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A WEB-BASED PAVEMENT PERFORMANCE AND MAINTENANCE MANAGEMENT AND GIS MAPPING SYSTEM FOR EASY ACCESS TO PAVEMENT CONDITION INFORMATION

Zhanmin Zhang
Michael R. Murphy

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

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16. Abstract

State Departments of Transportation, including the Texas Department of Transportation (TxDOT), have long been moving towards the development and implementation of pavement management systems that would enable monitoring of the performance of their roadways, as well as assist transportation officials with maintenance budget allocation and planning decisions. Various past attempts focused on using the available performance databases as well as state-of-the-art concepts for the development of such systems. The unique characteristics of the state of Texas, the most predominant of which is the vast size of the managed pavement network—79,696 centerline miles of highways including 49,829 bridges—have made some of the decision support models and/or algorithms a challenge to implement. This report presents a new approach to the development of such a decision-support system with its focus on maintenance management for TxDOT. The new system is web-based and provides functional capabilities that allow transportation officials and engineers to make informed decisions regarding their budget planning and budget allocation for pavement maintenance management, fully utilizing available historical data. The developed system has successfully supported some of the TxDOT Districts in the development of their 4-year pavement management plans. In addition, pavement conditions in Texas were analyzed in terms of the effectiveness of the 4-year pavement management plans.

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Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe St, Suite 4.202
Austin, TX 78701

www.utexas.edu/research/ctr

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Project Engineer: Zhanmin Zhang
P. E. Designation: Research Supervisor

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Introduction

The Texas Department of Transportation (TxDOT) maintains a vast network of highway pavements. Effectively managing the required maintenance in order to preserve pavement assets with a limited budget has always been a challenge. In addition, the Texas Transportation Commission (TTC) recently set a 10-year statewide goal of having 90% or more of Texas pavements maintained at "Good" or better condition for 10 years. This goal naturally increased the expectations for managing the state's roadways and has bolstered the need for the utilization of the existing state resources towards the attainment of this goal. As a result, the programs for closely monitoring the Texas pavement network and planning maintenance and rehabilitation (M&R) activities (with the corresponding budgets) have attracted once again the attention of the various TxDOT Divisions and Districts, as they are making every effort possible to achieve the goal set by the TTC. This latest development increased the need for and the anticipated benefits of a system that would help address these needs successfully.

TxDOT has been a proponent of pavement management systems (PMS) since their inception. As a result, a program for the development of a comprehensive inventory and condition database for the entire state of Texas was initiated in the late 1980s. The resulting database, termed Pavement Management Information System (PMIS), is still in use today and is updated annually with new data. However, the PMIS database is currently hosted on a mainframe computer system, making access to it difficult for Districts and area offices. In order to help TxDOT Districts and area offices with their maintenance decisions, the first step is to provide them with easy access to PMIS data on the conditions of their pavements in a user-friendly and easy-to-operate environment.

One ideal system to provide easy access to the pavement condition information is a web-based system powered by geographic information system (GIS) functions and operated with simple menus. The Center for Transportation Research (CTR) had developed a web-based GIS system for load-zoned roads for the Construction Division. However, the system needed to be revised and customized so that it could provide easy access to pavement condition information. As part of this effort, the Transportation Infrastructure and Information Systems (TIIS) laboratory at CTR has developed a new, interactive, web-based system for pavement maintenance management.

In addition, Rider 55 of TxDOT's legislative appropriations bill requires TxDOT to provide information regarding the impact of funds appropriated to TxDOT on the conditions of pavements in Texas. To fulfill this requirement, TxDOT modified the original scope of this project, asking CTR to conduct the pavement condition analysis in terms of the impact of the funds appropriated to TxDOT on the conditions of pavements in Texas.

PART I: Web-based System Powered by GIS Functions

The web-based system consists of two major modules: 1) a GIS module for displaying the PMIS information, and 2) a decision-support module termed Pavement Performance & Maintenance Management (PPMM) that focuses on monitoring the pavement network and managing its M&R activities. Details for developing this system are summarized in the following sections.

1.1 Features of the Web-Based Dynamic Information System

As shown in Figure 1, key features of the web-based dynamic information system include the following:

a) Overview Map: This appears in the top left corner of the website and gives the overview of the entire map. It can be turned on and off with the "Toggle Overview" button located at the top right corner of the toolbar.

