

MoDOT Pavement Preservation Research Program Volume VII, Re-Calibration of Triggers and Performance Models



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MoDOT PAVEMENT PRESERVATION RESEARCH PROGRAM
MoDOT TRyy1141

FINAL REPORT

VOLUME VII
RE-CALIBRATION OF TRIGGERS AND PERFORMANCE MODELS

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The opinions, findings, and conclusions expressed in this report are those of the investigators. They are not necessarily those of the Missouri Department of Transportation, U.S. Department of Transportation, or Federal Highway Administration. This information does not constitute a standard or specification.

EXECUTIVE SUMMARY

The objective of this task is to develop the concept and framework for a procedure to routinely create, re-calibrate, and update the Trigger Tables and Performance Models. The scope of work for Task 6 includes a limited review of the recent pavement management systems literature for key elements for inclusion, strategies and procedures used to 'update' pavement performance (deterioration) models, and triggers for initiating a treatment evaluation. Because this is a relatively new process, the task entailed contacting and surveying several state DOTs that already have an updating process in place. The task included interaction with MoDOT personnel in order to be sure that the proposed framework for the re-calibration procedure can be incorporated into what MoDOT already does to update triggers and performance models and is compatible with current MoDOT practices. It is incumbent upon MoDOT personnel to adapt and implement the re-calibration framework in order to continue to realize the full potential of the modified pavement management process.

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1 INTRODUCTION

Pavement maintenance treatment trigger tables and performance (pavement deterioration) models must represent the treatments being used by MoDOT and the conditions to which they are applied. As new treatments are adopted and additional pavement performance data become available it is essential to update and calibrate the performance models and treatment thresholds (triggers) in order to refine the decisions regarding which pavements to treat, what treatments are appropriate, when to perform the treatments and ultimately to save the greatest amount of money while maximizing pavement performance conditions. The objective of this task was to develop the concept and framework for a procedure to routinely update the pavement performance models and treatment thresholds (triggers).

This report comprises the final document describing the conceptual framework for updating the performance models and treatment thresholds. It is incumbent upon MoDOT to adapt and implement an updating framework in order to realize the full potential of the modified pavement management process.

1.1 Goal

The principal goal of the MoDOT Pavement Preservation Research Program, Task 6: *Re-Calibration of Triggers and Performance Models* was to provide a framework for updating the pavement management system developed in the other tasks.

1.2 Objectives

The primary objectives of this task were to:

- Summarize available literature regarding updating pavement management systems
- Identify existing updating procedures in place by other state agencies
- Describe any existing MoDOT procedures for incorporating new pavement information
- Develop a conceptual procedure for updating MoDOT's pavement management system

1.3 Scope of Work

The scope of work for Task 6 included review of the recent pavement management systems literature for key elements for inclusion, strategies and procedures used to update pavement performance (deterioration) models, and pavement treatment thresholds (triggers) for initiating a treatment evaluation. Because updating models and thresholds is a relatively new process, the task entailed identifying, contacting, and surveying several state DOTs who already have an updating process in place. Task 6 also included interaction with MoDOT personnel to be sure the proposed framework for updating performance models and treatment thresholds is compatible with current MoDOT practices.

1.4 Organization of the Report

Chapter 1 presents the goal, objectives, and scope of this task. Chapter 2 presents the results of a literature review related to updating pavement management systems. Chapter 3 summarizes a limited synthesis of updating procedures in place by other state agencies. Chapter 4 describes current MoDOT practice, and Chapter 5 presents a conceptual procedure for updating the proposed pavement management system for MoDOT.

2 BACKGROUND AND LITERATURE REVIEW

Pavement performance modeling and establishing treatment action thresholds (treatment triggers) are not new concepts; however, the amount and types of performance monitoring data are rapidly expanding resulting in ‘mega-data’ concerning pavement performance. The issues have become: what data to collect, how frequently to collect it, and how to most efficiently and effectively incorporate new data to update existing pavement management systems, including performance models and treatment triggers. In the Pavement Preservation Research program, more robust pavement performance models have been developed and treatment thresholds (triggers) have been established. Literature applicable to ‘updating’ the performance models and treatment triggers has been reviewed and the most applicable information for updating the new (proposed) performance models and triggers is described in this chapter.

2.1 Development of Pavement Performance Curves for Individual Distress Indices in South Dakota Based on Expert Opinion

The South Dakota Department of Transportation (SDDOT) and Deighton Associates Limited worked together to develop an improved pavement management system in the mid-1990s (Jackson et al. 1996). In order to develop the pavement performance curves SDDOT needed to establish pavement types, trigger indices for different pavement distresses, pavement performance curves for each distress, and a composite curve combining distress types into one curve. Due to lack of historical information available, SDDOT decided to ask for expert opinion to develop the pavement life for performance curves. The experts were asked to fill out a questionnaire focused on the lifespan of newly constructed flexible and rigid pavement types, pavement trigger levels, and the performance life of different treatments. The responses from the questionnaire were compiled to establish trigger indices and pavement curves. SDDOT concluded the pavement curves were a reasonable estimate of pavement performance but they should be improved with more data as it becomes available.

