THE UNIVERSITY OF TEXAS AT AUSTIN + COCKRELL SCHOOL OF ENGINEERING

TEXAS PAVEMENT PRESERVATION CENTER

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Past and Upcoming Events

TRB 89th Annual Meeting

The Transportation Research Board is a division of the National Research Council, which serves as an independent adviser to the federal government and others on scientific and technical questions of national importance. TRB's mission is to promote innovation and progress in transportation through research. The Transportation Research Board's 89th Annual Meeting attracted more than 10,000 transportation professionals from around the world to Washington, DC January 10-14, 2010. The TRB Annual Meeting program consisted of over 3,000 presentations in 600 sessions. Summaries of selected seminar papers related to pavement preservation are included in this issue. For more information on these papers please contact CTR library at 512-232-3126.

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Our Mission

The mission of the TPPC, in joint collaboration with the Center for Transportation Research (CTR) of the University of Texas at Austin and the Texas Transportation Institute (TTI) of Texas A&M University, is to promote the use of pavement preservation strategies to provide the highest level of service to the traveling public at the lowest cost. The executive sponsor for the TPPC is the Texas Department of Transportation (TxDOT).

TRB 89th Annual Meeting
Selected Pavement Preservation Papers

Performance Evaluation of Asphalt Pavement Preservation Activities by Elie Y. Hajj, Luis Loria, and Peter E. Sebaaly

FHWA guidance issued in 2005 explains that pavement preservation includes all those proactive measures that promise to extend pavement's service life without influencing its structural condition. Minor rehabilitation, preventive maintenance, and routine activities fall under this category. Previous research has shown that preventive maintenance methods cost only 15-20% of the ultimate failure repair cost that will occur in the absence of maintenance activities.

The paper cites examples of several previous studies that were conducted to determine the long term performance and appropriate time of application for various preventive maintenance methods. A study by Peshkin et al. in 2004 evaluated the expected life of several pavement preservation techniques such as crack filling and sealing (2 to 6 years), fog seals (1 to 2 years), slurry seals (3 to 5 years), scrub seals (1 to 3 years), micro-surfacing (4 to 7 years), chip seals (4 to 7 years), and thin HMA overlays (7 to 10 years). Other studies reviewed provided an estimate of the expected lives of common preservation methods in various states.

The paper emphasizes that it is essential for each highway agency to develop its own model for predicting the performance of preservation methods. Generic models developed for the purpose do not provide a good estimate, as they neglect the environmental, traffic, and material properties that are specific to the state.

This study details the development of an effective pavement preservation program to maintain Nevada's flexible pavements. The methodology included an evaluation and review of long-term performance and cost effectiveness of various strategies adopted over the last 15 years by Nevada DOT (NDOT) to preserve its asphalt pavements.

Several preservation methods commonly used by NDOT were identified for study, after consultation with NDOT maintenance personnel. Their performance evaluation and analysis were then conducted by reviewing NDOT's maintenance records over 15 years (1990-2005), conducting field studies of representative sections identified, and analyzing NDOT's pavement management system data. This methodology ensured that all factors which impact performance, namely construction technique, material characteristics, traffic, and environment conditions are considered in evaluation.

Recommendations for the pavement preservation programs on state roads and US and Interstate routes are made based on the analysis. The suggestions are based on the value of the Pavement Serviceability Index (PSI), Roughness Index (IRI), and pavement condition. The recommended treatment methods are listed preferentially based on performance, expected improvements by its application, and benefit-cost ratio.

Improving Pavement Preservation Treatment Strategy Selection Using Expert System Approach by DingXin Cheng, R. Gary Hicks, and Alfonso Ochoa

Generally, states make use of decision trees or decision tables to assist with the pavement treatment selection technique. However, decision trees can be difficult to manage when they include a large number of alternatives and complex conditions. Also, they do not always consider all the important factors or the ways to handle multiple distress types and/or they limit the use of various innovative treatments. In this paper Chen et al. propose to incorporate the expert system concept into pavement treatment selection process. An expert system was developed at the California Pavement Preservation Center based on the guidelines given by the Maintenance Technical Advisory Guide to assist pavement engineers in ranking appropriate pavement treatments.

The conventional method applies specific procedures to the input data and displays the calculated results without any logical reasoning for the final decision. The expert system, based on logical facts and expert knowledge, helps us in reaching the conclusions that a human expert would reach if faced with the same problem. Thus it projects the fact that it can handle complex real world problems with ease and accuracy.

An expert system consists of three main components: a user interface, an interface engine, and a knowledge base which stores knowledge from experts or experienced engineers. The working of the expert system is briefly described in this paper, and the advantage of using such a system is discussed. Some of the advantages are listed below:

- An expert system can support inexperienced engineers in strategic decision making, and can also help seasoned engineers streamline and explicitly present their decision making process.
- The system allows experienced engineers to modify default values to local practical values which provide the system with considerable flexibility.
- The system is also expandable, which means that a knowledgeable engineer can update default values and add new treatments.

Performance of Recycled Hot Mix Asphalt Overlays in Rehabilitation of Flexible Pavements by Regis L. Carvalho, Hamid Shirazi, Manuel Ayres Jr., and Olga Selezneva

Increased environmental awareness and appreciation of the limited availability of virgin materials have prompted the increased use of reclaimed asphalt pavements (RAP) in Hot Mix Asphalt (HMA) production. Focused research sponsored by federal, state, and other agencies has resulted in tremendous improvements in pavement recycling technologies over the years. Survey reports indicate a 33% reuse of RAP in HMA production.

