MDOT State Study 268— Development of a Pavement Management Manual and Data Quality Plan for the Mississippi Department of Transportation

Applied Pavement Technology, Inc. (APTech)

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16. Abstract
This project was initiated to update MDOT's existing pavement management process documentation, to develop a QMP for pavement management data collection activities, and to identify recommendations for improving the quality checks on pavement condition data collected by vendors. The *Pavement Management Manual* and the *Network-Level Pavement Condition Data Collection Quality Management Plan* are products developed under this research effort and are included as appendix attachments to the final report. The *Pavement Management Manual* contains relevant pavement management guidance and supplemental materials compiled into single document that describes current pavement management business practices. The *Quality Management Plan* follows the structure provided in the *Practical Guide for Quality Management of Pavement Condition Data Collection* (FHWA 2013) but is customized to MDOT's business practices. The plan identifies data collection contractor quality control requirements and describes the actions needed to resolve any data inconsistencies that are discovered. The quality assurance process used by the agency is outlined and space is provided to record the quality checks that are conducted each time data is submitted by the contractor.

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LIST OF ACRONYMS

ALDOT — Alabama DOT
CRCP — continuously reinforced concrete pavements
DCP — dynamic cone penetrometer
DMI — distance measuring equipment
FAST — Fixing America's Surface Transportation Act
FHWA — Federal Highway Administration
FWD — falling weight deflectometer
HPMS — Highway Performance Monitoring Systems
IRI — International Roughness Index
JCP — jointed concrete pavement
JPCP — jointed-plain concrete pavement
LADOTD — Louisiana Department of Transportation and Development
LRS — location reference system
MAP-21 — Moving Ahead for Progress in the 21st Century Act
NCAT — National Center for Asphalt Technology
NCDOT — North Carolina DOT
NHS — National Highway System
NMDOT — New Mexico DOT
ODOT — Oklahoma DOT
PDI — Pavement Distress Index
PennDOT — Pennsylvania DOT
PMM — *Pavement Management Manual*
PMS — pavement management system
QA — quality assurance
QC — quality control
QMP — Quality Management Plan
RMS — root mean square
ROW — right of way
STAMPP — Systematic Technique to Analyze and Manage Pennsylvania’s Pavements

EXECUTIVE SUMMARY

The Mississippi Department of Transportation (MDOT) is responsible for collecting, managing, analyzing, and reporting pavement-related data on the State's highways to drive investment decisions. MDOT has used a computerized Pavement Management System (PMS) since 1986 to manage its pavement network. The PMS contains a comprehensive construction history for the entire state-maintained highway system; pavement condition and distress data; and the route inventory, asset attributes, and test results from surface friction and structural evaluation testing. MDOT recently implemented new PMS software tools. As part of that activity, the agency established, and partially documented, business processes supporting its pavement management activities. However, MDOT recognized the need for further documentation to address the following needs:

- **Meet asset management requirements.** The Moving Ahead for Progress in the 21st Century (MAP-21) and Fixing America's Surface Transportation (FAST) Acts include requirements for certain pavement management capabilities and the existence of a Quality Management Plan (QMP) for pavement management data.
- **Ensure the quality of pavement management data.** Pavement management data is becoming increasingly important, driving the need for improvements to existing quality assurance (QA) procedures.
- **Preserve institutional pavement management knowledge.** Upcoming retirements and promotions are expected to lead to the loss of personnel and institutional knowledge in pavement management at MDOT.

This project was initiated to address these needs, by updating MDOT's existing pavement management process documentation, developing a QMP for pavement management data collection activities, and identifying recommendations for improving the quality checks on pavement condition data collected by vendors. The research was conducted under the five work tasks listed below.

- Task 1. Review background materials.
- Task 2. Develop a draft *Pavement Management Manual*.
- Task 3. Develop a draft *QMP*.
- Task 4. Develop a draft Technical Brief.
- Task 5. Finalize the project deliverables.

The *Pavement Management Manual* and the *Network-Level Pavement Condition Data Collection Quality Management Plan* are products developed under this research effort and are included as appendix attachments to the final report. The *Pavement Management Manual* contains relevant pavement management guidance and supplemental materials compiled into single document that describes current pavement management business practices. The first five chapters provide general background information on the fundamentals of pavement management, the role of pavement management at MDOT, legislative and policy directives impacting pavement management, and pavement management-related definitions. Information on the data collection-related activities can be found in chapter 6. Chapters 7 and 8 provide information on pavement performance modeling and treatment selection. Reporting requirements and templates are discussed in chapter 9 and chapter 10 provides an overview on planned improvements.

The *Quality Management Plan* follows the structure provided in the *Practical Guide for Quality Management of Pavement Condition Data Collection* (FHWA 2013) but is customized to MDOT's business practices. The plan identifies data collection contractor quality control requirements and describes the actions needed to resolve any data inconsistencies that are discovered. The quality assurance process used by the agency is outlined and space is provided to record the quality checks that are conducted each time data is submitted by the contractor.

It is recommended that both documents be reviewed approximately every three years to update role and responsibility changes within the agency in addition to changing technical requirements for evolving pavement management practices. For example, the *QMP* includes a recommendation to improve consistency in the data collection process by implementing an independent assessment of contractor and agency ratings on select sections across the State. The results of these assessments could be used to establish acceptance tolerances for the pavement distress information provided by the vendor to determine the reasonableness of the data.

PROJECT BACKGROUND

Introduction

Investments in transportation should achieve agency goals and lead to sound, long-term strategies. To successfully support transportation investments and achieve its goals, a state highway agency requires reliable business processes and software tools, particularly when managing its biggest assets, such as pavement. Once these processes and tools are in place, they should be continuously reviewed and evaluated to make sure they reflect advances in technology, improve effectiveness and efficiency, and meet regulatory requirements.

The Mississippi Department of Transportation's (MDOT) finds itself at the beginning stages of such a review. MDOT has used a computerized Pavement Management System (PMS) since 1986 to manage its pavement network. The PMS contains a comprehensive construction history for the entire state-maintained highway system; pavement condition and distress data; and the route inventory, asset attributes, and test results from surface friction and structural evaluation testing.

MDOT recently implemented new PMS software tools. As part of that activity, the agency established, and partially documented, business processes supporting its pavement management activities. MDOT recognized the need for additional documentation to address the following needs:

- **Meet asset management requirements.** The Moving Ahead for Progress in the 21st Century (MAP-21) and Fixing America's Surface Transportation (FAST) Acts include requirements for certain pavement management capabilities and the existence of a QMP for pavement management data.
- **Ensure the quality of pavement management data.** Pavement management data is becoming increasingly important, driving the need for improvements to existing quality assurance (QA) procedures.
- **Preserve institutional pavement management knowledge.** Upcoming retirements and promotions are expected to lead to the loss of personnel and institutional knowledge in pavement management at MDOT.

MDOT needs quality data to make effective pavement management decisions. Pavement deterioration rates and resulting treatment recommendations in the PMS are based on reported field conditions. To make sure data collected in the field is reliable, pavement management data collection tolerances and acceptance criteria need to be in place and applied to data collection contracts. These criteria are documented in a QMP that establishes acceptable levels of data quality. The QMP includes a summary of data collection procedures, quality control and acceptance criteria, roles and responsibilities for the data quality management team members, and reporting requirements. The resulting improvements in pavement condition data quality are expected to lead to more reliable PMS performance models that better represent expected network conditions and enable MDOT to better track progress towards its performance targets.