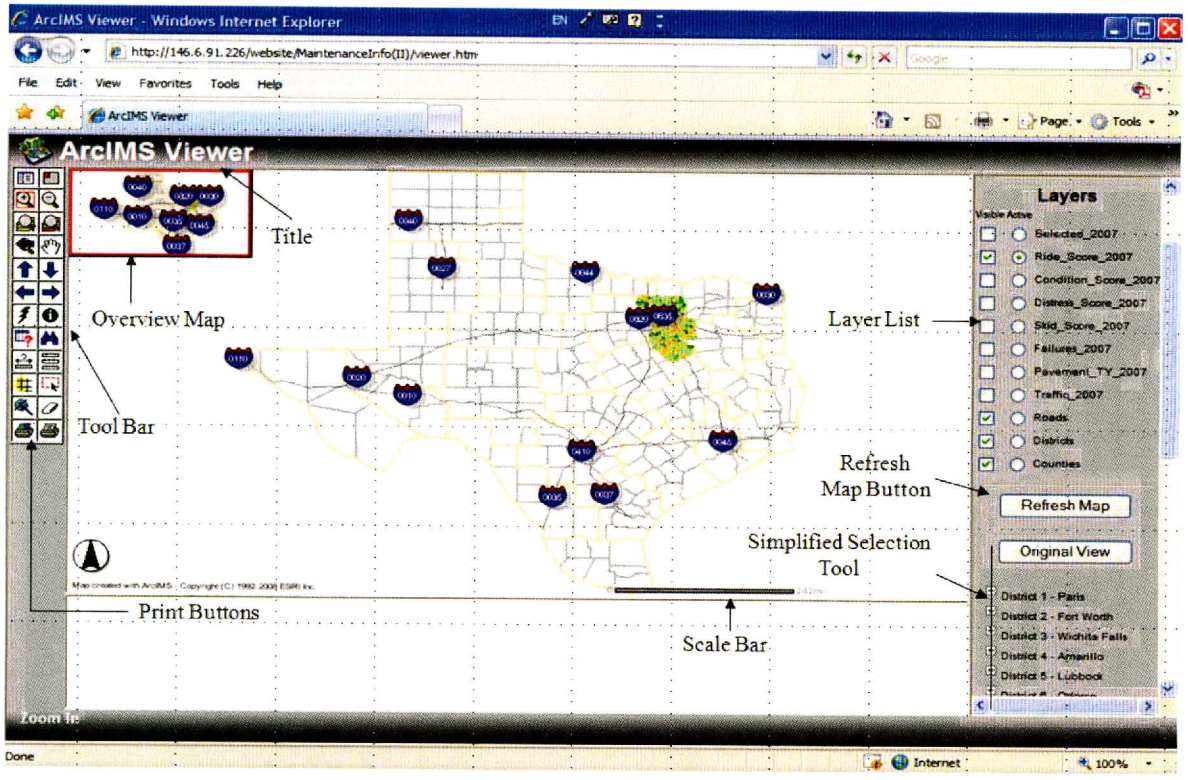

Figure 1. Features of the Online Dynamic Information System

b) Layer List Button: The layer list button is used to show the symbology for each layer in the information system. Users can toggle between the layer list and legends using this button.

c) Layer List: It supplies the users with the different layers present in the map and indicates which layers are active. Users have to check one particular layer to make it an active layer before they can extract any information regarding its features. This can be done by checking the radio buttons provided in front of each layer.

d) Simplified Selection Tool: This feature presents the user with a simplified tool to select and view the information for a particular District/county. When a user clicks on the name of the District/county, the system automatically focuses on the map for the selected District/county. Tables presenting the information for the focused features are also generated. The selection tool can also be used to extract the data pertaining to a particular county by clicking on the '+' sign next to the name of the respective District. This generates the list of counties in the particular District. Then, the name of

the desired county can be selected to have the map of the county as the focused feature.

e) Refresh Map Button: After checking or unchecking the radio button for any of the layers, this function button must be pressed to see the changes in the map. For example, if users have changed the active layer from "Ride_Score_2007" to "Condition_Score_2007," then the map must be refreshed to reflect any change.

f) Scale Bar: The scale bar shows the relationship between the actual distances on the earth and the map distances. In the dynamic information system, both the mile and kilometers scale bars are included to facilitate users with distance measurement.

g) Tool Bar: It carries various tools for the data extraction and map manipulation. Their functions and usage are discussed in detail in subsequent sections.

h) Print Buttons: The two buttons of the tool bar are used to generate printable versions of the maps and tables. The left print button allows the user to print the map; the right one is for printing the table.