Despite concerted efforts for promoting the use of RAP and several technological advancements, its use in pavement engineering is still limited. Conventional beliefs and traditional practices still stand in the way of RAP use becoming a common practice. Research and investigation of long-term performance of pavement overlaid with RAP HMA is necessary to challenge the belief that recycled materials are inferior in quality to virgin materials.

As a part of FHWA's Long Term Pavement Performance (LTTP) Program, Strategic Highway Research Program (SHRP) initiated a study to evaluate HMA performance, including RAP and virgin mixes. Referred to as Rehabilitation of Flexible Pavements, Specific Pavement Studies-5 (SPS-5), this study evaluated performance at early stages of SPS-5 pavements. Only limited full term performance data was available.

This study provides a comparative analysis of the performance of RAP and virgin HMA pavements which have been in service for a long period. Statistical techniques are employed to compare performance data of pavements overlaid with RAP and virgin HMA. Comparisons were made only among those mixes for which pavement was overlaid under similar conditions and subjected to similar environmental and traffic conditions. The evaluation was based on performance indicators including roughness, rutting and fatigue cracking, and deflection as structural parameter. The data collection and monitoring period ranged from 8-17 years after rehabilitation.

Statistical analysis showed RAP performance to be equivalent to that of virgin HMA mixes at most locations. All 18 sites monitored had statistically equivalent deflections, thereby indicating that RAP and HMA overlays provide similar structural improvement. The data showed that the statistical variance between results was significantly lower for thicker overlays than for the thinner ones. Thus a thicker RAP overlay can be expected to perform as well as a thick virgin HMA overlay. Pavement condition prior to rehabilitation and site environmental conditions are important for evaluation, but their impact did not alter the final result of the analysis which statistically shows that RAP overlays are as good as HMA overlays.

An Apparent Healing Mechanism in Asphalt-Based Crack Sealants by Scott Shuler, Colorado State University

Dr. Scott Shuler, representing Colorado State University, gave a brief summary about a method that can be used for the determination of short term and long term performances of crack sealing depending on the type of crack sealant used, method used for installation and location of the pavement. In this method the measurements of the amount and severity of cracking as a function of the original filled crack length were taken, from which the performance was evaluated.

In order to assess the performance, three crack sealants were installed in three environments using three different installation procedures and two crack filling methods. It was seen from the results that most of the failures increased with time during the first year and then decreased. This is conclusive of the fact that there occurs a 'healing' mechanism in the crack sealants which does not depend on the application methods, materials or location and that this behavior cannot be explained as an aftereffect of expansion and contraction of pavement slabs between transverse cracks. This 'healing' action is caused due to the kneading action of traffic and may occur during hot weather. Thus the sealants will continue to perform efficiently for longer periods of time than what was believed until now.

Bonded Whitetopping Overlay Design Considerations with Regards to Joint Sealing and the Preservation of Reflection Cracking by Julie M. Vandenbossche and Manik Barman, University of Pittsburgh

Dr. Julie Vandenbossche et al. of the University of Pittsburgh gave an overview of the evaluation of pavement performance to establish criteria on when reflection cracks might develop essentially on thin PCC overlays of HMA pavements. The process of planning this thin concrete overlay on top of the distressed HMA pavement is called whitetopping. For the purpose of this study nine test sections were constructed on I-94 at the Minnesota Road Research facility. For long term good performance thin Portland cement concrete overlays were constructed so as to ensure perfect bonding between the concrete layer and the underlying asphalt layer. Also, the effects of joint sealing and usage of dowel bars on the performance of bonded whitetopping was evaluated.

It was concluded that reflection cracking would depend on the thickness of PCC overlay and HMA layer, panel size, climatic conditions, and accumulated vehicle loads. The rate at which reflection cracking occurs is a function of temperature, load related stress and stiffness of the concrete relative to that of the HMA layer. It was also noticed that the driving lane was susceptible to more reflection cracking than the passing lane and that reflection cracking will develop in bonded whitetopping if the relative stiffness of the layers falls below 1. From the study it was deduced that the sealing of joints helps in prolonging pavement life by preventing infiltration of water into the pavement, ensuring a good bond between PCC and HMA, and maintaining the quality of HMA. It was also seen that the usage of small diameter dowel bars would help in improving the performance of the overlay.

An Investigation into a Generalised Framework for Pavement Data Asset Management by Dr. Matthew Byrne, Dr. Tony Parry, Nottingham Transportation Engineering Centre

Dr. Matthew Byrne et al of the Nottingham Transportation Engineering Centre explain the significance and importance of acquiring quality data for a pavement assessment management system (PAM). PAM is used for long term analysis and decision making, and thus the data that is entered in PAM should be of high quality so as to ensure quality decision making. The management of this data is required to guarantee the highest level of performance for a fixed expenditure. This paper provides a blueprint for the various engineering methodologies which will ensure quality management of data, and identifies models which can incorporate pavement data asset management (PDAM) with PAM or wider infrastructure asset management (IAM). In this paper the authors attempt to answers questions that determine the successful implementation of PDAM, such as what the current information quality is, whether this information quality will be acceptable to make meaningful decisions, and how to improve the quality of information in the most cost effective way. A new data mining algorithm is introduced by the authors for the successful implementation of PDAM.

There is a need to move toward a more holistic approach instead of an individualistic approach for the assessment of data through an infrastructure asset management system. Since there is always a set budget for data collection which is unable to meet the true requirements of asset management decision making, it was concluded from this paper that better management through PDAM of the type described here using the new data mining algorithm should yield significant savings. Through this paper, a new and effective work plan was proposed to meet the requirements of PDAM.