Improvements in the available pavement management documentation are also needed by MDOT to capture institutional knowledge about pavement management procedures and processes. The resulting documentation enables MDOT to better share available pavement management resources and create a "one-stop-shop" *Pavement Management Manual*. This comprehensive manual improves access to pavement management practices across disciplines and district lines, and provides consistent guidance to managers leading preservation activities across the state.

Research Objectives

To address the needs described in the previous section, Applied Pavement Technology, Inc. (APTech) conducted a research study that achieved the following objectives:

- Update MDOT's existing pavement management process documentation.
- Develop a QMP for pavement management data collection activities.
- Identify recommendations for improving the quality checks on pavement condition data collected by vendors.

A research plan was developed to describe the work activities that were conducted to accomplish the project objectives. The work was organized into the five tasks listed below.

- Task 1. Review background materials on pavement management quality assurance practices in comparable agencies.
- Task 2. Develop a draft *Pavement Management Manual*.
- Task 3. Develop a draft *QMP*.
- Task 4. Develop a draft Technical Brief.
- Task 5. Finalize the project deliverables.

Following delivery of these research products, and their subsequent implementation, MDOT will be able to satisfy MAP-21 requirements for a QMP, improve the quality of pavement management data, better manage Department assets, and provide documentation on current pavement management practices for training its pavement management staff.

REVIEW OF BACKGROUND MATERIALS

Agency personnel provided necessary MDOT pavement management documents, including process documents, automated data collection contract requirements, data dictionaries, decision trees, PMS models, existing quality management documents, descriptions of pavement management roles and responsibilities, existing data collection standards, and data processing requirements.

The information from the background review, as well as the information obtained during interviews, was compiled into a document summarizing the roles and responsibilities of the MDOT pavement and district staff, the service provider, and others identified as having a significant role in the program.

APTech reviewed available, relevant information on QMP's from other agencies and quality control practices provided by vendors. Sources included:

- Federal Highway Administration (FHWA) reports.
- State DOT research reports.
- Pavement Management Peer Exchanges.
- Vendor-supplied Quality Control Programs.

Key findings from the background materials, phone interviews, and literature review were used to develop both the *Pavement Management Manual* and *Quality Management Plan*. The most relevant findings are also summarized in the remainder of this section of the final report.

Alabama Department of Transportation (ALDOT 2015)

The Alabama Department of Transportation (ALDOT) collects pavement condition data through a selected vendor responsible for maintaining specific quality control (QC) and quality assurance (QA) protocols that promote data accuracy before, during, and after data collection. Before acceptance or decision making occurs using the data collected by the vendor, ALDOT carries out QA throughout four general phases of the collection process, including pre-collection, collection, processing, and post-collection. Each phase serves an essential purpose to assure data accuracy throughout the collection process and allows better planning and decision making for ALDOT.

Description of Distresses and Other Data Items

ALDOT requires the following distresses and other data to be collected for the entire length of each 0.01 mile (52.8 feet) segment.

- Location information.
- Surface type (predominant pavement type).
- Slope data (cross slope and longitudinal grade, both in percentage).
- GPS coordinates.
- Right of way/ shoulder images (beginning and midpoint of each 0.01 mile.

- Events:
  - Point Events:
    - ➢ Surface change.
    - ➢ Railroad crossing.
  - Segment events:
    - ➢ Multilane sections (true if more than 2 lanes in each direction, otherwise false).
    - ➢ Any period the test vehicle moves out of the collection lane coded as true, otherwise false.
- International Roughness Index (IRI) for each 0.01 mile separately for both wheelpaths. IRI data must be Highway Performance Monitoring Systems (HPMS) compliant and in in/mile.
- Required information for flexible pavements (record information in the following order):
  - Lane width.
  - Transverse cracking (record in linear feet).
  - Load associated cracking: cracks within the wheelpath (record in linear feet).
  - Non-load associated cracking: cracks outside the wheelpath that were not previously identified as transverse cracking (record in linear feet).
  - Rutting: record mean and maximum value for each wheelpath individually (record in sq. ft.).
  - High Severity Raveling: when the surface texture is extremely rough and pitted (record as yes when present or no when not present).
  - Patching: only if the condition of the patch affects ride quality (record as yes when present or no when not present).
  - Macrotexture (record mean right wheelpath root mean square [RMS]) amplitude of texture for wavelengths from 0.0196 in to 1.196 in).
- Required information for rigid pavements (record information in the following order):
  - Transverse joint and crack faulting: mean and maximum absolute values for each wheelpath.
  - Transverse cracking: a single crack must be greater than 6 ft. (record in linear feet).
- Additional information to be collected, measured by 0.1-mile segments (specified by the department):
  - Percent of cracked slabs.
  - Punch-out area (continuously reinforced concrete pavements [CRCP] only)

Vendor QA/QC Protocols

A protocol is a formal record of rules that govern a specific task. As mentioned above, QA/QC must be enforced before, during, and after collection, to properly address these during a project, the vendor is responsible for developing and enforcing the QA/QC protocols. Below are a series of topics that are to be addressed during each stage of the data collection.

- Pre-Collection
  - Prior to certification or delivery, all equipment (including accelerometer sensors, lasers height sensors and distance transducer) must be calibrated to meet set specifications.
  - Calibration must include block test, bounce test, and test runs to compare results with roughness from different pavement types and conditions. Data is compared to industry protocols and previous calibrations from ALDOT collections.
  - Schedule a kick-off meeting must be scheduled with ALDOT representatives to detail project-objectives.
  - Calibration site data is collected and processed to verify specifications are met prior to beginning data collection. This data serves as reference for later calibrations during data collection.
  - Collection databases containing detailed reference data must be developed to guide field staff.
  - When available, GPS data and maps are imported into the collection vehicle to facilitate navigation and repeatable results.
- Collection
  - Previously collected calibration sites are recollected throughout the collection cycle (calculation includes faulting, texture, rutting, and IRI in both wheel paths and average).
  - Real time graphs are used in the vehicle to assure correct data collection.
  - Bounce tests and equipment tests must be completed weekly.
  - The data collection software is used to enhance the efficiency and accuracy of the collected data as well as reporting and alerting the operator of any software, data, or equipment problems.
  - Driver, operator, and software checklists are employed daily to maintain consistency throughout the data collection.
  - Software daily reports of irregularities, vehicle equipment health, daily production and overall summary of the collection process are sent to the home office for QC.
  - Field staff verify collected data to ensure data completeness and quality throughout the day and maintain detailed logs and data backup on a daily basis.
- Processing
  - Incoming data is checked to assess data completeness and accuracy.
  - ALDOT specifies the use of PathView II software to scan for data outside the quality expectations and flag it for resurveying.
  - Preliminary reports created and compared to previous collection for historic reference.
  - All collected indexes undergo daily random sampling and consistency testing.
  - Sensor data is verified by software and manual spot checks to ensure quality display.

- Weekly management meetings to ensure all departments throughout the project are functioning adequately.

ALDOT QA/QC Protocols

While the vendor controls the data quality and deliverables, ALDOT is ultimately responsible for determining what equipment is suitable to achieve agency data goals. Likewise, the defined QA/QC protocols are enforced during data collection and address the topics listed below.