1.2 Tools for Working with the Dynamic Information System

In addition to the features described in the previous section, specific tools for viewing, extracting, and manipulating map information are outlined as follow.

a) Selecting and Extracting Map Information: The dynamic information system provides the users with a simple tool to extract the desired information.

b) Printing Maps and Tables: The generated maps and tables can be printed by using the two print buttons. While one of the buttons can be used to generate a printer-friendly page in a new window, the other is used to create a printer-friendly page for tables in a new page.

c) Exporting the Tables: The generated tables can be exported by using the button directly under the tables. By clicking the "Export Records to Excel Spreadsheet" button, a mechanism is initialized to generate a pop-up page for exporting the table to an excel spreadsheet.

More detailed information regarding these features and tools, along with additional features, is presented in the "User's Guide" published as a separate report of this project.

1.3 Pavement Performance and Maintenance Management (PPMM)

PPMM is a web-based application that aims to use the existing PMIS data to monitor and analyze current pavement performance. The key functions included in the system enable the user to

- Visualize multiple-year pavement condition data in PMIS with an interactive and user-friendly interface.

- Identify pavement sections of interest based on their location characteristics and retrieve their performance history according to available indices (Ride Score[1], Distress Score[2], and Condition Score[3]).
- Classify pavement sections according to various levels of "Attention" needs based on their recorded historical performance.

One of the most important features of the system is that the user can access the historical pavement condition information in PMIS from the web-based GIS interface as shown in Figure 2, making both the current pavement condition information and the historical trend of pavement conditions readily available to the user at the same time. The application has been pilot-tested with the PMIS data for its usability, reliability, and robustness.