Bituminous Overlay Strategies for Preventive Maintenance on Pennsylvania Interstate Roadways by Shreya Gopal, David Peshkin, and Amir Koubaa, University of Pittsburg

Shreya Gopal et al. discuss a two-stage process to identify appropriate bituminous overlay strategies for interstate pavements, initiated by PennDOT in 2008. Here, “bituminous overlay strategy” refers to the types of treatments that could be used to preserve high traffic volume bituminous surfaces. The first stage consisted of an extensive literature review of the preventive maintenance practices and best practices at a national level. The literature review was supplemented by a survey of selected states and PennDOT districts to determine the best practices with respect to different performance evaluation criteria such as climatic conditions, traffic conditions and volumes, geography, pavement age, pavement distress condition prior to application, pre-overlay repair, performance evaluation factors of pavement, and service life of maintenance strategy.

Some of the methods used for preservation of bituminous pavements include crack sealing, single course surface treatment / chip seal application, quick set slurry / slurry seal, cape seal application, fog seal, thin HMA overlay, micro-surfacing application, polymer-modified HMA overlay, and ultra-thin wearing course. Treatment type, traffic considerations, and treatment life are the main factors which influence the preventive maintenance treatments. The applicability of a treatment depends on a number of factors, such as the condition of the pavement, service life, geographical conditions, and the overall effectiveness of the applied technique. The post-treatment service life extension of the pavement is significant in determining the effectiveness of a practice. It was observed from the first phase of the study that the most common techniques used are thin hot mix asphalt overlays, micro-surfacing, chip sealing, and polymer modified hot mix asphalt overlay. It was also noticed that the treatment service life for micro-surfacing, thin HMA overlay and polymer-modified HMA were considerably higher than the other methods.

The second stage of the study focused on the maintenance practices used by state highway agencies with conditions similar to those in Pennsylvania or neighboring areas and within the districts of Pennsylvania. A survey was conducted with questions regarding preservation techniques, current and best practices for HMA overlays, techniques and guidelines for preventive maintenance, and effective methods of pavement preservation based on current practices. Five states – Michigan, Minnesota, Ohio, New York, and Virginia – participated in the survey. From this survey it was concluded that while most of the DOTs use similar treatments, some of them use measures and guidelines specific to the state. In addition to the survey of state DOT practices, a PennDOT district-level survey was conducted to study the practices and maintenance techniques in Pennsylvania. Chip sealing was found to be most effective in low traffic conditions, and cape sealing for higher traffic volume pavements. A list of available treatments for Pennsylvania interstate pavements was identified. Also, most of the districts reported the use of milling and overlay of 1.5 to 2 inches thick for high severity distress.

An Assessment of Procedures to Determine Intervention Levels for Pavement Preservation by Ghim Ping Ong, Tommy E. Nantung, and Kumares C. Sinha

For the selection of pavement preservation treatment, state highway agencies generally develop a set of intervention levels. Intervention levels for a specific project mainly depend on the measurements of pavement roughness, rutting on asphalt pavements, faulting on jointed or jointed reinforced concrete pavements, and pavement surface distresses. In this paper, Ong et al. discuss two different procedures to develop distress specific intervention levels for system wide pavement treatments: historical practices and decision matrices obtained from expert opinions. This is important because composite ratings representing the overall condition of pavement surfaces may not be suitable for triggering preservation treatments which tend to be distress-specific. Using information on in-house and contract maintenance/rehabilitation works, network-level pavement condition data, and highway pavement inventory data collected between 1998 and 2008, the mean historical intervention levels and their standard deviation were developed. Data used here are all relating to the state of Indiana. From expert opinion surveys conducted in 2008 decision matrices were developed.

It is seen that both historical and expert opinion based procedures suggest similar pavement treatment, except for some small differences in the levels of severity at which treatment is triggered. It was observed from the study that decision matrices using expert opinions were better suited for implementation within a statewide pavement management system compared to intervention levels based on historical practices, especially for new and innovative treatments where sufficient data for analysis may not be available. Some of the treatment preferences obtained from the study are listed below:

- Crack seals are preferred on pavements with low rut severity, excellent or fair international roughness index and medium crack severity.
- Micro-surfacing is preferred when IRI is fair and rut severity is low or moderate.
- Chip seals are only used on non-interstate pavements with poor friction and low or fair IRI.
- Thin overlays are used on pavements with fair IRI or on Interstate and non-Interstate pavements with poor friction (provided there is no significant structural deterioration).
- Crack seals are preferred on jointed concrete pavements with excellent or fair IRI, low fault severity, and low or medium crack severity.
- Joint-bump repair, load transfer retrofitting, and diamond grinding are preferred when faulting is of moderate severity at most.
- Partial and full depth-repairs are applied on jointed concrete pavements with moderate fault and crack severities.

Exploring Sustainable Pavement Rehabilitation: Cold In-Place Recycling with Expanded Asphalt Mix by Peter Chan, Susan Tighe, and Susanne Chan

Sustainable pavement rehabilitations are inevitable requirements for maximizing pavement performance with the available funds. Chan et al. explore the planning, design, construction, quality assurance, and environmental aspect of Cold In-Place Recycling with Expanded Asphalt Mix (CIREAM) in a qualitative manner. CIREAM is a sustainable pavement rehabilitation method currently used in the industry. It is an in-place recycling technique which makes use of expanded asphalt (foamed asphalt) without pulverizing the existing pavement. The CIREAM process is very similar to cold in-place recycling (CIR) in terms of milling existing asphalt pavement at partial depth, except for the fact that CIR rehabilitation makes use of emulsified asphalt to provide additional adhesion to the recycled aggregates, whereas CIREAM rehabilitation uses foamed asphalt during the rehabilitation process. Here water is used as an additive to cause asphalt cement to foam.

