each segment will deteriorate differently over time, this step is done to determine a different decay coefficient for each family type. Pavement families were created throughout the entire network based on five attributes and since each attribute had two levels, 32 families were created ($2^5 = 32$). Table 2 shows five attributes and their levels. Interpolated climatic index averages were used for both cold and hot climates as shown in Table 1. It should be mentioned that selected attributes and resultant families represent only one of many possible approaches. While several other assignments were also checked it was found that presented 32 families produced the most balanced dataset that lead to reliable PCI prediction equations for all families.

After assigning each pavement segment to a family, plots of pavement age vs. PCI were created. The minimum

Table 2. Categorical binning of pavement families

| | Cold climate index avg. | Hot climate index avg. | Traffic volume, vpd | Total pavement thickness, cm | Pavement type |
|---------|-------------------------|------------------------|---------------------|------------------------------|---------------|
| Level 1 | Average | Average | <80 000 | <25 | Flexible |
| Level 2 | Colder | Warmer | >80 000 | >25 | Composite |

number of segments assigned to a family was 18 and the maximum was 462. Using the least-squares approach the following exponential decay function was created to fit each family separately:

$$PCI = 100 \cdot e^{\frac{-age}{\alpha}}, \quad (1)$$

where α – decay parameter varying for each family (ranged from 16.57 to 46.21); age – time since the last reconstruction project, in years.

It should be noted that the decay function could have been represented by other algebraic function, i.e. polynomial, logarithmic, linear etc. While considering an appropriate function several factors were taken into account, such as the number of segments per family, age range within each family, and the number of function parameters. Power function was found to be the most robust and appropriate for this study, but it should be only considered as an example application.

5. Pavement management approach and implementation

The management approach used in this paper was to keep as many pavement segments above certain PCI thresholds as possible. In the case of segments which were well below this threshold level at the baseline year, i.e. beginning of 20-year simulation, they were set to deteriorate until they reached the reconstruction level. This is a reasonable modern day approach since many departments face significant budgetary constraints. If the entire budget is spent attempting to fix the poor condition roads, only a handful of roads will be fixed and all the pavements which are in fair condition will deteriorate further in the short-term future. This typically leads to an increase of poor condition roads over time and puts the department in a significant budgetary backlog.

The treatments used in the paper are common maintenance procedures identified in the relevant literature. The life expectancy of the treatments depends on two primary characteristics: condition of the pavement being treated, and traffic volume. The life extension (L.E.) for treatments is split based on the pavement condition being

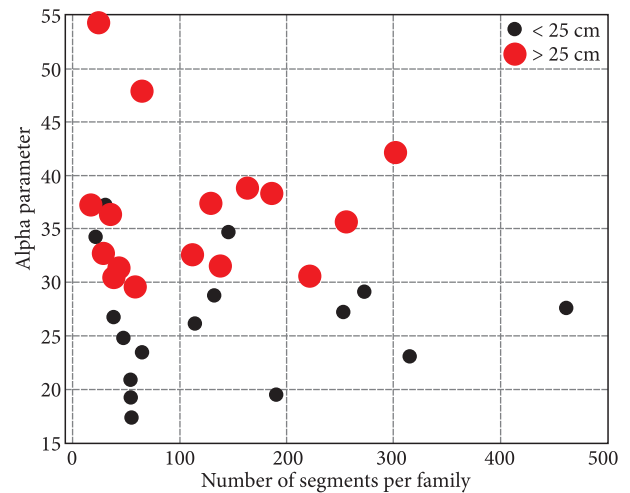


Fig. 6. Alpha parameter and the number of segments per family

good, fair, or poor. The values obtained for typical life expectancy and cost per one-mile (1600 m) and 9 m wide pavement section were selected from the literature review and are shown in Table 3 (Gao *et al.* 2012; Geoffroy 1996; Peshkin *et al.* 2004; Smith, Peshkin 2011). Since the pavement will deteriorate at a faster rate after each treatment is applied, a reduction value was created for each treatment to increase the alpha parameter depending on the quality of treatment (see Eq (1)). This reduction in alpha parameter was empirically assumed but it can be verified with a larger database of pavement maintenance activities.