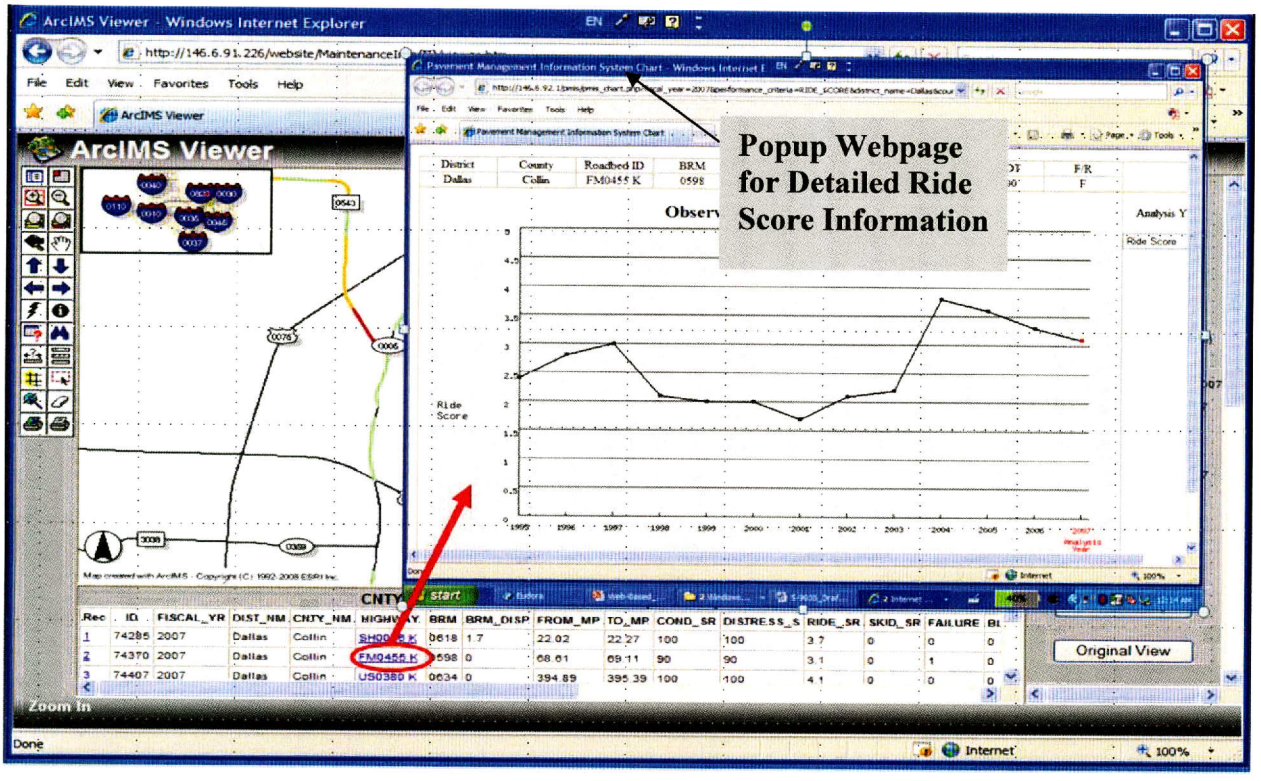

Figure 2. Popup Webpage for Detailed Ride Score Information

PART II: Pavement Condition Analysis for 4-Year Plans

Rider 55 of TxDOT's appropriations bill requires that prior to each fiscal year the department provide the Legislative Budget Board and the Governor with a detailed plan for the use of these funds that includes, but is not limited to, a district-by-district analysis of pavement

[1] The Ride Score is a measure of pavement functional performance defined by TxDOT based on the Present Serviceability Index (PSI).

[2] The Distress Score is a measure of pavement structural performance defined by TxDOT based on the measurement of various surface distresses.

[3] The Condition Score is a composite pavement performance index defined by TxDOT based on the combination of the Ride Score and the Distress Score.

score targets and how proposed maintenance spending will impact pavement scores in each District. To fulfill this requirement, TxDOT and its Districts develop the 4-year pavement management plans (PMP) and update them every year. Following are the plans' current goals:

- Develop a comprehensive and uniform PMP that is roadway specific to the greatest extent possible, and is fiscally constrained.
- Generate Pavement Condition Projections based on a financially constrained plan that can be reported in compliance with Rider 55 of the 2012–2013 Appropriations.
- Assure maintenance resources are directed towards pavement operations and roadway-related work.
- Provide a reporting mechanism for District Engineers, Administration, and the Commission to utilize in briefing elected officials.
- Allow Districts and regions to appropriately allocate resources through long-term planning in order to accomplish the plan.

The 4-year PMP provides TxDOT with a mechanism to predict pavement conditions based on a specified funding level and project-specific plan. The resulting report summarizes the number of lane miles that each District plans to treat as Preventive Maintenance (PM), Light (LRhb), Medium (MRhb), or Heavy Rehabilitation (HRhb), and the impact that those treatments are predicted to have on the pavement conditions.

The primary components of the plans include these elements:

- The financial constraint for all categories of funding for FY 2012–15 was identified from finance revenue projections and utilized to plan the projects.
- Projects for the FY 2012–15 planned lettings were identified in P6 and considered for impact on pavement condition.
- All maintenance expenditures (Strategy 105/144) were captured in the PMP system, taking into account all routine and PM work.

Each District developed their 4-year expenditure projections based on anticipated budgets. Certain expenses are fixed and are part of doing business, such as overhead and operational expenses. The roadside expenditures continue to be evaluated in order to find the balance with expectations. Traffic operational expenses are well established in order to maintain existing systems (Intelligent Transportation Systems [ITS], signals, illumination, etc.). The pavement expenditures include both in-house state force work and routine maintenance contracts. These pavement expenditures do not include construction.

2.1 Issues Related to the Pavement Condition Analysis

To conduct the pavement condition analysis for the 4-year PMPs, a portfolio of related issues were considered, with assumptions made as needed.

Pavement Network

The pavement network with which the analysis was conducted consists of the existing pavements under TxDOT's jurisdiction and stored in the existing PMIS database. The most

current version of the PMIS database was used in the analysis, based on the 2011 PMIS data collection.

Base Year Network Condition

The base year of the analysis was 2011. The condition of the entire state's pavement network was initially determined based on the individual scores of the pavement sections in the PMIS database. The Condition Score of these sections was used as the performance measurement index to calculate the "Good" or better pavement Condition Scores.