A successful CIREAM rehabilitation involves good planning, design, construction and quality assurance. The planning component for CIREAM rehabilitation requires a pavement distress survey to identify the distresses present. The design components to be considered for CIREAM rehabilitation are milling and processing depth, overlay thickness, and foamed asphalt mix design. To avoid breaking through into the granular, the mill depth should avoid the bottom 25 mm of existing pavement. Overlay design determines the thickness of the pavement depending on the traffic load. Various overlay design models and computer software are available to help in the overlay design, though these were not further discussed in this paper. The foamed asphalt mix design involves the determination of cold water injection rate and percent asphalt added during CIREAM rehabilitation so as to provide adequate thickness for the required traffic load.

The CIREAM rehabilitation process consists of the following 6 steps:

- Setup road closure and traffic protection
- Cold milling of pavement and process into CIREAM binder with the addition of expanded asphalt
- Cure CIREAM binder for three days
- Sweep and clean the cured surface
- Provide tack coat to CIREAM binder course to enhance adhesion of final overlay
- Provide new asphalt overlay and compaction

Some of the quality assurance tests that are performed were also discussed. Dry tensile strength, wet tensile strength, and tensile strength ratio are used to determine moisture susceptibility, rutting potential, and cracking potential of the binder. Bulk specific gravity tests are used to provide an indication of how well the CIREAM binder is mixed during the recycling process. Last, the environmental impact of CIREAM construction was evaluated using PaLATE software, from which it was seen that it provides emission and energy savings when compared to conventional mill and overlay.

The potential benefit of CIREAM includes savings in asphalt cement, savings in aggregates, significant money and time savings incurred by reducing transportation cost and disposal cost, and short curing time after rehabilitation for traffic. It is expected that CIREAM will become more popular in the future because of its immense potential benefits.

An Exploration of Matter-Element Analysis for Pavement Preventive Maintenance, Optimal Timing Determination and Treatment Selection by Qiang Li, Xiaohong She, Kevin C. P. Wang, and Kevin D. Hall

Qiang Li et.al. explore a new methodology for treatment selection and its optimal timing based on Matter-Element Analysis (MEA). MEA methodology is used to solve problems with contradictions and incompatibilities. Pavement preventive maintenance decision-making accurately fits into this category.

Definition of matter elements, extension mathematics, and matter element transformation theory form the three main pillars of any MEA. A matter element is a representation of the characteristics of the object under study, which can be defined using an ordered triad such as ME = (N, C, V), where N denotes the name of the matter, C is its characteristic (or representative parameter), and V is called the “Field” session (which can be a number, an interval, or a verbal description). Once the matter elements are defined, matter element based transformation processes can be executed to determine quantitative relationships among the various elements, from which decisions can be made.

Data set consist of SPS-3 pavement sections from the Long Term Pavement Performance database. Using this data, statistical performance deterioration models are developed for do-nothing and post-treatment scenarios for four typical preventive treatments (chip seal, slurry seal, crack seal, and thin overlay). These models capture the variations in environment, traffic level, structural condition and pavement age; the performance indicators employed are International Roughness Index, Rutting, and Friction Number.

Calculation of post treatment benefits is done by calculating the area under the curve for indicators that decrease over time (e.g., Friction Number) and area above the curve for condition indicators (e.g., IRI, Rutting). Based on NCHRP 14-14 recommendations, Equivalent Uniform Annual Cost (EUAC) was used to compare the different cost streams associated with each preventive maintenance method. A discount rate of 4.0 percent is used in the analysis.

The optimal timing for each treatment is calculated following the matter element transformation by evaluating the correlation coefficients among the matter elements. The timing corresponding to the largest overall correlation coefficient is taken as the optimal timing of the treatment application. When more than one preventive method is suitable for a pavement under consideration, the optimal timing corresponding to each is determined separately, and then the corresponding benefits and cost for each treatment type at the optimal timing scenario are integrated to generate another matter element. Then by following the same method the overall correlation coefficient is determined, forming the basis for the selection of the most appropriate method.

This method is theoretically simple, easy to understand and implement, but it is important for each agency to develop its own models and review the selected factors regularly, as performance models for preventive treatments are critical to obtaining accurate analysis results. Also, the complex relationships among treatment, cost, timing, weighting factors, time value of money and performance deterioration require future exploration.

Assessment of Surface Treatment with Textiles for Pavement Rehabilitation and Maintenance by Lita Davis and John Miner

Surface treatments such as chip sealing or thin asphalt overlays are generally used to preserve and extend the life of a pavement. Placement of paving fabric during asphalt concrete resurfacing operations has been practiced for decades. Davis et al. discuss the climatic regions where chip sealing can be done successfully over paving fabric, as well as the cost effectiveness of this method. The use of paving fabric in conjunction with chip seal combines the benefits realized from chip sealing and those realized with a paving fabric interlayer when used hot mix asphalt concrete resurfacing. This method has been used in warm climates of California and Texas for over 25 years, and it was observed that the paving fabrics can extend the life of a chip seal by an additional 50 to 75 percent. Since chip seals have temperature requirements that are more restrictive than those for placing a paving fabric with asphalt concrete resurfacing, there is a need to develop a reasonable approach for placing chip seals over paving fabrics in various climatic conditions of the US, in addition to those experienced in California and Texas.