2.2 Calibration of Controlling Input Models for Pavement Management System

The Oklahoma Department of Transportation (ODOT) conducted a study in 2013 to assess the performance of the current pavement performance curves (Lewis et al. 2013). ODOT is currently using a software program called Deighton Total Infrastructure Management System to develop maintenance and rehabilitation plans but the models need to be validated with data collected from historical data. Models have been developed for each of three pavement families: Asphalt, Concrete, and Composite. The pavement families are subdivided by traffic volume. In order to simplify the re-calibration of the models, the authors summarized the curves in a spreadsheet by name and location of highway, volume of traffic, and pavement family. The spreadsheet can be used to help determine the most cost effective way of managing the roadways. The authors recommend updating the curves with new data as it becomes available.

2.3 Creating Mechanistic Based Performance Models in Pavement Management Systems (PMS)

Swan and Hein (2006) report that the difficulty with developing pavement performance curves which accurately reflect pavement deterioration is trying to predict future road conditions. The data collected to make the curves is usually based on historical or observed data. Use of historical data for future predictions is limited since the curves are only applicable for certain pavement types under given traffic volumes. If new pavements are used or new techniques are developed in roadway construction, new performance curves will need to be developed. The authors report the Mechanical Empirical Pavement Design Guide (MEPDG) can be used to predict pavement performance when there is a lack of historical data.

2.4 Modeling the Roughness Progression on Kansas Portland Cement Concrete (PCC) Pavements

Felker et al. (2004) developed models of pavement roughness for Portland Cement Concrete (PCC) pavements for the Kansas Department of Transportation (KDOT). Roughness was quantified using the International Roughness Index (IRI). Pavement performance models were developed to predict the IRI with time using statistical techniques. In order for the pavement performance models to be accurate over time, the IRI values need to be input into the models regularly as to accurately represent the pavement performance. Long term predictions are more difficult due to variability from factors not considered in the IRI prediction model. One reason IRI values are difficult to predict is the roads frequently are treated in order to maintain a minimum IRI, and this treatment changes the model. The authors therefore recommend obtaining IRI values on a defined schedule so more data points can be input into the model before the pavement model no longer applies.

2.5 Summary

The sources referenced in this chapter all acknowledge the importance of updating pavement performance models to ensure a reliable pavement management system. None of the sources specifically addressed a routine for updating models, but the work of Lewis et al. (2013) for ODOT shows that a spreadsheet tool for pavement management, while limited for database management purposes, provides some utility with respect to ease of updating models.

3 SYNTHESIS OF STATE DOT'S APPROACH TO UPDATING AND RECALIBRATING THEIR PERFORMANCE CURVES AND TREATMENT THRESHOLDS (TRIGGERS)

Updating and re-calibration schemes for pavement performance models and treatment thresholds (triggers) are only in the early stages of development. As demonstrated in the previous chapter, the published literature on the topic is limited and departments of transportation are just beginning to implement updating procedures or are in the process of modifying their existing updating schemes. Thus, it became necessary to examine what state agencies have updating schemes and to contact them for their insight on which aspects for updating performance models and treatment thresholds are working best, any methods they have tried, and how their attempts have fared. The findings from several states with experience in updating their pavement performance models and treatment thresholds are presented in this section.

3.1 Michigan DOT

The Michigan Department of Transportation (MDOT) updated its Pavement Design and Selection Manual in 2012. MDOT uses a Life Cycle Cost Analysis (LCCA) for developing a plan to build and maintain the roadways. The LCCA is the managerial approach of looking at the entire cost of the roadway from building to maintaining the roadways for a given period of time. MDOT evaluates projects based on the Equivalent Uniform Annual Cost (EUAC) method when deciding on what type of roadway to build. EUAC is the method of taking the total cost of the project, building and maintenance, and averaging that cost over the entire life span of the project. MDOT also used a software package Construction Congestion Cost (CO3) for calculating the cost of delays due to construction. The building cost of the project is relatively easy to define because the project is bid out in the present so costs can be accounted for and predicted. The maintenance costs are more troublesome because the construction costs may increase or the processes for pavement management may change with time. MDOT uses past historical data to develop a treatment schedule for a project.

MDOT is responsible for updating the LCCA inputs every four years based on the newly updated system put in place in 2010. The update for the system includes a re-evaluation of all the inputs into the system. Critical inputs include unit prices for construction and maintenance treatments, discount rates for the calculation of the EUAC, and pavement preservation strategies based on the performance of existing pavements and treatments. The unit prices will be based on the current building costs of the roadways and will be adjusted for future cost increases due to material prices. The construction and maintenance prices are to be derived from a qualified project list that contains prices from the previous 18 months and uses regional average unit prices. If there are no bids from the previous 18 months, the prices from the last 24 months may be used; if there are no prices available for a region, the state average may be used. The discount rate accounts for the time-value of money in a LCCA. Higher rates correspond to lower present value of future cash flow. MDOT's policy is to use the 30-year real discount rate, which is obtained from the Federal Office of Management and Budget Circular A-

94. (A “real” discount rate, unlike a nominal one, does not include the effect of expected inflation.) The maintenance cost for the life of the project is inflated using the Producer Price index.