- Pre-Collection
  - This phase consists of verifying the vehicle, its systems, and the data reduction process are capable of producing accurate data. A series of checks are prepared to validate the vehicle's suitability for the collection phase.
  - The vehicle is certified with respect to IRI (accuracy and repeatability) at the National Center for Asphalt Technology (NCAT) test track. Then the vehicle establishes a target IRI and is tested for repeatability at a minimum of ten of ALDOT's control sites.
  - The vehicle's data collection capabilities and targets for rutting are determined at the same ten or more control sites where IRI is certified.
  - The capability of the data reduction process to detect cracking is determined through the use of ten calibration sites selected before data collection commences. If significant difference in ratings (through a Pearson's r correlation for total transverse cracking, wheelpath, and non-wheelpath cracking) are found the issue must be investigated and resolved prior to data processing.
  - For faulting values using the certified inertial profiler, the ProVAL software is used to compute faulting for a minimum of two locations with jointed concrete pavement (JCP) and compared to those obtained with the inertial profiler.
- Collection
  - IRI and rutting values must be verified weekly with a control site previously established in the pre-collection phase.
- Processing
  - Right of way (ROW) images by sub-region are checked for clarity and brightness (the word "mile" on a milepost must be readable). The images are then used to verify start and end of segments, if they are incorrectly set the vendor must emend.
  - IRI, rutting, faulting, and cracking values determined, along with reporting interval fixes are determined by the vendor in their processing phase. This provides a basis for ALDOT's QA in the post-collection phase.
- Post-Collection
  - The majority of ALDOT's QA is conducted in this stage since at the end of the process data is accepted as final.
  - Reported location reference system (LRS) values are verified against provided GPS values in ALDOT's WALDO program. Segments with differences greater than 0.1 and 0.25 miles are listed and the error causes are determined by ALDOT and the vendor and resolved prior to final acceptance.

- Reporting intervals from the processing phase are used to produce a list of 264-ft. samples (assumed to represent a mile). From this list, 3 percent of the collected mileage is randomly chosen for field verification. When substantial differences are found, re-rating by the vendor may be required.
- National Highway System (NHS) routes are surveyed annually while all other routes are checked on a biennial basis. IRI, rutting, faulting, and cracking are compared for each pavement section. An overlay list is used to reconcile segments where conditions may have improved over time.
- Once all of the data has been checked and issues have been resolved, the data is accepted as final.

Quality Management Team Roles and Responsibilities

To obtain quality data, it is necessary to establish roles and responsibilities for the following tasks. ALDOT specifies the tasks for each team member, as shown in table 1.

Table 1. Quality management team roles, resources, and responsibilities (ALDOT 2015).

Team Role	Assigned Resource	Quality Management Responsibilities
Agency Manager	Frank Bell, P.E. Pavement Management Engineer	• Set quality standards, acceptance criteria, and corrective actions. • Approve each deliverable per quality standards. • Approve resolution of quality issues. • Assess effectiveness of QM procedures. • Recommend improvements to quality processes. • Communicate weekly with data collection manager. • Supervise manual measurement of control, verification, and blind sites. • Establish reference values with data collection team. • Monitor schedule adherence. • Prepare QM report.
Agency Assistant Manager	Vacant Data Quality Analyst	• Monitor resolution of quality exceptions reported to data collection team. • Submit acceptance exceptions log to data collection team. • Observe and maintain records of control, verification, blind site testing. Analyze and document results. • Perform data acceptance checks and document results. • Maintain acceptance log and submit quality exceptions to agency assistant manager.
Agency Staff	Kelli Marshal Data Quality Technician	• Perform right-of-way imagery checks. • Submit acceptance exceptions log to data collection team. • Assist in field verification site data collection.

Team Role	Assigned Resource	Quality Management Responsibilities
Project Data Manager (Contractor)	Scott Mathison Vice President, Operations	• Assure practice of QC measures in QM plan.. • Assure proper protocols used. • Assure training plan addresses all personnel skill levels. • Assure reviews by Distress Rating Lead, Data Reduction Lead, and Video Lead. • Assure performance of all quality audits and reporting of all data quality exceptions using QC log. • Assure correction of all quality issues and changes in procedures as needed. • Perform and document final deliverables quality review. • Compile documentation of all QC activities.
Data Collection Manager (Contractor)	To be determined by the Contractor	• Assure deliverables meet broad set of data quality requirements. • Communicate weekly with agency assistant manager. • Assure quality issue resolution and report results to agency assistant manager.
Project Engineer (Contractor)	To be determined by the Contractor	• Assure and document initial equipment configuration, calibration, and verification.
Field Crew Lead (Contractor)	To be determined by the Contractor	• Perform daily and/or periodic equipment start-up checks, tests, inspections, and calibrations. • Perform daily review of data logs and video samples. • Assure real-time monitoring of data and video quality • Assure performance of weekly control, verification, and blind site testing • Assure documentation of all field QM activities and reporting of any problems using QC log

Team Role	Assigned Resource	Quality Management Responsibilities
Distress Rating Lead (Contractor)	To be determined by the Contractor	• Perform and document initial rater training and ensure raters are adequately trained in protocols • Document testing of raters on initial calibration site • Perform and document quality audits, including intra- and inter-rater checks. Report any problems using QC log. • Perform retraining as needed.

British Columbia Ministry of Transportation and Infrastructure (BCMoTI, 2012)

Since 1993 the British Columbia Ministry of Transportation (BCMoTI) has collected automated surface condition data. These surveys include profile measurements (IRI), surface distress (longitudinal wheel path cracking, longitudinal joint cracking, edge cracking, transverse cracking, meandering longitudinal cracking, alligator cracking, bleeding, and potholes), rutting (calculated from rut depth profile data), and ROW images for 25,000 lane miles of the main highway network. The data is averaged and reported over 164ft. intervals. Quality control for the collected data is divided into two phases to assure specifications are met.

Initial Quality Control

Initial QC testing serves the following two purposes:

1. To test field safety procedures and assure the vendor's equipment is operating accordingly, and
2. To clarify BCMoTI's required distress nomenclature, severity, and extent levels to the vendor.

Four 2,460-ft. long (820-ft. lead-in included) control sites are selected. Control sites must represent the survey conditions and contain a variety of distress types, pavement deterioration levels, and surface types. Selection is based on the prior year's survey data and field exploration. Whenever previous year control sites have not had maintenance and/or rehabilitation applied, they may be used for subsequent inspections.

Manual distress surveys include crack mapping for each 164-ft. pavement segment, rut depth measured in each wheelpath at 33-ft. intervals, and pavement profile measured using a Class I profiler (ASTM E 950 compliant). These manual surveys are used to compare the automated vehicle collected data using five passes of each of the four control sites. The three criteria listed below are used to assess the vendor's surface distress measurement ability.

- Pavement Distress Index (PDI): zero to ten index used to compare manual to automated surveys and assess repeatability of the vendor's equipment.
- Keystroke totals: used to compare severity and extent of manual to automated surveys. Each distress severity and extent combination is analyzed to verify that no particular

distress type is being rated too severely, a particular distress is being rated at a different density level, or a particular distress has been missed.

- Kappa Statistic: used to evaluate the level of agreement between the manual and the automated surface distress rating (see equation 1 and table 2).

$$K = 1 - \frac{\sum_{i=1}^{k}\sum_{j=1}^{k} w_{ij}x_{ij}}{\sum_{i=1}^{k}\sum_{j=1}^{k} w_{ij}m_{ij}} \quad (1)$$

where:

K = Kappa Statistic
k = Number of codes
w_{ij} = Weighted value
x_{ij} = Observed value
m_{ij} = Expected value

Table 2. Kappa statistic level of agreement (BCMoTI, 2012).

Kappa Statistic	**Strength of Agreement**
< 0.00	None
0.00	Chance
0.01 to 0.20	Slight
0.21 to 0.40	Fair
0.41 to 0.60	Moderate
0.61 to 0.80	Substantial
0.80 to 0.99	Almost Perfect
1.00	Perfect

Automated roughness and rut depth measurements for each wheelpath are determined on 164-ft. intervals and compared to the manually measured values. The average IRI and rut depths are then determined for each wheelpath over the 1,640-ft. test site. Once evaluated, the agency determines whether the acceptance criteria for surface distress, roughness, and rut depth measurements were met. Table 3 summarizes BCMoTI's acceptance criteria.