33 chip seal over fabric projects were installed in varying climatic regions across the United States including Colorado, Illinois, Michigan, Minnesota and Washington DC, as well as other parts of California and Texas. Field experiments were conducted, from which it was concluded that year-round climatic conditions were found to be as important as the day of construction, and also that identifying a roadway as a proper candidate is important to guarantee success. It was also observed from the experiments that many of the regions were able to obtain the same success rate as California and Texas.

The climatic regions where there was a high success rate of using chip sealing over paving fabric were quantified, and the climatic regions or environmental conditions that prevent successful performance were determined. The method of using chip seal over paving fabric was found to be highly beneficial for preserving flexible pavements and reducing future road maintenance. All in all, Davis et. al. explain the treatment's economic and environmental benefits, quantify the climatic areas where chip sealing over paving fabric can be done successfully, and discuss the application of construction material depending on climatic condition.

Network-Level Multi Objective Optimal Maintenance and Rehabilitation Scheduling by Lu Gao, Chi Xie, and Zhanmin Zhang

Pavement Maintenance and Rehabilitation (M&R) is a major cost for all transportation agencies. The process involves making several complicated decisions with regard to which pavement to select for treatment, when it should be treated, and which treatment should be used within cost constraints.

Pavement Maintenance is the more routine procedure that ensures pavement is in a good condition. It may be preventive or reactive, and includes activities like crack filling, patching potholes, chip seal coating, or use of slurry seal among others. Pavement rehabilitation, on the other hand, is a more expensive procedure which is performed to improve the pavement's structural capacity. Resurfacing (overlay), resurfacing with partial construction (localized reconstruction), and complete reconstruction fall into this category.

All agencies today use the Pavement Management System (PMS) to help make relevant decisions to meet the objective of providing the best performance while minimizing the cost incurred.

In this study, Gao et al. formulated a multi-objective pavement maintenance and rehabilitation scheduling model that would simultaneously optimize the two parameters involved in the decision – pavement condition and budget utilization – for a pavement network.

Generally, the solution for a multi-objective optimization problem is a set of non-dominated solutions rather than a single superior solution. This set of solutions is called the Pareto-optimal solution set. The general practice in any multi-objective situation is to identify the Pareto-optimal solution set and then select the alternative that provides the best trade off for the system with regard to objectives and preferences.

Earlier models that were developed with similar objectives used integer programming (IP) or linear programming (LP) formulation, but these approaches work well only for a small and homogeneous network. Genetic algorithm (GA) was then considered, but it proved to be very complex and time consuming. This paper used the Markov-based multi-objective linear programming approach for scheduling and parametric method for obtaining the Pareto-optimal (non-dominated) solution sets. This proved efficient at providing optimal solutions for network-level problems.

The model proposed in the paper was applied to a road network in Dallas, Texas. Through this case study it was verified that parametric method is more efficient for solving multi-objective pavement M&R scheduling problems. Furthermore, it ensures a full set of Pareto-optimal solutions. Sensitivity analysis for budget constraints and condition requirement was also performed. It showed that altering the condition requirement would not significantly change the outcome. The study thus successfully provides an efficient decision making tool for M&R activities that would enable decision makers to make more informed and optimal decisions.

Network-Level Pavement Roughness Prediction Model for Rehabilitation Recommendations by Nima Kargah-Ostadi, Shelley M. Stoffels, and Nader Tabatabaee

Transportation agencies today rely heavily on Pavement Management Systems (PMS), an indispensable tool that helps in decision making with respect to Maintenance and Rehabilitation (M&R) activities. A typical network-level PMS consists of a repository of information that includes performance data, condition assessment, and pavement performance models that identify need, prioritize M&R alternatives, and predict future performance. Moreover, it includes a feedback mechanism that is essential for Life Cycle Cost Analysis (LCCA).

Pavement performance models utilize performance indicators to accomplish the task of future performance prediction. Pavement surface roughness is a critical indicator of pavement performance. It is characterized by the irregularities on the pavement surface, and is determined by mapping the longitudinal pavement profile. It is directly correlated to ride quality, and previous research has shown it to be a good indicator of pavement structural condition as well.

This paper details the development of a performance model that is based on changes in International Roughness Index (IRI) over time. IRI was modeled as a dependent variable, while the parameters that impact pavement roughness were input as independent variables in the model. Traffic, climate, subgrade properties, pavement structure and material, construction quality, M&R, and drainage all affect pavement roughness. The large number of factors that impact pavement roughness and their interdependency complicated the model. Furthermore, collecting data on all these factors is not economically feasible.

Artificial Neural Network (ANN) pattern recognition technique was thus used to deal with the complex relationships among variables. The modeling used data from SPS-5 asphalt concrete rehabilitation experiment available in FHWA's Long-Term Pavement Performance (LTPP) database. The model developed is used to predict possible pavement performance after the application of any rehabilitation alternative, based on IRI variation trends. The output from the model, along with LCCA, is used to make M&R recommendations.

The model was tested using real data, and the predicted IRI and roughness trends were found to be close to actual performance. Thus the ANN model developed using SPS-5 database can be applied for M&R decisions for pavement sections in conditions similar to those of SPS-5 experiment, i.e. in Wet-Freeze climate. For other databases, specific ANN model would need to be trained before implementation in the decision making process. For the example data set, the life cycle cost of thick overlay without milling was found to be the least among the available rehabilitation alternatives. Furthermore, the predicted IRI trends of thick overlay were far better than those of thin overlays. Milling did not result in any significant difference in the treatment performance. These findings were concurrent with previous research.