The pavement preservation strategy is also to be updated every four years. MDOT’s strategies are presented in terms of remaining service life (RSL), and are based on distress models (deterioration curves) from “network/system wide historical averages.” An example pavement preservation strategy table for asphalt pavement is shown with the accompanying distress model in Fig. 3.1. The MDOT manual does not detail how the pavement preservation strategies will be updated, but it references the use of new data and “decisions ... based on engineering judgment.”

PAVEMENT PRESERVATION STRATEGY

Fix Type: New/Reconstruction HMA Pavement

Activity	Approx. Age	Distress Index (Before)	Distress Index (After)	RSL (yrs) (Before fix)	Life (yrs) Extension	RSL (yrs) (After fix)	Cost per Lane-Mile	Time to Fix 1 Lane-Mile (In Days)
Initial Construction	0		0			14	Computed	
Prev. Maintenance	8	12	3	6	5	11	\$25,544*	0.48
Prev. Maintenance	12	9	4	7	3	10	\$36,757*	0.62
Prev. Maintenance	16	12	1	6	6	12	\$46,564*	0.90
Prev. Maintenance	20	7	1	8	5	13	\$27,350*	0.65
Rehabilitation or Reconstruction	33							

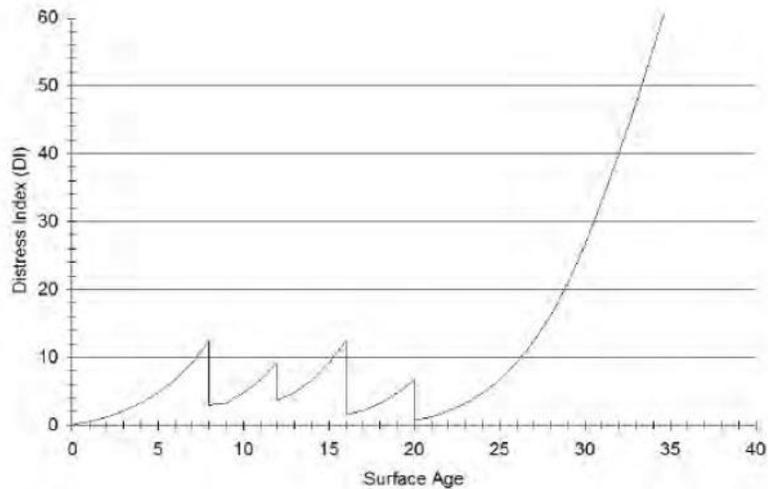


Figure 3.1 – Example pavement preservation strategy and distress curve for asphalt pavement from MDOT (2013).

3.2 Kansas DOT

KDOT is responsible for maintaining about 11,300 miles of roadway. Their pavement management system was described by Rick Miller, Pavement Management Engineer (personal communication, May 2014). KDOT’s pavement performance is evaluated by grouping the pavement as percent of miles of pavement in “good/fair/poor” condition for Interstate and Non-Interstate. The pavement conditions are further divided into performance based on the pavement type (concrete, asphalt, or composite). The pavement conditions are quantified using a three-digit Distress State, with the first digit representing pavement roughness, the second representing joint distress for rigid pavements or transverse cracking on flexible pavements, and the third digit representing faulting on rigid pavements or rutting on flexible pavements.

Each digit takes a value from 1 to 3, with 1 indicating the best condition and 3 the worst. For example, a Distress State of 123 for a flexible pavement would indicate good overall smoothness (i.e. low roughness), fair transverse cracking, and poor rutting performance. Based on pavement type, the overall pavement performance level is assigned based on the Distress State according to Table 3-1.

Table 3-1 – Performance Level definitions for KDOT pavement management systems. Performance Levels are a function of Distress State and pavement type. From KDOT, 2015.

Distress State	Performance Level			
	Concrete	Composite	Full-Depth Asphalt	Partial-Depth Asphalt
111, 112	1	1	1	1
113	1	1	1	2
121, 122	1	1	1	1
123	1	2	2	2
131-133	2	2	2	2
211	1	1	1	1
212	1	1	1	2
213	1	1	2	2
221	1	2	2	2
222	1	2	2	2
223	2	2	2	2
231-233	2	2	2	2
311	2	2	3	3
312, 313	3	3	3	3
321-323	3	3	3	3
331-333	3	3	3	3

KDOT has been using this system since 1983. In order to predict pavement performance, KDOT uses a Markov process which uses the current distress state. This process starts by assuming some percentage of roads will deteriorate from good to fair or good to poor and the remaining roadway will stay at a good condition state. The percentages of roadway deterioration every year were based on a modified Delphi method in the mid-1980s. The models were reviewed in the mid-1990s and were rebuilt with historical data in 2001. The models developed give performance prediction for roughness, transverse cracking, joint distress, rutting, and faulting based on historical data. The models are occasionally checked to make sure they are predicting the pavement performance correctly but no changes have been made since 2003.