Table 3. Initial QC criteria (BCMoTI 2012).

Category	Criteria	Acceptance Criteria Value
Surface Distress	Measure	PDI value (0-10 scale)
	Calculation	1,640-ft. average based on 164-ft. values
	Unit	Lane
	Accuracy	±1 PDI value compared to manual survey
	Repeatability	±1 standard deviation of the PDI values for five runs
Roughness	Measure	IRI
	Calculation	1,640-ft. average based on 164-ft. values
	Unit	Outside wheel path
	Accuracy	±10% of Class I profile survey
	Repeatability	±6.3 in/mi standard deviation for five runs
Rutting	Measure	Rut depth

Category	Criteria	Acceptance Criteria Value
	Calculation	1,640-ft. average based on 164-ft. values
	Unit	Average for both wheel paths
	Accuracy	±0.12 in of manual survey
	Repeatability	±0.12 standard deviation for five runs

Were the vendor to fail any of the acceptance criteria, resolution would be required until the acceptance criteria are met.

Production Survey Acceptance

Blind sites are utilized to closely monitor the condition rating and equipment during data collection. All blind sites are manually surveyed by BCMoTI and are unknown to the vendor. These sites are located to evaluate the first two to three days of data collection. If the performance is proven to be satisfactory, blind sections are selected every three days. The size and condition of each blind site should be similar, and manual surveying should be done prior to data collection by a single rater to maintain consistency. Each day of data collection the vendor must update BCMoTI on the survey progress. Whenever the vendor has passed over a blind site, notification is provided and the contractor is required to submit a distress rating report for the length of the blind site. Prior to continuing data collection activities, the vendor must successfully meet the acceptance criteria for the blind sites using the acceptance criteria shown in table 4. The four initial QC sites must be rerun monthly or before moving to a new region.

Table 4. Blind site QC criteria (BCMoTI 2012).

CATEGORY	CRITERIA	ACCEPTANCE CRITERIA VALUE
Surface Distress	Measure	PDI value (0-10 scale)
	Calculation	1,640-ft. average based on 164-ft. values
	Unit	Lane
	Accuracy	±1 PDI value of manual survey
Roughness	Measure	IRI
	Calculation	1,640-ft. average based on 164-ft. values
	Unit	Outside wheel path
	Accuracy	±10% of Class I profile survey
Rutting	Measure	Rut depth
	Calculation	1,640-ft. average based on 164-ft. values
	Unit	Average for both wheel paths
	Accuracy	±0.12 in of manual survey

Were the vendor to fail any of the acceptance criteria, on-site discussions and digital image reviewing with BCMoTI, pavement condition resurveying, equipment repairs and/or modifications, or retraining and/or replacing rating staff would be required.

Acceptance of Submitted Data

Three data acceptance processes are employed to ensure the vendor's submitted data is in accordance with the BCMoTI's expectations. If any discrepancies are found, they are provided to the vendor for correction.

- Manual Review: manual review to check that all road segments have data, traversal definitions, correct data file structure, start and end boundaries, lane references, no null or negative values, and are within tolerance parameters.
- Prior Year Comparison: current year data is compared to prior year data to ensure there are no unexpected changes in pavement condition.
- Pavement Management System Data Upload Tests: the PMS includes standardized and user-defined verification tests that are run once data is uploaded. If any errors are reported, the data is corrected and reloaded into the PMS.

Colorado Department of Transportation

The Colorado DOT developed a *Pavement Management Manual* in which the quality assurance (QA) protocol for verifying pavement management condition is detailed. The protocol instructs the contractor to carry out quality control (QC) in compliance with its own procedures while CDOT will review the quality of the data through two protocols, an office and a field review (Keleman et al. 2005).

Office QA Protocol

- Smoothness and rut data repeatability for 0.1-mile segments on each correlation is reviewed to verify the specified threshold values are met (variance for ride is 50 in/mile and 0.1 in. for rut). Whenever the variances are out of range, the contractor must recalibrate and rerun specific correlation sites.
- Images are checked randomly to assure clarity and ID flag/counter continuity. The first 500 miles of image data are meticulously checked, subsequently random spot checks are carried out for the upcoming deliveries. If unacceptable quality, clarity, or continuity is found in the images, they are returned to the contractor for repair or replacement.
- Random 0.1-mile condition data records are spot checked against the digital images, and quantified results are compared to the reported values to ensure they correlate properly. If poor correlation exists, the extent of the error is investigated and report to the contractor for reconciliation.
- A QA computer program is used to check for the following data faults:
  - Duplicated records.
  - Missing segments.
  - Wrong highway limits.
  - Missing highways.
  - Wrong pavement type.
  - Highway not in network.
  - Wrong raw data value: the distress values must not exceed the values listed in table 5.

When the software reports significant errors that cannot be addressed by CDOT personnel, the contractor is responsible for the investigation and restoration of the faulty data.

Table 5. Expected data value maximums (Keleman et al. 2005)

Distress Type	Maximum Threshold
Ride	800 in./mile
Rut	1.5 in.
Fatigue (total)	7,000 sq. ft.
Fatigue Low	7,000 sq. ft.
Fatigue Moderate	7,000 sq. ft.
Fatigue High	7,000 sq. ft.
Transverse (total)	150 ft.
Transverse Low	150 ft.
Transverse Moderate	150 ft.
Transverse High	75 ft.
Longitudinal (total)	3,000 ft.
Longitudinal Moderate	3,000 ft.
Longitudinal Moderate	2,500 ft.
Longitudinal High	1,000 ft.
Corner Break (total)	50 (count)
Corner Break Low	50 (count)
Corner Break Moderate	30 (count)
Corner break High	20 (count)

Field QA Protocol

- Previous year's condition data test sites list is reviewed and specific sites are added, removed, or modified as required.
- One section is chosen as an orientation site and all attending staff rate the cracking distress on this section together as a committee as accurately as possible (in compliance with FHWA 2014).
- The remaining test sites are rated in the field by two person teams (in compliance with FHWA 2014).
- All of the test site data is compiled and compared with the contractor's data to ensure the quality of the condition data. If significant unexplainable differences exist, the contractor may have to re-collect the data or the agency may reject the data.

Schedule

- Contractor typically begins data collection the first week of February and all condition data must be error free by the first week of July to input the data into the pavement management software.
- The contractor must submit weekly batches of data. Once submitted, CDOT has one week to analyze the data and report all the errors back to the contractor. The contractor then has one week to repair the errors and return the data to CDOT.
- Test site field rating should be completed before the finalized data is received from the contractor.

- CDOT must approve the annual condition data in July. Once approved, the QA protocols are compiled for the annual Condition Data Assurance Protocol report that must be completed by the end of August.

Louisiana Department of Transportation and Development

The Louisiana Department of Transportation and Development (LADOTD) maintains approximately 20,000 directional miles of highway. It has collected automated pavement condition surveys biennially since 1995.

Data Collection

Pavement data is collected for both directions on interstates and multi-lane divided highways and one direction for two-lane highways. Data shown in table 6 summarizes LADOTD's data to be collected and reported for every 0.1 mile of the surveyed length.

Table 6. LADOTD condition data (LADOTD 2011).