A New Tool for Minimizing Total Asphalt Pavement Life Cycle Costs by Goran Mladenovic and Cesar A. V. Queiroz

Life Cycle Cost Analysis (LCCA) is an essential part of decision making when selecting between alternatives for pavement maintenance. Budget constraints make it necessary to choose the alternative that would minimize the total transport cost, including both the road agency and user cost. Mladenovic *et al.* present a graphical tool in this paper which can provide a fast and reliable Life Cycle Cost Analysis. This, in turn, would help in identifying the alternative for asphalt pavement rehabilitation which would cost the least. Life Cycle Cost Analysis Graph Tool (LCCAGT) thus compares the *Base* and *Project* alternatives and presents the comparisons graphically for visual and easy interpretation. Key project indicators are calculated for a pre-determined analysis period which may be as long as 40 years. The *Base* here refers to the option when only routine maintenance is performed during the analysis period and pavement is reconstructed in its last year. The *Project* alternative, on the other hand, would include a maximum of three overlay treatments along with routine maintenance during the analysis period.

LCCAGT has been developed using MS Excel® 23 using Visual Basic for Applications. It uses the following four models for analysis:

- Road deterioration model
- Road work effect (RWE) model
- Routine maintenance cost model
- Road users' cost model

All models are well defined in the tool, and an option is available to change pre-determined parameters if required. The tool has a user-friendly interface and all models used in it can be altered as per specific conditions, thus enabling it to be used for analysis of different roads under different conditions. It can also be used for Sensitivity Analysis to determine how Life Cycle Cost would vary with change in input parameters such as number of overlay treatments during analysis period, time of application, cost, etc.

The tool was tested on a project level basis, and further research would be required to develop a model on similar lines that could be used for a road network. Future development of the tool, it is suggested, should include a procedure that would automate the optimization process. Modeling of preventive maintenance treatments is also recommended.

Pavement Maintenance Methods Effect Reducing Cost and Prolonging the Service Life of Roadway Pavement – A Discussion and Case Studies by Lorena Gutierrez, Fazil T. Najafi, and Harold Boudreau III

This paper emphasizes the importance of "Preventive Maintenance," also known as "Pavement Preservation," to ensure serviceable pavement conditions under the constraints of shrinking budget. Preventive maintenance includes timely application of relatively economical treatments to prevent pavement from deteriorating further, thereby prolonging its service life and improving its condition. State transportation agencies have begun to appreciate the need for preventive maintenance to ensure pavement functionality and delay costly rehabilitation needs.

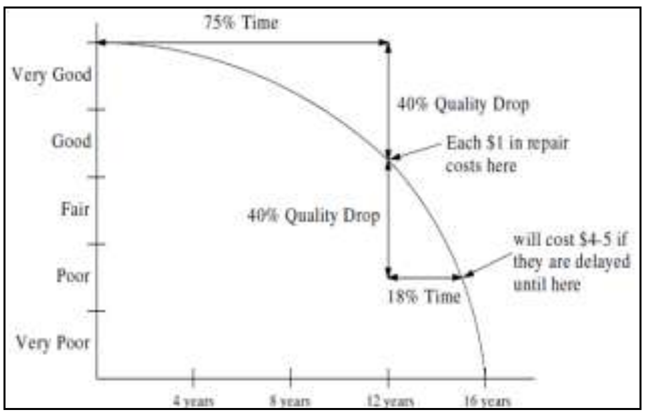

Figure 1. Pavement Life

Though Pavement Maintenance Methods (PMMs) vary from state to state, the paper outlines the general steps involved in the process:

1. Distress Data Collection - Type of pavement, flexible or rigid, governs the type and method of distress data collection. Distress data includes cracking, raveling, spalling and settlement, among others. The data collection methods have also evolved from mere visual inspection to the use of imaging and laser/sensor based technologies that scan the road surface to determine condition.

2. Data Evaluation and Roadway Network Inventorying - Distress data collected is quantified to give either the Pavement Condition Index (PCI) or the Pavement Condition Rating (PCR). Based on the Index, the pavement is characterized from very good to very poor. The index is also used to determine alternative treatments available that would restore the pavement condition to very good level.

3. Creation of a Maintenance Cost Plan - Pavement management systems are used to determine the impact of several combinations of fund allocations for reconstruction, rehabilitation, and preventive maintenance on long-term pavement conditions. This enables decision makers to make more informed decisions.

4. Project Improvement Ranking - A Project Improvement Ranking table is developed to ranks the improvement projects based on several factors. This helps identify where funding is essential and would provide the most long-term benefits.

5. Fund Allocation Using Project Improvement Ranking - For an effective pavement management program, it is essential for an agency to implement "The Right Treatment at the Right Place and the Right Time." Legislators and customers need to be educated on the benefits of preventive maintenance to ensure that a dedicated funding is available for the program.

The paper further describes the above approach being implemented by the City of Gainesville, Florida, and the Minnesota Department of Transportation.

Quantifying Pavement Sustainability in Economic and Environmental Perspective by Peter Chan and Susan Tighe

Infrastructure sustainability is a key concern today that aims to maximize performance in the present without compromising the ability to meet future needs, thus minimizing environmental impact. Sustainability of highway infrastructure is thus important and has gained recognition with the development of LEED™, Greenroads, and GreenLITES evaluation systems.

This paper is based on a research project conducted at the Center for Pavement and Transportation Technology (CPATT) at the University of Waterloo. The study was initiated by the Ministry of Transportation Ontario (MTO) to improve the sustainability of highway infrastructure in Ontario. The goal was to develop a decision support tool that would enable MTO to incorporate sustainable practices in its daily practices. This paper details the initial step in the process that includes quantification of pavement sustainability.