Proposed Improvements

The projects identified in the Planned Lettings and in the Maintenance portions of the PMP were applied to the model with the appropriate work type as defined here:

- **Routine Maintenance:** sealing cracks, patching, pothole repair, level up, etc.
- **PM:** Seal coats (chip seals), thin overlays, micro-surfacing
- **LRhb:** 2 in. < overlays < 3 in., widening pavement and seal coat, base repairs and seal coat, mill, seal and thin overlay
- **MRhb**: 3 in. < overlays < 5 in., mill and inlay (mill and fill), mill, stabilize base and seal, level up and overlay, base repairs and overlay
- **HRhb:** Full pavement reconstruction, bomag, add base and overlay or seal (2R)

Deterioration Modeling

Before planning for the M&R actions for the road network, the deterioration process of the pavements was studied in order to understand when their condition would reach a critical level that would trigger intervention. In this study, a statistical analysis was carried out to analyze the deterioration rate distribution for the various pavement structure types and highway functional classifications. As a result, nine broad groups of deterioration models were defined as presented in Table 1.

Table 1. Summary of Nine Groups of Deterioration Models

Highway Functional Class		Pavement Type		
		Flexible	Rigid	
			CRCP	JCP
Interstate Highways	IH	Group 1	Group 4	Group 7
US Highways	US			
State Highways	SH	Group 2	Group 5	Group 8
Farm-to-Market	FM	Group 3	Group 6	Group 9

These nine groups were found to have distinctive deterioration rates, and therefore a different set of models was developed for each group. The daily temperature range and precipitation levels play an important role in the pavement deterioration process. As a result, instead of developing pavement condition models for every District in Texas, these models were developed instead for the four climatic regions of Texas, as shown in Figure 3. For each climatic

region, separate pavement condition models pertaining to the Distress Score and the Ride Score were developed.