3.3 Virginia DOT

The Virginia Department of Transportation (VDOT) uses two types of prediction models, site specific and default models. The site specific models must have a minimum of three historical

performance measurements as well as rehabilitation history information. The pavement management system will verify that the models predict the correct pavement performance. Before a site specific model is approved the predicted maximum and minimum values from the model are compared to the historical data and must produce results within a specified range.

Default models are used for sections when there is not enough historical data or when the data available is not sufficient to produce accurate models. Default models are also used to predict future treatment for a section of pavement, and therefore default models are needed even when there is historical data for a given site.

The two main inputs into model development are historical data and the type and age of any rehabilitation. "Windshield Data," i.e. data based on visual observations of pavement, is used to make the performance models along with performance indices and estimated age of the pavement. Data outliers, defined as representing non-typical performance of a given roadway category, are removed from the model.

VDOT implemented current performance models in 2007. The models were developed by Stantec Consulting Services and H.W. Lochner, Inc. (2007). The process for model development is summarized above. VDOT's current practice is to use the Stantec models with a known pavement surface age to predict the remaining service life (RSL). The performance curves have not been updated since they were implemented. When the curves were implemented, VDOT's plan was to use them to predict the performance of new pavements, and then update the models as data became available during the life of the pavement.

3.4 Caltrans

The California Department of Transportation (Caltrans) is currently updating its entire pavement management system including the software, condition rating system, and collection method. The collection segments are at 10-m intervals which has led Caltrans to use per-lane management segments. Caltrans used ground penetrating radar for structural assessment and an annual pavement condition survey. Caltrans contracted Agile Assets to compile the data collected and develop software. The software developed, named "PaveM," was put into practice in August 2013. The models used by Caltrans still need to be established, then monitored and verified. After the models are developed, there is no set number of years before another update is made to the system. The previous pavement management process had remained in place since 1978.

4 MODOT'S EXISTING UPDATING PROCESS

MoDOT's current pavement management tool was developed by the department's planning division. The tool was described by Jay Whaley, MoDOT's transportation data systems coordinator, in a meeting with the research team held on April 10, 2014. The GIS-based tool is updated annually to include a proposed schedule of treatment for all roads based on estimates of remaining service life (RSL). RSL estimates are based on IRI measurements (also updated annually) and the last treatment applied to each road. The pavement tool therefore does not consider the shape of the performance curve, only the time at which the performance is predicted to reach a threshold level. Mr. Whaley makes these predictions annually for each road, a significant undertaking made somewhat simpler by the assignment of similar expected lifespans for similar treatments within MoDOT's arsenal. The frequency of IRI measurements also makes the prediction undertaking less critical; another prediction will be made in the following year based on new IRI data (and not considering the previous year's data). Mr. Whaley also noted the predictions are easier for major routes since their traffic volumes are more consistent. He also noted the IRI trends are typically easy to predict for three to four years after treatment, after which the IRI typically increases more abruptly. The IRI consistency for the first three to four years and the department's current focus on maintenance efforts justify the RSL approach, which ignores mathematically-determined pavement deterioration curves.

5 CONCEPT FOR UPDATING MODOT'S PAVEMENT PERFORMANCE MODELS AND PAVEMENT TREATMENT THRESHOLDS (TRIGGERS)

The steps in the proposed pavement management process for MoDOT are shown in Fig. 5.1. The goal of the process is to ensure optimization of pavement performance given budget, manpower and technological constraints. The effectiveness of the process depends on the amount and quality of the data used to develop the pavement family models and trigger tables. The models and performance data should be considered 'living' functions, i.e., the characteristics (structural aspects of the pavement, subgrade conditions, traffic, and environment) are changing with time. The changes must be routinely accounted for by refreshing the data used in development of the pavement family models, segment-specific models, treatment performance models, and the trigger tables.