In order to simplify the maintenance approach for such a large network, six treatment sequences were created based on common practices and treatment constraints. Each segment was assigned to a specific treatment sequence based on the baseline PCI value and traffic volume. Once the sequence was established, all steps were performed sequentially each time the PCI reached the starting trigger shown in Table 4. Fig. 5 shows a sample plot of a segment in the network which falls under Sequence #3 (Table 4), and Scenario #2 to keep the PCI above 60. Comparatively, if nothing was done to the segment, it can be seen that it would reach the reconstruction PCI threshold

Table 3. Pavement treatments with associated costs

| Treatment | L.E. good | L.E. fair | L.E. poor | Cost/ mile (1.6 km), \$ | Alpha reduction |
|-------------------------|----------------|---------------|---------------|-------------------------|-----------------|
| Crack Seal/Fill | 2 to 7 years | 2 to 5 years | 1 to 4 years | 13 200 | -3 |
| Chip Seal | 6 to 10 years | 4 to 6 years | 2 to 4 years | 30 800 | -2 |
| Double Chip Seal | 7 to 12 years | 5 to 7 years | 3 to 5 years | 48 400 | -1 |
| Microsurfacing | 7 to 12 years | 5 to 7 years | 3 to 6 years | 52 800 | -1 |
| Thin Overlay | 8 to 11 years | 6 to 9 years | 3 to 7 years | 61 600 | -1 |
| Thin Mill/ Overlay | 10 to 13 years | 9 to 11 years | 8 to 10 years | 74 800 | -0.5 |
| Cold in place recycling | PCI to 85 | PCI to 82.5 | PCI to 80 | 96 800 | -0.5 |
| Reconstruction | PCI to 92.5 | PCI to 90 | PCI to 87.5 | 110 000 | -0.5 |

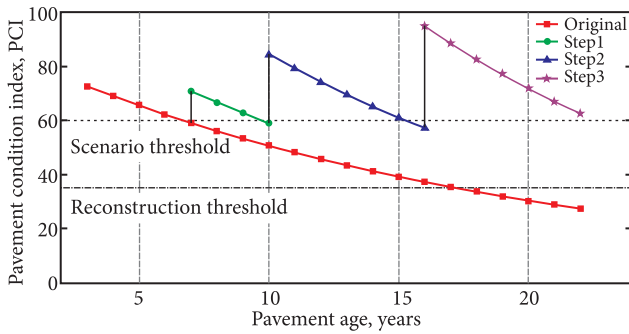


Fig. 7. Sample segment treatment sequence (sequence threshold: PCI = 60, reconstruction threshold: PCI = 35)

of 35 merely 17 years into its life. Table 4 displays the six different treatment sequences along with their selection constraints using treatment options in Table 3.

In order to determine which sequence to use, both PCI and traffic were used as primary decision makers, as shown in the flowchart in Fig. 8.

6. Pavement management scenarios

Four different management scenarios were used in this study in order to demonstrate the changes in pavement condition over time, as well as associated costs. The four scenarios were: “Do Nothing for 20 years”, PCI threshold at 60, PCI threshold at 70, and PCI threshold at 80. These scenarios were used to determine the advantages and disadvantages of keeping the pavement condition of the network at a high level and obtaining the most significant lifetime extensions from the treatments. All four scenarios were tested for a simulation period of 20 years. Since a treatment L.E. is not a “fixed” number and it depends on

many factors, this study used a stochastic approach. Random lifetime extensions were computed in each simulation iteration based on the appropriate L.E. range from Table 3. In total, 25 iterations of the entire network of 4070 segments were done for each of the four scenarios. In order to compare the difference in pavement conditions between the scenarios, the following PCI brackets were assumed:

- good condition, pavement segments with $PCI > 70$;
- fair condition, pavement segments with $50 \leq PCI \leq 70$;
- poor condition, pavement segments with $PCI < 50$.

The estimated cost was calculated depending on the simulation year in which the treatment occurs in order to incorporate the future cost correctly. This was done for all segments and the total annual cost for maintaining the network at the threshold level was calculated. Next, the pavement condition throughout the simulation period was observed after incorporating the treatments done each year.