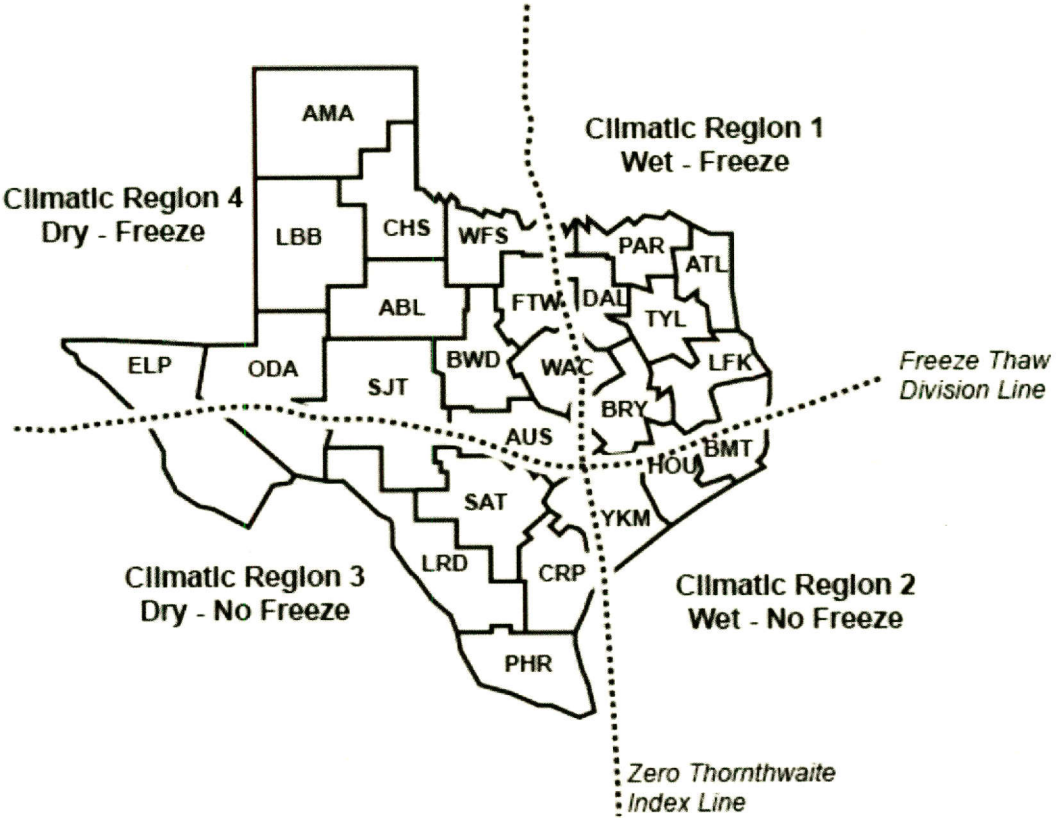

Figure 3. Climatic Regions in the State of Texas

Next Year Network Condition

The condition of the network for each subsequent year was based on the condition of the previous year with the addition of the effects of natural deterioration and the M&R work planned for the previous year. These new values, in terms of the Ride Score and their Distress Score, were determined, then combined to calculate the new Condition Score of each section. The new Condition Scores of all sections were then averaged together, with each score weighted by its respective lane-miles, to get the new statewide Condition Score.

Maintenance and Rehabilitation Costs

Finally, the implementation of each treatment action corresponded to a specific cost for the agency, based on the unit cost of the action by lane-mile treated and the lane-miles of the treated section(s). The unit costs of each action were set to the values shown in Table 2, and varied for flexible and rigid pavements. The costs are based on project delivery costs, which include estimated costs for mobilization, traffic control, materials, labor, and ancillary items necessary to actually complete the pavement project. These costs generally differ from PMIS treatment costs, which primarily include the cost for pavement materials (i.e., hot mix, portland

cement concrete, etc.). In addition, the treatment costs used in this analysis are based on constant FY 2008 dollars.

Table 2. Maintenance and Rehabilitation Action Unit Costs

M&R Action	Unit Cost (per mile per lane) for Flexible Pavements	Unit Cost (per mile per lane) for Rigid Pavements
Needs Nothing	$0	$0
Preventive Maintenance	$29,000	$36,000
Light Rehabilitation	$173,000	$60,000
Medium Rehabilitation	$237,000	$256,000
Heavy Rehabilitation	$442,000	$651,000

Maintenance and Rehabilitation Improvements

Each M&R action was assumed to have a specific effect on the section it was applied to, in terms of the section's Ride Score and Distress Score. The correspondence between the various M&R actions and their respective effect on the pavement sections are shown in Table 3.

Table 3. Maintenance and Rehabilitation Action Improvements

M&R Action	Ride Score Improvement	Distress Score Improvement
Needs Nothing	0	0
Preventive Maintenance	0.5	95
Light Rehabilitation	1.5	100
Medium Rehabilitation	Reset to 4.8	Reset to 100
Heavy Rehabilitation	Reset to 4.8	Reset to 100

2.2 Examples of the Pavement Condition Analysis Results

The conditions of the pavements were analyzed for each of the 25 TxDOT Districts, with results being summarized both by Districts and for the whole state, and presented in a report. The main components of the condition summary include the following:

- Treatment lane miles by treatment types (PM, LRhb, MRhb, and HRhb) for each year
- Treatment lane miles by pavement conditions (Good or Better, Fair, Poor, Very Poor) for each year
- "Good" or better pavement condition scores by District for the entire state and by counties for each District
- Predicted "Good" or better scores for the 4-year plan period

Some examples of the pavement condition analysis results are shown in Figure 4 through Figure 6 and Table 4.