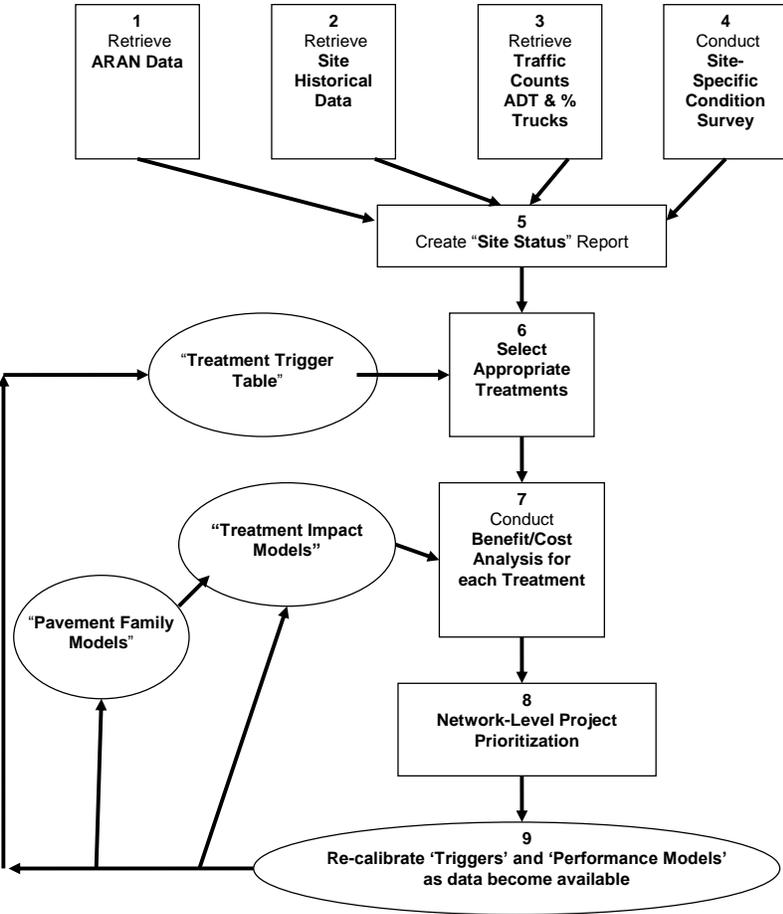


Figure 5.1 – Procedural steps for implementing a MODIFIED Pavement management process (Zimmerman et al., 2011)

The information necessary for development of the pavement performance models and the treatments (Table 5.1) was described in detail in the Task 1 (Volume II) report (Chapters 3, 4, and 5), and in particular in Appendix 1C “Guidance Document for Creating and/or Updating Pavement Family/Treatment Models.” A flowchart for updating the models is shown in Fig. 5.2.

Table 5-1 – Information desired vs. successfully collected in this study, modified from Table 4-1 of the Task 1 Report.

Significant Data Collected/Desired in the Literature	Significant Data Collected in This Study	Frequency of Success
<i>Roadway Segment:</i>		
Original pavement type	Original pavement type	Always
Layer thicknesses	Layer thicknesses	Sometimes
Subgrade type	Subgrade type	Estimate-only
Condition prior to treatment	Condition prior to treatment	Sometimes
Condition after treatment	Condition after treatment	Sometimes
Interim maintenance types	Interim maintenance types	Usually
Interim maintenance intervals	Interim maintenance intervals	Usually
AADT	AADT	Always
Accumulated truck traffic	Accumulated truck traffic	Estimate-only
Layer ages	Layer ages	Sometimes
Climate	Climate	Always
<i>Performance Data:</i>		
IRI, segment average	IRI, segment average	Always
IRI, raw	IRI, raw	Always
Composite Condition Index		PASER too new; old CI phased out
Individual distress Indices		Old indices phased out
Individual distress extent		Old data phased out
Individual distress severity		Old data phased out

5.1 Updating Existing Models

A step-by-step procedure for updating an existing pavement performance model is given in Task 1, Appendix 1C (Volume II). To update an existing model, which means keeping the same variables in the model, one would simply append newly acquired data onto the database file previously used to develop and validate the existing model, i.e., enlarge the database created just prior to Step 14 in Appendix 1C, then fit the existing model to the enlarged database. One should not forget to use the SecLength parameter as a weighting factor and check the regression results using criteria discussed in Step 15c in Appendix 1C. If the regression analysis is not satisfactory, meaning one’s confidence in the predictive ability of the model is diminished, it may help to remove the oldest data in the database and re-run the regression. It

seems logical that confidence in the model's predictive ability would increase by removing the oldest data in the database as newer data are added. Adding newer data and discarding older data would better reflect temporal changes in material properties, data collection protocols, and the quality of construction/maintenance methods, to mention a few. If, however, keeping the database approximately the same size as during the previous model development while simultaneously improving the quality of the data does not produce a model of equivalent predictive ability, one should consider developing new models using the upgraded data.

5.2 Creating New Models

To create new models, one would follow the basic methodology outlined above but one would (hopefully) begin with more, complete, reliable, and up-to-date data. Also, there could be a greater variety of potential predictor variables to evaluate in the model selection process. A flowchart of the model-building and updating process is shown in Fig. 5.2. Ideally, all MoDOT routes will eventually be divided into homogeneous sections, and there would be no need for family models. Each roadway segment would have its own condition plots of real data for IRI deterioration. In use, when a segment is being analyzed for a life cycle-type analysis, the IRI deterioration curve plus a variety of possible treatment strategies would be plotted over an analysis period of, say, 30 years. In addition to IRI data, in the future when sufficient PASER data is available, a PASER rating deterioration curve would also be constructed for the segment, and RSL determined (if desired) for each of the two performance curves. The shortest RSL would be chosen with which to go forward.