Scenario #1 – Do Nothing

This scenario was done initially to assess what would happen if nothing was done to the pavement network for the next 20 years. This is a management approach for considering the worst case scenario and the resulting outcomes to both the pavement condition as well as the overall costs. The condition change of the segments over time is shown in Fig. 9. Nearly all segments would be in poor condition at the end of simulation period and they would require the most significant, and costly treatment. For this scenario, treatments were selected based solely on PCI and ADT of segments after 20 years of simulation. Nearly all segments needed to be reconstructed and were assigned

Table 4. Six treatment sequences

| Sequence # | Step 1 | Step 2 | Step 3 | Starting triggers |
|------------|-------------------------|------------------|----------------|------------------------|
| 1 | Crack seal/Fill | Chip seal | Thin overlay | At threshold value |
| 2 | Crack seal/Fill | Double chip seal | Thin overlay | At threshold value |
| 3 | Crack seal/Fill | Microsurfacing | Thin overlay | At threshold value |
| 4 | Thin mill/ Overlay | Crack seal/Fill | Microsurfacing | At threshold value -5 |
| 5 | Cold in place recycling | Crack seal/Fill | Microsurfacing | At threshold value -20 |
| 6 | Reconstruction | Crack seal/Fill | Microsurfacing | At threshold value -20 |