General Data	Asphalt Pavements	Concrete Pavements
• GPS Coordinates – Longitude – Latitude – Elevation • Bridges • Distance to overhead obstructions • Geometric data	• Alligator Cracking • Random Cracking – Longitudinal – Transverse • Block • Rut Depth • Patching • Blowup • Potholes • IRI	• Transverse cracking • Longitudinal cracking • Joint faulting • Concrete patching • Blowups • Punch-outs • IRI

The contractor must review the collected data for completeness on a daily basis. ROW images, raw data from the data collection vehicle, calibration test results, and sensor verification results must be delivered weekly. Whether an issue is found by LADOTD or the service provider, the contractor must resolve the issue.

QC Requirements

Preliminary activities required by LADOTD include developing a QC plan, personnel training and certification, and equipment calibration. The developed QC plan specifies the service provider's equipment be checked against a Class I profiling instrument prior to data collection, and during data collection, known IRI, rutting, and faulting QC sections are used.

Inter rater training must be completed and reported to LADOTD for review. This process ensures protocols are understood and that distress identification is correct and consistent across raters. Data collection vehicle crew members must also be trained to ensure the proper data collection methods are followed. Equipment calibration is carried out pre-data collection and during data collection to verify the equipment functionality is maintained throughout the collection process. Throughout the collection process, the collection vehicle is checked daily for proper calibration, operation, and maintenance.

Control site data are collected by the service provider to show repeatability (three runs minimum), then data is compared to the previous year's data to verify consistency and validity. When the data collection vehicle leaves the State or begins a new district, the control site must be revisited and the equipment verified. When the data collection vehicle must collect data while traveling towards the sun, while excessive water is on the roadway, while inclement weather is present, or while daylight is diminished, data for the control sites should not be collected. To avoid erroneous data collection, real time data checks are completed within the vehicle for rutting, IRI, GPS, faulting, and distance measuring equipment (DMI). As an additional check LADOTD reviews and evaluates pavement distress data for 5 percent of the control section length and divides the samples into 0.1-mile increments. Images are checked (using the service provider's proprietary software) to identify missing high severity distresses, missing 5 or more low/medium severity distresses, or incorrect distress type, severity or over-rating. Pavement surface and ROW images are observed during and after the day's collection to avoid re-runs. Also, LADOTD verifies clarity, minimum skipped images, proper lighting, and correct image "stitching".

Microsoft Access queries are utilized to check for the following data inconsistencies:

- Change in pavement type and/or texture from the previous year's survey.
- Sudden changes in roughness and/or rut depth (major improvement/deterioration).
- High quantities of distress with low roughness values and vice versa.
- Reasonableness of the maximum extent of distress.
- Segments that are incorrectly marked as a construction zone and lane deviation.
- Segments that are identified as a bridge, but not identified as such in the data.
- Control sections that are found to have a longer length than specified.
- Control sections where the service provider did not collect the required 0.1-mile lead in/lead out pavement length.
- Pavement segments with incomplete data collection.

Any inconsistencies or problems with the data must be documented, summarized in a report, and given to the service provider for revision to the LADOTD's satisfaction without additional cost. LADOTD specifies the minimum QC deliverables to be:

- All reports.
- All correspondences relating to the project.
- Abnormal calibration explanations.
- Data collection schedule adherence or changes.
- Vendor's key project personnel listing for data collection.
- Encountered issues that were addressed during the data collection.

- Improvement recommendations.

Acceptance Requirements

LADOTD's data collection quality control is carried out on three data components including ROW images, pavement images and rated distresses, and database checks. ROW images are evaluated for image quality, adequate section collection, and to verify that all sections have been sampled. Image quality is checked to verify compliance with the agency's standards for image clarity (highway signs must be readable and distresses evident), brightness (good lighting condition), dry pavement, image replay (maintain sequence), and there are no missing images.

To ensure accurate data collection, LADOTD checks the following series of items:

- Control sections' beginning and ending points must be checked to verify that data collection started and ended at the correct location. Whenever discrepancies exist, data must be recollected.
- Images for the first 0.10 mile (lead-in) should be checked. Distress images should be sampled throughout the entire control section.
- Measured length differences should be within 5 percent or less.
- Pavement images are evaluated based on the ability to identify proper distress type, severity, and extent. Images should be synchronized with ROW images (pavement type and texture should match) and should play in the correct order. For efficiency purposes, pavement distress image rating must be done with different colors, line types, and hatches.
- All sections must be sampled to verify proper rating and evaluation. The following criteria are used to verify proper rating:
  - Open a grid with the quantified data and review the numerical amount of a specific distress.
  - Query the database, filter the segments, and review the ratings.
  - Open the inventory view to show all rated distresses within a specific segment.
  - Randomly sample the control section (quickest and most efficient).

Control section sampling frequency (0.1 mile samples) is defined in table 7. When errors are found, LADOTD thoroughly reviews ratings to identify and report all errors to the service provider.

Table 7. Control site sampling frequency (LADOTD 2011).

Control Section Length	Sample Frequency
≤ 1 mile	2
> 1 and ≤ 5 miles	3
> 5 and ≤ 10 miles	5
> 10 and ≤ 15 miles	8
> 15 and ≤ 30 miles	13
> 30 miles	5% of control section length

To finish the acceptance process, the database is checked for completeness, significant changes with respect to previous year's value are evaluated, and compliance is verified within the agency's tolerances. GPS is plotted in a GIS map to compare against previous data and the pavement management software validates the database. If discrepancies are found they must be further investigated, documented, and reported to the service provider for resolution.

New Mexico Department of Transportation

The New Mexico Department of Transportation (NMDOT) maintains approximately 15,300 centerline miles on the State Highway System. Data is collected yearly for HPMS and NHS routes, the remainder of the network is collected on a two-year cycle. The entire length of the state maintained network is collected and reported in 0.1-mile increments in accordance with FHWA HPMS guidelines. NMDOT utilizes a QMP to ensure reliable, accurate, and complete condition data to support the agency's decision making and budget planning. The plan's details are outlined below.

Automated Distress Survey Scope

The contractor must submit roughness, rutting and pavement distress data in accordance with FHWA's HPMS.

- On flexible pavements, the contractor must measure severity and extent for the following distresses:
  - Raveling and weathering.
  - Bleeding.
  - L&T cracking (separate).
  - Fatigue cracking.
  - Edge cracks.
  - Patching.
  - Block cracking.
- On rigid pavements, contractor must measure severity and extent for the following distresses:
  - Corner breaks.
  - Faulting of transverse joints and cracks.
  - Joint seal damage.
  - Longitudinal cracks.
  - Patch deterioration.
  - Spalling of transverse and longitudinal joints and cracks.
  - Transverse and diagonal cracks.

Collection of pavement condition data must follow the series of general requirements listed below.

- Data is collected in the right hand driving lane only. Shoulders, turning lanes, unpaved roads, or roadways under construction must not be collected.
- On 2-lane highways, data must be collected in the positive direction only.
- On 4-lane highways, data must be collected in both directions.
- Data must be submitted for revision by NMDOT at the end of each week.
- Gouges and joints must not be considered as cracks.
- Contractor should list exceptions when:
  - Data collection sections are not in NMDOT's database.
  - Incorrect surface type is listed.
  - Sites could not be collected due to construction or obstruction.