Sometimes, however, there will not be sufficient data to plot a segment-specific curve, especially in the early going of setting up this part of a PMS. In order to plot a segment-specific curve, the Colorado DOT recommends at least five condition points, with an R^2 of at least 0.50. So, in the case of an insufficient number of points, in lieu of a "real" curve, a family curve can be substituted until sufficient data is available. The family curve is one fitted to many other similar sections. In the present study, family curves have been presented for Full-Depth Asphalt, Composite, and Concrete pavements. Because there was not enough data available to create segment-specific curves at the time of this study, only family and treatment models were developed, thus Fig. 5.2 refers to family and treatment models only.

The Task 5 report makes the following recommendations for creation of new models:

1. In regard to thin overlays, the data available for this report was constrained to 1-in. Section 402 surface leveling mixes on Full-Depth Asphalt pavements. As data becomes available, models should be developed for 1¼-in. and 1¾-in. Section 401 plant mix mixtures.
2. In regard to structural overlays, the data available for this report was constrained to 3¾-in. Section 401 plant mixes and 403 Superpave mixes on concrete pavements (thus

Composite pavements). As data becomes available, models should be developed for thicker overlays on Concrete and Composite pavements.

3. In regard to surface treatments, the data available for this report was constrained to single chip seals on Full-Depth Asphalt pavements. As data becomes available, models should be developed for double chip seals, slurry seals, micro-surfacing, UBAWS, polymer chip seals, scrub seals, and scratch-and seal applications on Full-Depth Asphalt pavements. The same type of surface treatment models should be developed for Composite pavements as appropriate.
4. All routes should be divided into homogeneous sections. Annual data IRI and PASER should be collected, cleansed, and made available as presented in Appendix C of Volume II (Task 1) and Volume III (Task 2). QA on the data can be done in a method similar to that described in Appendix B of Colorado DOT's PMS manual (Colorado 2011). Site-specific IRI and PASER deterioration curves should be developed for each section. Where sufficient data is not available, family models can be substituted as surrogates until sufficient data is available. Remaining Service Life (RSL) values should be calculated, and used in a system such as a Service Life Extension (SLE) comparison, or an incremental B/C method for ranking treatments at the project level, and possibly at the network level. This would entail developing or acquiring software specific to this purpose.
5. More family models should be developed as necessary (see #4 above).