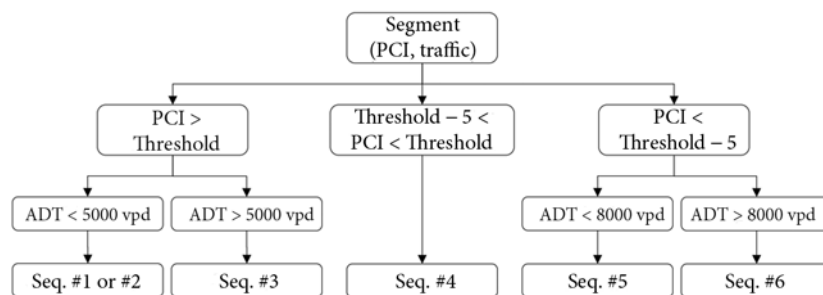


Fig. 8. Sequence decision flowchart

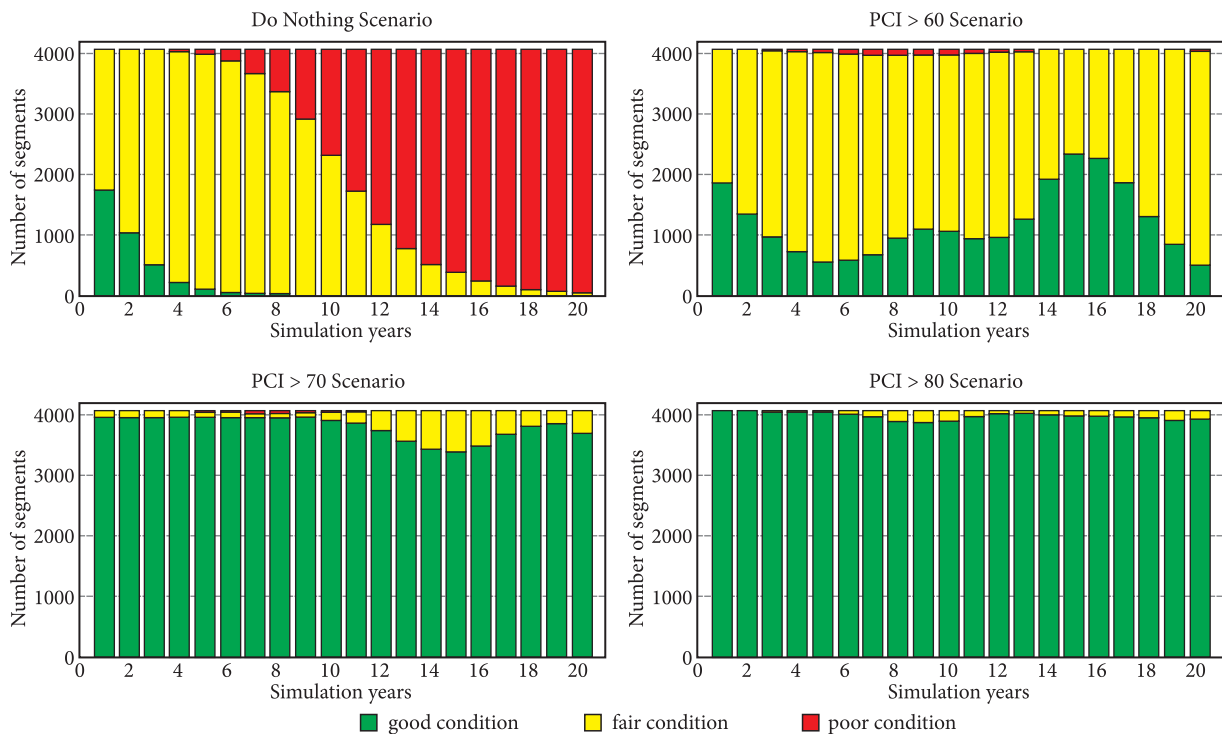


Fig. 9. PCI condition simulations

to either Full-depth Cold in Place Recycling or Reconstruction (Sequence #5 and #6 from Table 4).

Scenario #2 – Keep PCI above 60

The next scenario was to simulate the next 20 years by keeping the PCI above 60. This was done by using PCI = 60 in the constraint equations in Table 4 and assigned specific treatment scenarios for each segment in the network based off this threshold. Once treatment scenarios were assigned, the simulation began for 20 years and once the PCI fell below 60, the following step in the sequence was triggered. In this scenario, random values from the L.E. Fair column were used from Table 3 for the 25 iterations. Fig. 7 shows the different treatment steps in the sequence being triggered once the pavement falls below the threshold. Fig. 9 shows the pavement condition over time for this scenario using the same condition grouping of good, fair, and poor as discussed in the previous scenario. The vast improvement between this scenario and the previous is evident with only minimal segments achieving a poor condition over time and most maintaining at least fair condition.

Scenario #3 – Keep PCI above 70

The biggest difference between this scenario and the previous of keeping PCI above 60 is the improvement of lifetime extension of treatments. Since the PCI threshold is increased to 70, the treatments will occur on pavements which are considered to be in relatively good condition. For this scenario L.E. good extensions from Table 3 were used. Also, the alpha value reductions shown in Table 3 were cut in half assuming that the decay rate will not increase as much when treating a good condition pavement. Fig. 9 shows the pavement condition for this scenario.

There is a noticeable increase in the number of good condition segments compared to the previous scenario.

Scenario #4 – Keep PCI above 80

The last scenario done was to analyse how keeping the PCI above 80 would affect the costs and condition of the network. Although the reality of keeping the condition of a network at such a high level is unlikely due to limitations in resources, it is done to allow for comparative analysis. This scenario also uses the lifetime extensions in the L.E. good column of Table 3, however generates a random number from the top half of the range. For example, chip sealing has an extension between 6 and 10 years in the L.E. good column, but only the top half of the range was used for this scenario making the range between 8 and 10 years. Alpha reductions were treated the same as Scenario #3. It is seen in Fig. 9 that the condition of the network when simulated for 20 years consists of nearly all good condition segments.

7. Pavement management cost analysis

In order to fully assess the different scenarios, a cost analysis must be done to put valuation with respect to the pavement condition. It can be seen from the previous section that naturally a highway department would prefer to use Scenario #4 to keep the PCI threshold high and the network in good condition assuming availability of resources. For each scenario presented in the previous section the cost of the treatments was recorded based on the year in which they occurred. The inflation rate of 2.7% was used to adjust the cost to future years. Fig. 10 shows the comparison in annual costs for the Scenarios 2, 3, and 4. Scenario