Chan and Tighe indicate that pavement sustainability depends on maintaining a judicious balance between economical, societal, and environmental factors during design, construction, and rehabilitation phases. The environmental and economic saving quantification is done using the PaLATE (Pavement Life-Cycle Assessment Tool for Environmental and Economic Effects) software. It is Excel based software developed by Dr. Arpad Horvath from the University of California at Berkeley. "*The tool takes user input for the design, initial construction, maintenance, equipment use, and costs for a roadway, and provides outputs for the 1 life-cycle environmental effects and costs.*"

The MTO Green Pavement Rating System (GPRS) and LCC were both used for evaluation of sustainability of project alternatives. The PaLATE analysis showed Cold-in-Place Recycling (CIR) and Cold In-Place Recycling with

Expanded Asphalt Mix (CIREAM) to be the most environmentally friendly rehabilitation alternatives, while CIR and Full Depth Reclamation (FDR) were found to be the most economical options. An interesting indication from this analysis was that flexible pavement is more environmentally friendly, while rigid pavements result in more saving of construction material.

Preservation of Flexible Pavements in Connecticut – Case Study by Iliya Yut, Derek Nener-Plante, and Adam Zofka

The concept of perpetual pavements came into existence in 1960s. Because of the increasing maintenance and rehabilitation budget and a need to improve the effectiveness of roadway paving, the State Highway Agencies (SHA) adopted longer service lives of 50 years or more for pavement design. Pavement structures are classified as perpetual if they are one of the following:

- Full-depth pavement with a thick asphalt course placed directly on subgrade
- Deep strength pavement consisting of an asphalt surface and asphalt base layers supported by a minimal aggregate base layer.

The Asphalt Pavement Alliance (APA) selected a 2.75 mile segment of Route 82 in Connecticut for the 2007 Perpetual Pavement Award. This study reviews the construction, maintenance, and operations history of this pavement with particular focus on pavement preservation techniques and their timing of application. The pavement data is compared to that of another similar pavement section (Route 9) in Connecticut to identify factors that might have resulted in better performance and longer life of Route 82.

The paper includes a review of pavement preservation techniques used for this particular pavement segment, namely crack filling and HMA overlays. A detailed analysis of the effectiveness of these strategies is presented based on historical performance data collected by the Automatic Road Analyzer (ARAN).

The data review indicated that this segment of Route 82 had exemplary performance for over 38 years, despite being overlaid only once 25 years after construction. Its deep strength pavement structure and low truck volume are cited as major reasons for its improved service life. Moreover, the availability of good quality aggregates from cutting rocks further added to its strength.

The performance data and deterioration trends of Route 82 were compared with those of Route 9. The Route 9 segment selected was similar in structure and age to Route 82, but had four times higher traffic volume. It survived without major rehabilitation for the same period as did Route 82, but required crack filling on several occasions and overlay at 20 years of age owing to high rate surface deterioration.

Comparisons of the two pavements revealed that

- The 2-in HMA overlay appeared to be more beneficial in terms of both performance and cost-effectiveness for a thinner pavement subjected to a higher traffic volume.
- The crack sealing is expected to last longer at lower costs for a thicker pavement in a better condition.

Selective Flexible Pavement Rehabilitation Based on Forensic Investigation and Deflection Analysis: Seventeen Years Case Study in Virginia by Mohamed Elfino and Hari Nair

This paper details a comprehensive forensic investigation conducted for a flexible pavement that showed signs of premature failure. The subject pavement is a 3 mile long, four lane, divided primary road on Route 3 in Lancaster County, Fredericksburg, Virginia. Constructed in 1992, this pavement was comprised of 6 inches of soil cement treated layer that rested on natural subgrade. A 6 inch dense graded aggregate layer followed the soil-cement layer, and finally a 4.5 inch asphalt concrete top layer.

By 1994, several white stains were observed on the pavement surface but no distress was reported. Fatigue and alligator cracking caused failure of truck lanes at many locations by 1998. In response, the top 4.5 inches of asphalt layer was milled and replaced. The treatment proved to be inadequate as similar distresses appeared again by 1999 and the pavement failed all the more severely. The second failure made it necessary to identify failure mechanism before selection of rehabilitation strategy to ensure a permanent and effective solution. Furthermore, cost effectiveness of rehabilitation strategy is also a pre-requisite. This requires analysis of adequate background information as well as field data.

Structural performance data for the pavement was determined using Falling Weight Deflectometer (FWD) analysis. Forensic investigation revealed further field and background information. The forensic study and FWD tests were conducted in 2000 to determine the cause of failure. Together, the above two methods were found to provide adequate and relevant information to determine an economical and effective rehabilitation strategy for the prematurely failing pavement.

Figure 2. Pavement Condition before Rehabilitation, 1999

Based on information collected, the pavement failure was attributed to the dense plain aggregate layer that had an unduly high percentage of fines. In the absence of pavement edgedrains, this caused moisture to get trapped between the stiff top and bottom layers. Moisture weakened the pavement structure and caused premature failure due to heavy axle loading in truck lanes.

This analysis led to a unique and selective rehabilitation strategy for truck lanes with heavy loading and passing lanes with light loading. In the truck lane, the asphalt layer was removed and the aggregate layer was cement stabilized to improve pavement strength. The pavement performance since then has been exceptional, with no distress having been reported. This study provides a well documented resource that may guide similar rehabilitation studies in future.