<u>Additional Data Items</u>

- Roadway geometry
  - Horizontal and vertical curve information is recorded in a separate file from pavement condition.
  - Curve data should be synchronized with GPS and the spatial database.
  - Average grade, percentage of cross slope, and elevation should be provided for each 0.1 mile.
  - Roadway Location Data-Base:
    - ➢ Digital images must be individual files associated to GIS/GPS data. Each image should be clear, free of distortions, no parts of the vehicle should be visible, wide-angle, high resolution, and angled to include the entire roadway, shoulders, signs and as much right of way as possible.
    - ➢ Minimum accepted resolution is 1920x1080 pixels.
    - ➢ Horizontal aspect must achieve a minimum of 120-degree viewing angle per image.
  - Minimum number of images per mile is 200.
  - The photolog must be query-able and have a schedule along with it.
  - The photolog must be completed annually and correlate to the conditions of the roadway.
- Pavement Photolog
  - The contractor shall deliver to NMDOT a pavement imaging standard operating procedure addressing pavement image collection and storage QC. The procedure must be approved by NMDOT prior to commencing data collection.
  - Pavement images must cover 100 percent of the pavement from left lane stripe to right lane stripe as a minimum. Resolution of the images should be such that cracking distresses can be accurately quantified (must be able to resolve 1 mm cracks at 60 mph).
  - The photolog must be query-able.

  - Images will be segmented and synchronized with the 200 (minimum) per mile roadway images.
- GPS Coordinates
  - Longitude, latitude, and elevation data with a minimum accuracy level of 0.001 mile.
  - Must be synchronized with IRI, rutting, pavement distress, roadway curvature results, and roadway photolog in equal intervals of 200 (minimum) per mile.
- Number and Length of Lanes
- Surface Area
  - The count must be complete for the entire state and interstate roads.
  - Data must be extractable into a spreadsheet.
  - One surface area is defined as 12 feet wide by 1-mile long.
  - Width (from edge of pavement to edge of pavement) and length measurements must be to the nearest 2 percent.
- Shoulders
  - Length and width of both shoulders from edge of paint to edge of pavement.
  - Type of shoulder.
  - Report data for 0.1 mile intervals.
  - Record shoulders that terminate with curb and gutter along the 0.1 mile.
- Signs (location, longitude/latitude, text)
  - Location.
  - Longitude/Latitude.
  - Sign text.
  - *Manual on Uniform Traffic Control Devices* (MUTCD) code/ State Code.
  - Minimum of 90 percent of the signs must be identified with at least 90 percent accuracy for required sign attributes.
  - More than 10 percent failure rate is unacceptable.
  - Construction signs must not be inventoried.
  - New signs must be able to be input into the database.

Data Resolution (must meet specifications)

AASHTO and LTPP guidelines are enforced as a specification for automatic data collections. Minimum expected resolutions for collected data are shown in table 8.

Table 8. NMDOT resolution specification (NMDOT 2015)

Data Item	Required Resolution	Protocol
IRI	0.06 in/mile	LTPP
Rut Depth	0.01 in.	AASHTO
Fault Height	0.01 in.	AASHTO

Data Item	Required Resolution	Protocol
GPS Latitude and Longitude	0.00001 degree/0.001 mile	Agency

Data Accuracy and Repeatability

Data collection may be carried out only when conditions do not impact the rating (no rain, smoke, fog, snow, salt, etc.).

- Data Completeness
  - A minimum of 98 percent (collectable miles) of the total contracted miles must be delivered to NMDOT.
  - For the delivered data, 100 percent of the description items (system, route, direction, and location) must be populated and accurate, and 98 percent of the sections must be populated with data values.
- Data Accuracy
  - No more than 10 consecutive fixed segments must be missing. If this were not met, re-collection will be required. For the remaining 2 percent, a section must be re-collected if more than 2 percent of the length of the section is missing.
  - At least 95 percent of the delivered data must be within the accuracy specifications.

Pavement Images for QC

Up to 20 percent of the annual mileage collected on the NHS is reviewed by NMDOT. Independent analysis checks (distress type and severity) are performed on randomly selected segments (0.1 to 1 mile) through an analysis software provided by the vendor.

Profiling QC

- Calibrate sensor, accelerometer, and distance measuring systems. Perform daily checks on the profiler (bounce test and static height of sensor check).
- Clean lenses and check tire pressure prior to measuring.
- Set sensor spacing to meet the smoothness specification.
- Collect profile data along the path specified in the smoothness specification (avoid lateral wandering).
- Do not collect profile data outside the speed range specified for the profiler.
- Maintain a constant speed during data collection.
- Provide an adequate lead-in distance prior to test section to initialize data collection filters and to reach necessary speed. Strictly follow manufacturers' guidelines.
- Initiate data collection at specified location (utilize automated method when available).
- Do not profile wet pavements.
- Do not collect data on pavements that have surface contaminants (e.g., gravel, construction debris).
- Evaluate collected profile data for the presence of spikes.

Contractor Control Sites

Control sites are selected to ensure that diverse conditions exist for calibrating the equipment. Each site within the vicinity shall be run once a week by the QA provider and at least 3 times by the contractor to determine data accuracy and validity.

Acceptance of Deliveries

NMDOT receives data on a monthly basis and has 10 business days to review and report inconsistencies. Both photolog and tabular data review must be in compliance with the following guidelines:

- Navigating to section
  - Double click the selected route that contains the assigned section in the route list.
  - Pavement condition table and two Photolog Viewers (one for forward and one for downward images) should be open.
  - Click the green milepost sign on the toolbar to access the Jump to Mileage window. Enter the mileage in order for the photolog viewer to display it. Then back-up 1 frame to catch the section beginning.
  - When the pavement distress table is blank, select flexible or rigid, check the filter by Route, and click on the binoculars to load the tables.
- Verifying pavement condition
  - Drive the section while in photolog, noting any particular areas of concern.
  - Verify the distresses are consistent and within the following limits:
    - Raveling: values must sum to 528 ft.
    - Bleeding: maximum value should be 528 ft.
    - Maximum fatigue (alligator) cracking: 6336 sq. ft.
    - Maximum longitudinal cracking: 1584 ft.
    - Maximum edge cracking: 528 ft.
    - Maximum block cracking: 6336 sq. ft.
  - Verify forward facing and downward photolog's quality. If any segments require re-collection note the frame number.
- Additional Checks
  - Note any areas of concern in the photolog. In the route location tab, look at the milepoint of the area of concern. In the pavement tab, find the section that contains the milepoint in question, right click, and select jump to mileage and verify.
  - Find any locations that have large amounts, low amounts, or zero distresses, right click on one, and select jump to mileage to verify the distress. Find any data values that are improbable and correct them.
  - Construction zones should not have any distress information.

Data Validation and Acceptance Criteria

The average deviation about the median is the data validation and acceptance criteria for NMDOT's collection process. Each distress will have its own scale, as each distress has its own measurable attributes to be evaluated. For the control sections, the vendor is to do 5 separate runs at the beginning of each week on the three selected control sites to determine data reliability. If the measurements fall outside the limits, corrective action must be taken to resolve the problem before additional data is collected. The maximum tolerance percentage that any distress can differ is 10 percent.

NMDOT requires that several distresses be collected, and they rate severity on a 1-4 scale. If certain high severities are recorded, they require that the section be reevaluated to assure data accuracy. Variability for flexible and rigid pavement are limited for each distress. All data for sections are considered and the sections with the highest and lowest value measured will be compared. For the data to be accepted, 95 percent of these values must compare within 10 percent. NMDOT uses measured variability between production and QA site surveys to accept the following distresses.

- Raveling/weathering.
- Bleeding.
- Longitudinal cracking.
- Edge cracking.
- Block cracking.
- Patching.
- Alligator cracking.
- Transverse cracking.
- Rut depth.
- IRI.
- Corner break.
- Faulting.
- Joint seal damage.
- Longitudinal cracking.
- Patch deterioration.
- Spalling of joints and cracks.
- Transverse and diagonal cracks.
- Joint count (HPMS requirement).
- Percent cracking (HPMS requirement).

North Carolina Department of Transportation

The North Carolina Department of Transportation (NCDOT), which manages an 80,000 mile state roadway network, developed a QMP for network level pavement condition data collection. The QMP validates that deliverables are completed with an acceptable level of quality through identifying key activities, processes, and procedures.