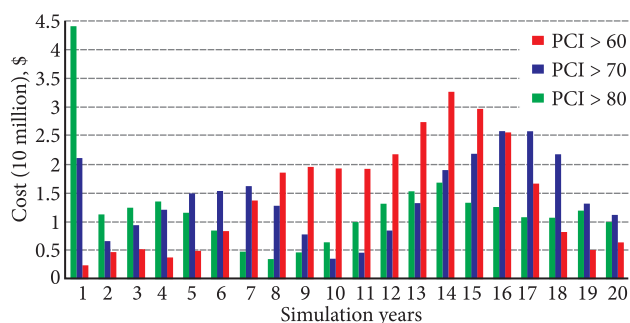


Fig. 10. Annual costs for Scenarios #2, #3, and #4

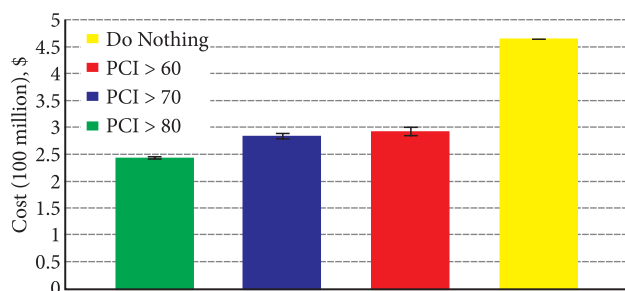


Fig. 11. Net present value for all scenarios

I was not included in this Fig. because it only has a single cost at year 20.

Initially the highest costs are associated with Scenario #4 (PCI > 80), since most segments in the network need to be initially treated to go above the threshold value. Afterwards however, the costs associated with this scenario outperform both Scenario #2 and 3 since the extension of the treatments last longer and the number of required treatments decrease. Scenario #3 also follows a similar trend but to a much lesser extent. Although the initial costs are much higher than Scenario #2, it doesn't provide reduced costs later on in simulation years like Scenario #4 does. However, since it maintains a higher level of condition than Scenario #1, it should still be considered a better alternative. Unlike the others, Scenario #1 starts off with very low costs for treatments, since most segments are above this threshold and waiting to trigger for their first treatment. Since the L.E. for the treatments is less the other scenarios, the demand for more treatments occurs at a higher frequency resulting in higher costs as the simulation periods increases.

To further investigate the lifetime costs, a comparison was done to evaluate the differences between the Net Present Value (NPV) costs for all four scenarios again with error bars representing three standard deviations from the 25 iterative runs, shown in Fig. 11. Scenario #1 has the most expensive NPV associated with it since the pavement decays and the most expensive treatments are required after 20 years. Scenarios 2, 3, and 4 all have fairly similar values, however there is an appealing trend showing a decrease in cost when a higher PCI threshold is used. This is primarily due to longer life extensions which may end up avoiding the later and more expensive steps in the treatment sequences.

8. Conclusions

1. Scenario #1 for doing nothing for 20 years shows the importance in maintaining road networks frequently, as nearly all segments in the network deteriorated to poor condition in this time. The cost associated with repairing the network after nothing was done after 20 years far surpassed the other scenarios.

2. Scenario #2 had low costs initially since many segments were above the pavement condition index threshold of 60. However the life extension of treatments was lower since the treatments were being done on fair condition pavements and resulted in more frequent repairs and higher costs than both Scenario #3 and Scenario #4.

3. Both Scenario #3 and Scenario #4 kept the condition of the network at remarkable high levels; however, the cost analysis supported the use of Scenario #4. If a highway department has enough capital and resources to support the high initial costs and extensive workload of these scenarios, they would be rewarded with longer treatment extensions, less frequent applications, and less cost in future years.

4. Scenario #1 Do Nothing is about two times more expensive according to Net Present Value than Scenario #4.

5. It should be noted that the elements of pavement management system presented in this paper were created with significant assumptions that could affect above observations. In the mature system most of these assumptions should be verified based on the historical data of maintenance activities. The main purpose of the paper is to demonstrate the pavement management process and stochastic approach to the life extension of treatments and their implication on the net present values of different scenarios.

Acknowledgements

Authors would like to thank the ConnDOT for providing the raw data necessary for this study. However, the ConnDOT or any other government or private organization did not support this study in any other way, and all findings are solely based on authors' observations. Also, authors would like to thank Dr. Mo Y. Shahin for his invaluable contributions to the area of pavement management.

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Received 28 October 2013; accepted 3 February 2014