Figure 3. Pavement Condition after Rehabilitation, 2005

Study of Evaluation Method to the Transverse Crack for Freeway Asphalt Pavements by Lan Zhou, Fujian Ni, and Yanjing Zhao

Transverse cracking is an essential indicator of pavement condition. The transverse cracking is generally assessed based on either Transverse Crack Spacing (TCS) or Transverse Crack Width Ratio (TCWR). However, there is still need for a comprehensive indicator.

This paper proposes a scientific method for evaluation of transverse cracks. The model was developed based on the existing conditions of asphalt pavement freeways in China. The model establishes a Transverse crack Condition Index (TCCI) to provide an objective means for evaluation of pavement transverse cracking condition. TCCI is a numerical assessment that is based on factors such as longitudinal distribution of cracks and degree of crack severity.

Several existing transverse crack evaluation methods adopted worldwide were reviewed, but all the methods were found to be inadequate in determining the distribution of transverse cracks in pavements. Hence they did not clearly establish the influence that transverse cracking has on pavement condition.

Transverse Crack Condition Grade	Range of Transverse Crack Evaluation Index	Maintenance Classification	Treatment Method
Very Good	≥ 90	Routine Maintenance	No action
			Minor Crack Sealing
Good	80-90	Routine Maintenance	Crack Sealing
Fair	70-80	Preventive Maintenance	Fog Coat
			Extensive Crack Sealing
Poor	60-70	Corrective Maintenance	Thin overlay of 1.5cm ~ 3cm thickness with fiberglass-polyester paving mat
			Hot-mix patching
			Hot or cold recycling technology
Very Poor	<60	Rehabilitation	Traditional overlay of 4 cm thickness with fiberglass-polyester paving mat
			Partial depth removal & resurfacing
			Reconstruction

The TCCI model was developed with data available from Wu Xuan freeway in Anhui province. The reliability of the index was proven with data from two other freeways in Jiangsu province. The results corroborated the utility of TCCI in providing an accurate assessment of transverse crack condition of freeways.

In order to enable the use of TCCI as a tool in comprehensive pavement performance assessment, its compatibility with other pavement condition parameters was essential. Thus TCCI was normalized to a 1-100 scale using an “Expert Score Method.” A questionnaire was prepared and a survey conducted, the results of which were used for the normalization. The normalized index is called Transverse Crack Evaluation Index (TCEI). The index ranges from 0 to 100 and is divided into five performance levels. Each level has an associated maintenance recommendation, derived from the survey analysis and practical maintenance experience. Thus TCCI is a useful aid in determining preventive pavement maintenance methods that would result in maximum benefit for pavement.

Removing Excess Asphalt: Intial test of ultra high pressure water a success by Cindy Estakhri– Texas Transportation Institute

Summertime in Texas means rising temperatures, long days, and the emergence of maintenance forces ready to take on over 186,000 lane miles of roadways. The Texas Department of Transportation (TxDOT) spends close to $180 million maintaining the state’s roadways, and seal coats are a very part of TxDOT’s preventative maintenance program. But what happens when the maintenance needs maintenance?

A recent test study lead by Darlene Goehl, a pavement and materials engineer in the TxDOT Bryan District, sought to find a cost-effective option for correcting “bleeding” or “flushing,” which is a common problem with seal coats and surface treatments in Texas.

“Bleeding or flushing occurs when excess asphalt binder is pushed to the pavement surface, covering the aggregate,” explains Texas Transportation Institute Research Engineer Cindy Estakhri. “What you will see is a black and frequently sticky surface, which can lead to a loss of skid resistance.”
The demonstration project was conducted on March 3 on a half-mile stretch of farm-to-market roadway in Grimes County, Texas. The process involved using a truck called “The Blaster Vac” that shot super high-pressure water at 34,000 psi into the flushed roadway to remove the excess asphalt, where it was then vacuumed up. Rampart Hydro Services from Pennsylvania provided the truck, which is commonly used to remove rubber from airport runways.

“This is the first time this technology has been used in Texas,” said Goehl. “We picked a test section that exhibited heavy flushing across the roadway, not just in the wheel paths. It truly is a worst-case scenario type of road that is able to give us a true measure of how this technology works.”

The removal width of the truck’s sprayer and vacuum is two-feet, and after one pass the observers were able to notice a significant amount of asphalt removed from the roadway.

“One of my concerns was that the water would blast not only the asphalt, but also the aggregate down to the base,” said Goehl. “This test showed that not to be the case, and that the aggregate was restored.”

Texas Tech Assistant Professor of Civil Engineering William Lawson agreed with the assessment, noting an unexpected benefit. “If you look at the results closely, not only did it nearly restore the seal coat to its original condition, but the high-pressured water also increased the angularity of the aggregate, which will improve friction.”
Lawson was the research supervisor on a project (TxDOT RMC 0-5230) that studied short-term solutions to “bleeding” asphalt pavements. The use of ultra high-pressure water cutting to remove excess asphalt was one of the published recommendations from this research project.

“Certainly this test is encouraging,” said Goehl. “This technology has the potential to save the state time and money by performing maintenance on a roadway instead of having to do a full rehabilitation project.”

For more information, please contact Darlene Goehl at (979) dgoehl@dot.state.tx.us or William Lawson at William.D.Lawson@ttu.edu.
A PDF of a project summary report of TxDOT research project 0-5230 can be accessed at ftp://ftp.dot.state.tx.us/pub/txdot-info/rti/psr/5230.pdf.
The Blaster Vac specifications can be found at http://www.rampart-hydro.com/rubber-removal-equipment.htm