Creating and/or Updating Pavement Family/Treatment Models

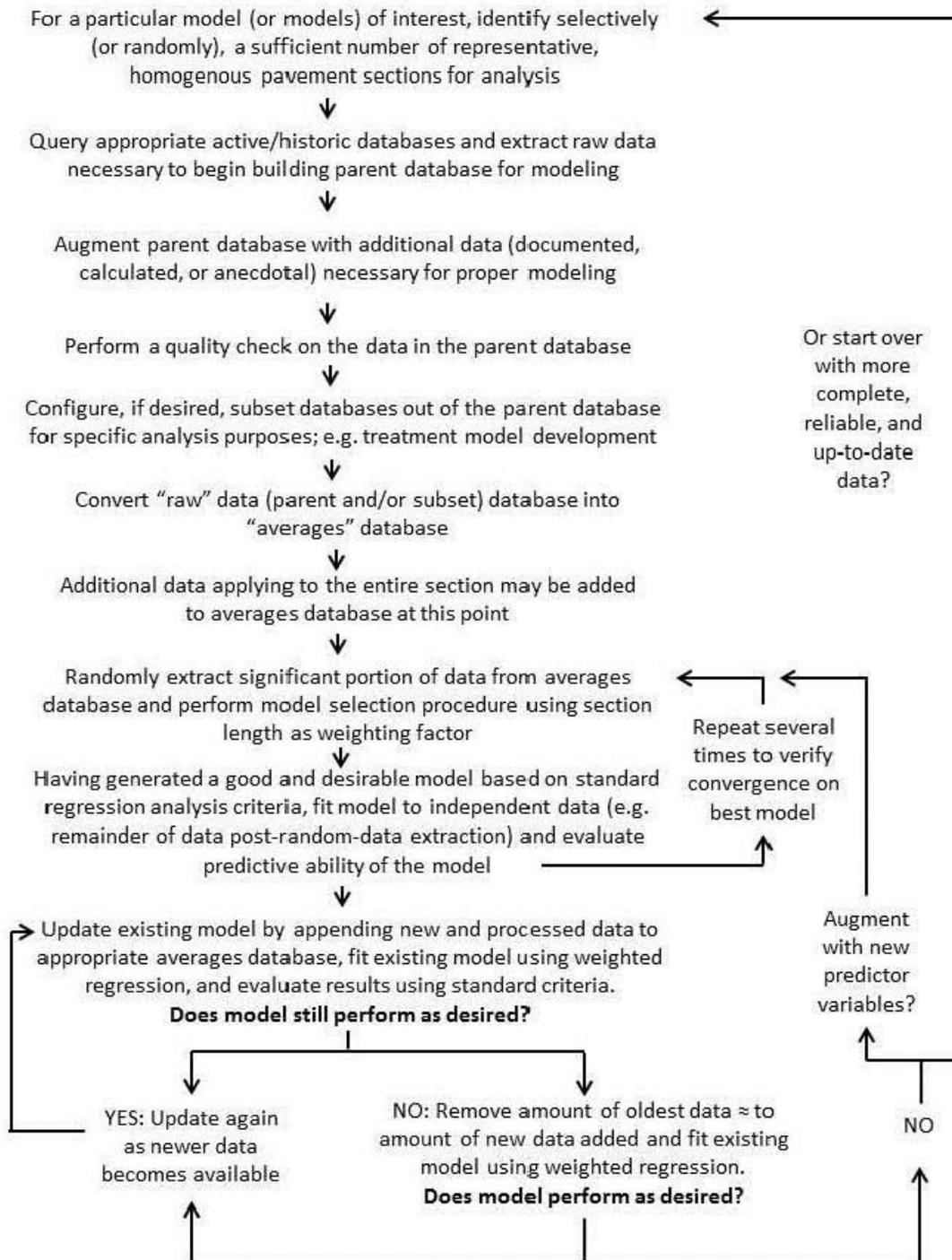


Figure 5.2 – Flowchart for model updating.

5.3 Updating Existing Pavement Treatment Thresholds (Trigger)

In addition to pavement performance models (segment-specific models, family models, and treatment performance models), the other key elements in the pavement management system are the pavement treatment thresholds or trigger levels. One must decide when a maintenance action is warranted and then what maintenance options are appropriate. The Task 5 report provides details on MoDOT's existing thresholds for maintenance action based on PASER (Figs. 7.1 – 7.5 of the Task 5 report) and IRI levels (Fig. 7.9 of the Task 5 report). The idea in using the trigger tables is to decide what optional treatments it will take for a given roadway segment to keep a Good road Good, move the rating from Poor into Good, or in an extreme case, from Poor-Unsafe to Poor-Safe. Updated treatment trigger tables are provided in Tables 7.22a and 7.22b of the Task 5 report for asphalt minor roads with greater than and less than 400 AADT, respectively. The triggers are based on PASER and IRI ratings. As long as the definitions of acceptable PASER and IRI levels remain unchanged, there should not be any reason to change or update the trigger tables; however, if the driving public's opinion or MoDOT's opinion changes resulting in policy changes as to what are acceptable PASER and/or IRI levels, then the trigger tables will need to be re-calibrated. Also, the relationship of IRI and PASER thresholds in the Task 5 report is a placeholder, and should be updated as data becomes available.

5.4 Recommendations for Future Work

Good modeling requires existing pavement layer thickness and material types, granular base data, subgrade soil and drainage information, quality of treatments, all types of vehicle traffic data, climate data, and a variety of pavement condition indicators. The following improvements should be made, consistent with the recommendations from Chapter 5 of the Task 1 (Volume II) report. Prior to implementing the list below, missing historical pavement data and pavement data errors and inconsistencies should be resolved. Examples of the missing pavement data and errors were described in Section 5.4.3 of the Task 1 report.

1. Regarding future data collection and storage, standardization of the various database fields and record entry descriptions (and codes) across *all* stakeholder departments would be extremely beneficial. The language and terminology used by the maintenance personnel should translate effortlessly with the pavement engineers, materials technicians, construction inspectors, etc.
2. In addition to all of the databases and other data sources outlined in Task 1 report section 5.3, the Pavement Tool (maintenance-oriented) should be incorporated into the MoDOT TMS. The Tool could be improved by adding features such as the following, thereby allowing more input flexibility for district maintenance personnel:
 - More treatment type choices and details (e.g. limestone or trap rock chip seals)
 - Milling details such as depth of cut and transverse location of milling-machine passes

- Bituminous treatment thickness data whether input directly or estimated based on tonnage, design mix density, project width and length
 - Specific bituminous mix types
3. It would be beneficial to pavement engineers to be able to access construction data from SiteManager through the MoDOT TMS. Because material sampling and testing data collected during a project is entered into SiteManager, detailed information such as core data (as-built density and layer thickness [especially if full-depth coring information is available as recommended elsewhere in this document]) and mix characteristics (which may raise red flags and prompt requests for more detailed data, such as coring), may help fine-tune the decisions made by planners on a future treatment selection for that project segment. If the ProjectWise (engineering) application and the SAM II (maintenance costs) database supply valuable, pertinent capabilities, they, too, should be easily accessible through the MoDOT TMS.

Characterizing the structural configuration of existing roadways would be extremely helpful in improving the treatment selection process and the upgrading of performance models. It is evident that coring is the most reliable method for determining structural layer thickness, material makeup, and current condition. It is understood that this is an expensive recommendation, but it may be economically feasible to incorporate random coring during construction projects. For example, take one full-depth core (including sufficient subgrade) at some optimum frequency as part of the QC/QA process during projects involving Sections 401 and 403 mixes when cores are being cut anyway. The thing is that this full-depth coring would only have to be done once on any given segment of Missouri's roadways. Once documented, those existing structures would remain as such unless significant rehabilitation/reconstruction occurred. Over time, a considerable amount of full-depth core data could be accumulated with a minimal amount of effort.