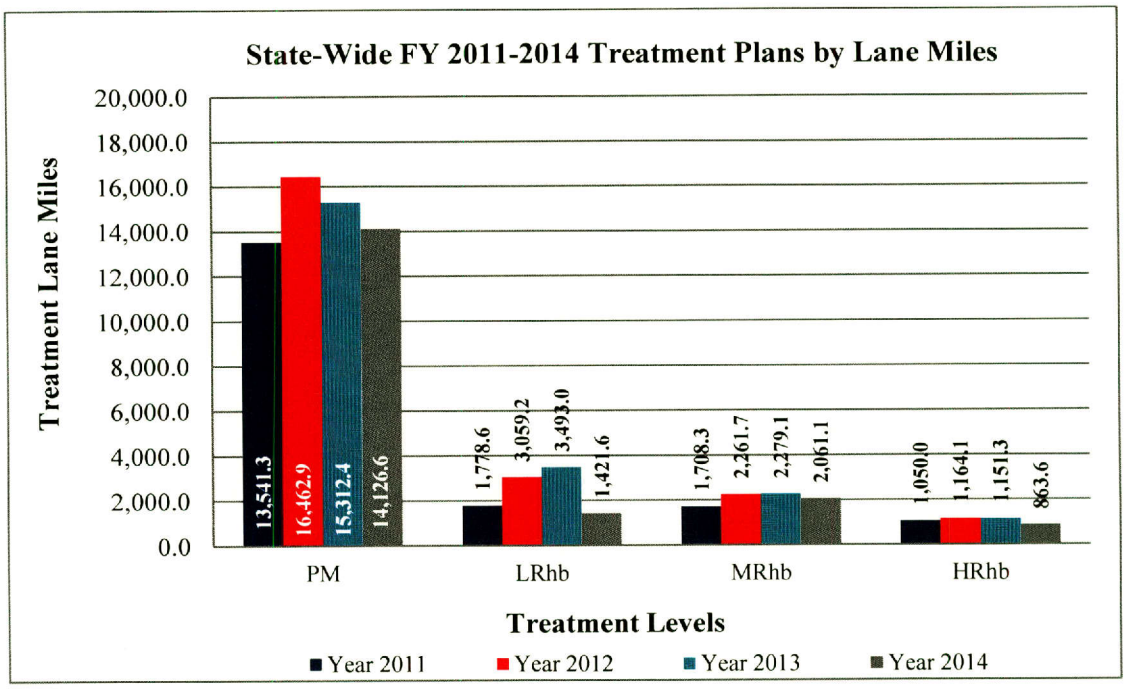

Figure 4. Statewide Treatment Plans for FY 2011–2014

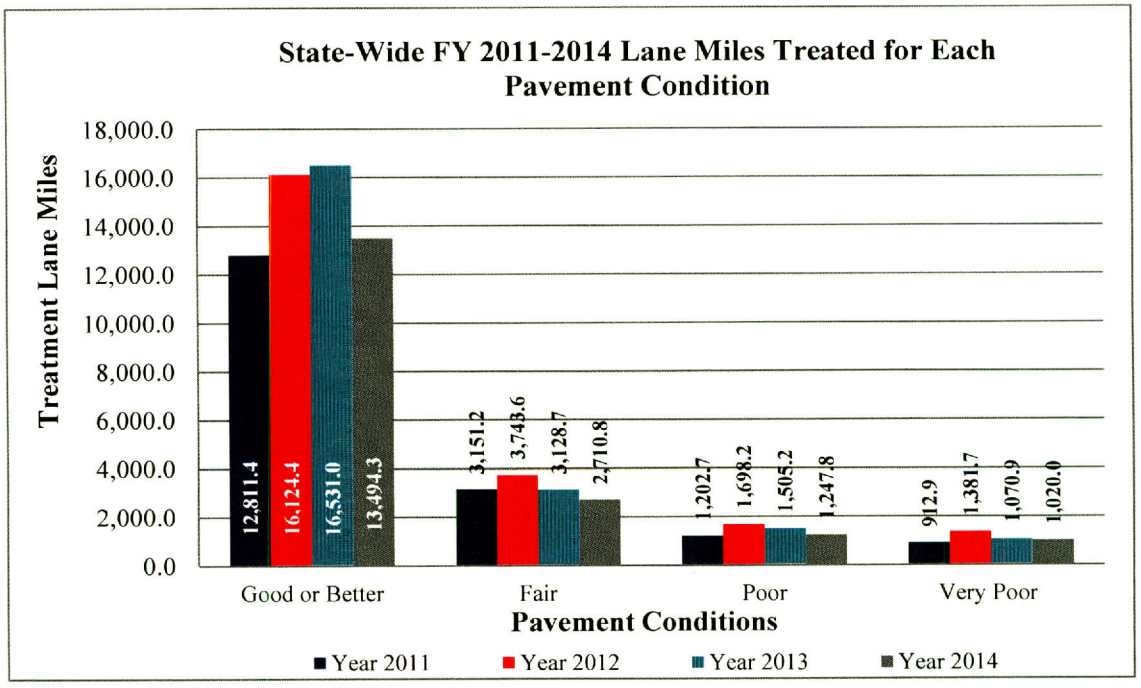

Figure 5. Statewide Lane Miles Treated for Each Pavement Condition

Table 4. Pavement Performance Summary for Beaumont District and Counties

			Base Year	Analysis Years			
			2011	2012	2013	2014	2015
Beaumont District		**Achieved Goal (%)**	**89.97**	**88.92**	**88.32**	**86.3**	**84.14**
		Achieved Average CS	**92**	**90**	**88**	**85**	**83**
Counties in Beaumont District	**Chambers**	Achieved Goal (%)	88.83	91.06	90.42	89.65	87.02
		Achieved Average CS	92	92	89	87	84
	Hardin	Achieved Goal (%)	95.91	93.17	92.99	92.64	88.55
		Achieved Average CS	96	93	91	89	85
	Jasper	Achieved Goal (%)	94.31	92.99	91.57	86.69	85.53