Deliverables, Protocols, and Quality Standards

The NCDOT collects pavement data to monitor conditions and ensure an acceptable level of service to the network's users. To achieve these objectives, longitudinal and transverse road profiling, coring, falling weight deflectometer (FWD), dynamic cone penetrometer (DCP), skid testing, pavement cracking and distress data collection, and forward facing, downward facing, and right of way images are collected throughout NCDOT's maintained network. Pavement condition deliverables are performed by contractors; two different methods are used depending on the functional classification within NCDOT's network.

- Pavement condition data for primary routes (Interstate, US, and NC Highways) is collected with automated data collection vehicles (multiple vehicles).
- Pavement condition data for secondary routes is collected using the windshield method (using two-person data collection teams).

Quality standards are defined for each deliverable. Deliverable quality is determined based on compliance of the data with resolution, accuracy, and repeatability standards. Table 9 summarizes NCDOT's key deliverables, collection protocols, and associated quality standards based on the data collection process.

Table 9. NCDOT Deliverables, Protocols, and Quality Standards (NCDOT 2016).

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)
Profile Data Collection with State-Operated Equipment			
IRI (left wheel, right wheel, and average)	• ASTM E1656. • ASTM E950 Class 1, NCDOT Asset Mgmt. Plan for High Speed Profilers. • NCDOT Profiler testing and Calibration Procedures.	1 in/mi	• 90% or better agreement with reference profile for each of 5 runs, as defined in the NCDOT Profiler Testing and Calibration Procedures. • For weekly/monthly checks, mean IRI value in each wheel path within ± 5% of reference IRI value by wheel path.
Automated Condition Data for NCDOT Primary Routes			
IRI (left wheel, right wheel, and average)	• AASHTO R56-10. • AASHTO R43-13.	1 in/mi	• Bias and precision statistics calculated for control sites should be less than 5%.

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)
	• ASTM E950-09 Class 1. • NCDOT-approved IRI measurement standard operating procedure (SOP). • Data must be synchronized by time or distances for positive location.		• Location accuracy within 0.001 mile (5.28 ft.)
Rut depth (each wheel path)	• Maximum interval of 10 ft. • NCDOT-approved rut measurement SOP. • Data must be synchronized by time or distance for positive location.	0.01 in	• Bias and precision statistics calculated for control sites should be less than 5 percent. • Location accuracy within 0.001 mile (5.28 ft.)
Downward Pavement Image	• NCDOT-approved pavement imaging SOP. • Full 14-ft. view of pavement surface. • Uniform and consistent illumination required. • Downward and forward images synchronized to image the same location. • Data must be synchronized by time or distance for positive location.	1/8 in crack resolution at survey speed	• Image resolution must meet approval of NCDOT Project Manager. • Images bearing ambient or vehicle shadows that obscure pavement features will not be accepted. • Location accuracy within 0.001 mile (5.28 ft.)
Forward, rear, 360-degree, and ROW image	• NCDOT-approved pavement imaging SOP.	1/4 in wide cracking	• Image resolution must meet approval of NCDOT Project Manager.

Deliverable	Protocols	Resolution	Accuracy (compared to reference value)
	• Forward perspective and two side views clearly visible. • Forward perspective resembles windshield view. • Downward and forward images synchronized to image the same location. • Data must be synchronized by time or distance for positive location.	visible on pavement.	• Images may not be collected during times when visibility is continuously obstructed. • Location accuracy within 0.001 mile (5.28 ft.)
Pavement Distress Data	• NCDOT High Speed Distress Manual V1.0 11-15-2011. (NCDOT 2011) • Evaluate surface distress for 100 percent of pavement sections (continuous). • Data must be synchronized by time or distance for positive location.	None Specified	• Data to be reported for each 0.1-mile • Location accuracy within 0.001 mile (5.28 ft.)
Windshield Condition Data for NCDOT Secondary Roads			
Pavement Distress Data	• 2015 NCDOT Pavement Condition Survey Manual (NCDOT 2015).	None Specified	• Data loaded into data log maintained by NCDOT for roadway assignments.
Roadway Alignment Changes	• None	None	• Reported to NCDOT by occurrence.

Quality Control (QC)

Quality control activities focus on deliverables and processes to verify quality, completeness, and correctness. NCDOT separates QC measures by pavement data collection process, each with specific deliverables, quality expectations, QC activities, and frequency (see table 10).

Table 10. NCDOT quality control measures (NCDOT 2016).

Deliverable	Quality Expectations	QC Activity	Frequency/Interval
Profile Data Collection with State-Operated Equipment			
IRI (left wheel, right wheel, and average)	• 92% or greater repeatability • 90% or greater accuracy	Operator/Equipment NCDOT Control Site Certification	Once
	• Repeatability within 3% mean IRI for each wheel path • Accuracy within 5% of reference IRI for each wheel path	Operator/Equipment NCDOT Control Site Verification	Weekly/Monthly
Equipment Operation	Pass	• Bounce Test • Tire Pressure • Lasers Clean and Operating • Accelerometer Warmup	Daily
	Pass	• DMI Accuracy • Accelerometer • Test Runs on Control Site (see above)	Weekly
	Pass	• Block Test • Test Runs on Control Site (see above)	Monthly
Data Processing	Pass	File Processing Completion	Each Test
Process	Following operational guidelines.	Management Observation of Equipment Operation.	Random/Periodic
Automated Condition Data for NCDOT Primary Routes			
Staffing	Meet or Exceed Requirements as stated in contract.	NCDOT Project Manager confirm staffing meets stated requirements.	Confirmed at project award and ongoing.

Deliverable	Quality Expectations	QC Activity	Frequency/Interval
Sensor and Distress Data Assessment QC Plan	NCDOT Approval	NCDOT Review	At project commencement.
IRI, Rut, Distress Data	Data Consistency	Review for significant year-to-year change.	Continuous after first year.
Equipment Calibration	Data collected with calibrated equipment at all times.	Documentation of Weekly Calibration.	Weekly
IRI, Rut Data	• 0>IRI>500 – Reject • 30>IRI>300 – Investigate • 0>Rut>2.5 in – Reject • Rut>1 inch - Investigate	Investigation of data exceeding range checks.	Continuous
Startup Process	NCDOT approval of precision and bias on up to 20 sections.	NCDOT or agent review results of startup process.	Annual
Data Delivery	NCDOT Acceptance by May 15.	Data Delivery	Annual
Data Consistency	5 percent or less difference between vehicles.	NCDOT or agent review documentation of comparison.	Annual
Windshield Condition Data for NCDOT Secondary Routes			
Staffing	Meet or Exceed Requirements as stated in contract.	NCDOT Project Manager confirm staffing meets stated requirements.	Periodic/Routine
Equipment	Meet or Exceed Requirements as stated in contract.	Area coordinators review survey vehicle and equipment for conformance with contract requirements.	Periodic/Routine
Process	Follow General Guidelines per 2015 NCDOT Pavement Condition Survey Manual.	Area Coordinators review operations for adherence to guidelines.	Periodic/Routine
Data Completeness	100% Section Data Collection.	Confirmed with PCS Manager.	Bi-Weekly
Change Forms	100% section changes properly documented.	Review of error messages during processing.	Bi-weekly

Deliverable	Quality Expectations	QC Activity	Frequency/Interval
Complete and error free distress data and PCR	Error resolution/successful import to PMS.	Batch processing through data review programs.	Bi-weekly

Acceptance

Acceptance focuses on validating deliverables meeting the established quality standards, this process differs by route functional classification. An independent QA contractor evaluates primary routes, and secondary routes are evaluated by NCDOT area coordinators. For both cases, pavement distress are evaluated on 5 percent of the sections selected randomly. The vendor's pavement condition ratings will be accepted if at least 90 percent of the data is within a 10 point difference of the QA ratings. A secondary QA process is carried out by Division Engineers, who review ratings during their program needs assessment. Table 11 summarizes the acceptance range, testing, frequency, and actions if criterion is not met for each deliverable.