4. Traffic data in terms of AADT is useful, but uniform and plentiful information for heavier axle load distributions is not now readily available in the databases commonly used. Truck data is only in terms of commercial truck counts, and data is not necessarily even tied to the purported roadway segment, nor in the same direction.
5. Quality of treatments is so important, yet is not well documented. For instance, it is difficult to determine the combination of mix type, specification year, and construction records for any given treatment on any given segment of a route. It should be understood that the full-depth asphalt pavement models are built from data from the Central District; treatments using aggregate from another district may not last as long.

It is recommended that records be kept as to what materials are going into the treatments. In the future it would be of great help but would take little effort if someone, perhaps from the Field Office in Construction and Materials division, would

maintain a running commentary, construction season-to-construction season, with a very brief description of what changes were made in the specifications, the reasons for making them, and the resulting successes and failures. The commentary should be easily available somewhere for all MoDOT personnel to access. In this way, a judgment could be made as to predicting how well a given treatment with a given material constructed during a given season would last.

In some manner, treatment decision-makers should be able to find out what specification edition was in-force for a given job. In this way, when predicting longevity of a particular treatment for planning, specification-change induced quality could be taken under consideration., i.e., say a given route is being programmed for treatment, if it was known what mix specification was in-force, the programmed treatment date could be delayed or brought forward in consideration of the particular mix's reputation.

6. Any other activity that may lend itself to documenting the existing pavement structure characteristics should be considered. For example, culvert inspection and/or construction, or utility work may be conducive to evaluating the state of the pavement structure, e.g. thickness and type of layers, granular base thickness, and subgrade soil type. Again, some sort of centralized documentation procedure would be necessary.
7. The technology exists at this time to augment the ARAN capabilities with more objective methods of evaluating different pavement distress measures; e.g. video-based evaluation and analysis of crack severity and extent. Consideration of moving to this new technology should be in any plan going forward.
8. The issue of continuing to use logmiles has been ongoing. Fields for longitude and latitude are currently in the ARAN tables and partially populated. Adopting a GPS approach to locations of state assets should be in any future plan.

5.5 Summary of Future Augmentation of Treatment Models and Trigger Tables

1. Add more non-IRI distress data: old Condition/Distress Indices were phased out, replacement PASER system not in place long enough at the time of the study (i.e. keep accumulating PASER data)
2. Augment the ARAN with more automated method of distress evaluation
3. Collect/generate more complete/accurate original pavement thickness data
4. Collect/generate more complete/accurate pavement treatment thickness data
5. Collect/generate more complete/accurate/timely pavement condition prior and after treatment
6. Collect/generate more complete/accurate pavement treatment material type data

7. Collect/generate more complete/accurate pavement treatment material and construction quality data
8. Continue adding subgrade data as it becomes available
9. Continue adding pavement base data as it becomes available
10. Continue adding treatment dates
11. Continue adding pavement core data as it becomes available
12. Make more detailed axle load/truck data available (e.g. TTCs)
13. Actually measure truck traffic for all routes
14. Develop NDE database (FWD and other NDE methods)
15. Develop models for other pavement families and treatment methods
16. Eventually have most routes set up for individual Remaining Service Life models

REFERENCES

Felker, V., Najjar, Y.M., and Hossain, M., 2004, "Modeling the Roughness Progression on Kansas Portland Cement Concrete (PCC) Pavements", KTRAN: KSU-00-6, Kansas Department of Transportation, Topeka, Kansas, 47 pp.

Jackson, N.C., Deighton, R., and Huft, D.L., 1996, 'Development of Pavement Performance for Individual Distress Indices in South Dakota Based on Expert Opinion', Transportation Research Record, Journal of the Trans. Res. Bd. No. 1524, pp. 130-136.

Kansas Department of Transportation, 2015, "Condition Survey Report," 381 pp. Accessed online at http://ksdot1.ksdot.org/bureaus/matResLab/pmis/2015/CSR2015_SW.pdf

Lea, J.D., Harvey, J.T., and Tseng, E., 2013, 'Aggregating and Modeling Automated Pavement Condition Survey Data of flexible Pavements for Use in Pavement Management', Transportation Research Record, Journal of the Trans. Res. Bd. No. 2455, pp. 89-97.

Lewis, M.P., Jeong, D.H., and Khaleghian, H., 2013, "Calibration of Controlling Input Models for Pavement Management System", OTCREOS11.1-31-F, Oklahoma Transportation Center, Midwest City, Oklahoma, 60 pp.

MDOT, 2012, "Pavement Design and Selection", Michigan DOT, Lansing, Michigan, 50 pp.

Stantec Consulting Services and H.W. Lochner, Inc., 2007, "Development of Performance Prediction Models for Virginia Department of Transportation Pavement Management System," Richmond, Virginia.

Swan, D.J. and Hein, D.K., 2008, 'Creating Mechanistic Based Performance Models in PMS', 7th International Conference on Managing Pavement Assets, Calgary, Alberta, Canada, 14 pp.