		Achieved Average CS	95	93	90	86	85
	Jefferson	Achieved Goal (%)	83.43	80.66	79.36	76.67	75.14
		Achieved Average CS	87	85	82	80	78
	Liberty	Achieved Goal (%)	90.18	88.22	90.23	87.52	87.54
		Achieved Average CS	93	90	89	86	86
	Newton	Achieved Goal (%)	93.47	94.57	95.6	95.16	92.74
		Achieved Average CS	95	94	92	90	88
	Orange	Achieved Goal (%)	81.14	78.49	74.94	73.6	68.63
		Achieved Average CS	86	82	79	77	74
	Tyler	Achieved Goal (%)	98.36	99.02	98.4	96.75	94.99
		Achieved Average CS	98	96	93	90	88

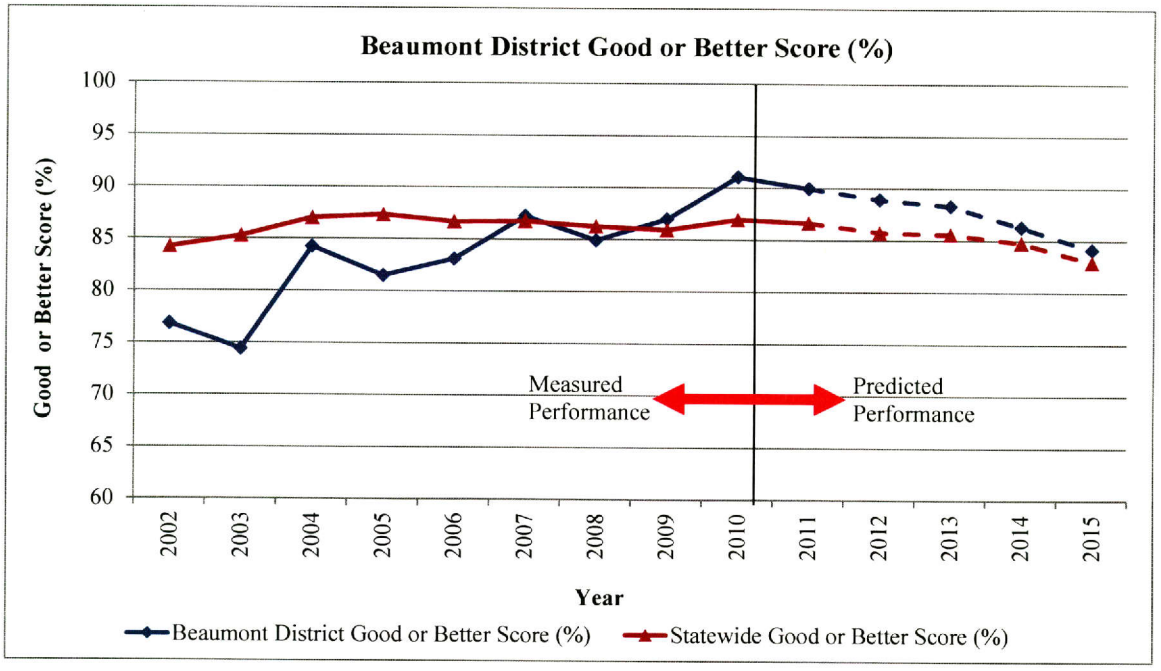

Figure 6. Beaumont District Overall Pavement Performance of FY 2002–2015

Center for Transportation Research
The University of Texas at Austin
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