Table 11. NCDOT acceptance criteria (NCDOT 2016).

Deliverable	Acceptance (Percent Within Limits)	Acceptance Testing & Frequency	Action if Criteria Not Met
IRI, Rut Depth	500in/mi>IRI>0in/mi 2.5in>rutting>0in	Approved through the startup verification process and collected data verified for inconsistencies. If more than 1 vehicle was used for data collection, Bias and Precision statistics shall be calculated between the two vehicles in accordance with NCDOT regulations.	Reject deliverable; data must be re-collected.
Pavement condition ratings-primary roads	±10 points	90 percent of the contractor and independent quality assurance determined indices for randomly selected section are within 10 points.	Return deliverable for correction.
Pavement condition ratings-secondary roads	None Specified	5 percent of the contractor and NCDOT area coordinator determined distresses for randomly selected section are within 10 percent difference.	Return deliverable for correction.
Location Reference System (High Speed Primary Data Collection)	90 percent	Reported landmarks are within 0.01 mi for ground truth sections less than 1 mile in length and 0.05 mi for sections greater than 1 mile.	Return deliverable for correction.

Deliverable	Acceptance (Percent Within Limits)	Acceptance Testing & Frequency	Action if Criteria Not Met
Images	No more than 5 images within 100 continuous images shall be inferior in quality.	5 percent sample inspection upon delivery.	Reject deliverable; images must be re-collected.

Quality Team Roles and Responsibilities

Roles and responsibilities for the data collection team are specified prior to beginning data collection. Table 12 serves as an example of the quality team roles and responsibilities for a specific NCDOT project.

Table 12. Example of NCDOT Quality Team roles and responsibilities (NCDOT 2016).

Team Role	Assigned Resource	Quality Management Responsibilities
State Pavement Management Engineer	Judith Corley-Lay	Oversee the activities of the Pavement Management Unit; address concerns and make corrections as required; report condition and progress towards objectives to State management.
State Pavement Management Systems Engineer	Randy Finger	Oversee the automated data collection and data submission by the data collection contractor to the State Pavement Management Unit.
Pavement Systems Engineer	Camille Coombes	Process and enter automated and windshield pavement condition data in to the pavement management system.
State Pavement Data Collection Engineer	Matt Hilderbran	Oversees data collection activities on secondary routes. Manages activities of four Area Coordinators. Oversees technicians responsible for State collection of profile, friction, FWD, and coring.
Area Coordinator	Steve Hinnant; Jeff Chinlund; Others	Oversees collection for windshield survey data collection teams. Conducts annual training for teams. Performs random surveys for quality control and records results on dedicated State laptop computer.
Independent Quality Assurance for Automated Data Collection	Morian Properties	Review 100 percent of delivered data for completeness and reasonableness. Review 5 percent of delivered distress data for conformance with Data Quality Manual. Review sensor calibration results. Review weekly and monthly vendor status reports. Provide Summary QA reports.
Automated Data Collection Vendor Quality Control	Quality Assurance Manager	Implement Vendor Quality Control Plan. Assure personnel certification training, validation of equipment accuracy and

Team Role	Assigned Resource	Quality Management Responsibilities
		precision, daily QC procedures, and routine QC procedures. Provide weekly calibration schedule and maintain records of calibration.

Quality Reporting Plan and Acceptance of QM Plan

All quality management activities must be documented. Quality is monitored through acceptance testing and issues are reported as soon as they are discovered. NCDOT has standard QC and acceptance logs to itemize, document, and track items reported throughout the QC and acceptance processes (see table 13).

Table 13. NCDOT example of QC and acceptance logs (NCDOT 2016).

QC Log						
ID Number	**Review Date**	**Deliverable Reviewed**	**Location Information**	**Findings**	**Resolution**	**Resolution Date**
QC-1						
QC-2						
QC-3						
QC-4						
Acceptance Log						
ID Number	**Review Date**	**Deliverable Reviewed**	**Location Information**	**Findings**	**Resolution**	**Resolution Date**
Accept-1						
Accept-2						

Final QM reporting is done by both the data collection team and the pavement management engineer. The data collection team provides the final database and other deliverables, including a copy of QC logs; a summary of scope and schedule; a list of the collection vehicles and personnel used on the project; documentation of equipment calibration and maintenance; results of all control, verification, and blind site testing; and documentation of other problems encountered along with corrective actions taken. The pavement management engineer, upon acceptance of the final products, prepares a Quality Management Report (when applicable a copy is provided to the vendor for review and feedback) including a summary of scope and schedule; a description of control, verification, blind-site testing; a description of all global and sampling tests performed with the results; and recommendations for improvement.

Acceptance of QM Plan

A signature page is prepared for the NCDOT representative and the contractor to sign accepting the quality management plan terms and conditions.

Oklahoma Department of Transportation and Development

Oklahoma DOT (ODOT) maintains approximately 12,300 centerline miles of highways. The agency has utilized PMS as a project prioritization tool since 2001. To have a robust and dependable PMS, pavement condition data, geometric data, and video are collected annually for interstates and NHS routes and the remaining routes are collected biennially.

Data Collection

Data collection is executed over the entire length of the network at 0.01-mile increments following AASHTO standards and ODOT's pavement management distress rating guide [11]. Data items collected are summarized in table 14.

Table 14. ODOT condition data (ODOT 2009).

General Data	Asphalt Pavements	Jointed Concrete Pavements	Continuously Reinforced Concrete Pavements (CRCP)
• Surface type • Macrotexture • Roadway geometrics • Cross slope • Radius of curvature • Longitudinal grade • GPS Coordinates • Roadway events • Bridges • Railroad crossings • Approach slabs • Construction • Lane deviation • Detours	• IRI • Rut depth • Transverse cracking • Fatigue cracking • Miscellaneous cracking • Asphalt patching • Raveling	• IRI • Fault (average) • Transversely cracked slabs • Longitudinally cracked slabs • Multi-cracked slabs • Spalled joints • D-cracked joints • Corner breaks • Asphalt patching • Concrete patching • Number of joints	• IRI • Longitudinal cracking • Punch-outs • Asphalt patching • Concrete patching

ODOT establishes requirements for accuracy, resolution, and repeatability of the service providers collected data. Table 15 summarizes the agency's expected data quality.

Table 15. ODOT's data quality requirements (ODOT 2009).

Data Element	Minimum Required Accuracy	Required Resolution	Required Minimum Repeatability
IRI	± 5 percent compared to dipstick or Class I profiler	1 in/mile	± 5 percent run to run for three repeat runs
Rut Depth	± 0.08 in. compared to manual survey	0.01 in.	± 0.08 in. run to run for three repeat runs
Faulting	± 0.08 in. compared to manual survey	0.01 in.	± 0.08 in. run to run for three repeat runs
Distress Ratings	± 10 percent compared to ODOT ratings	N/A	N/A
GPS Coordinates	0.00005 degrees compared to ODOT provided coordinates	0.000001	N/A

As part of the pre-selection process, prospective service providers are required to collect four 0.5-mile-long control site sections (two jointed concrete and two asphalt pavements). A collection file describing each control section to be collected with a physical description, beginning- and end-point GPS coordinates, and a GIS shapefile will be provided. Each service provider is required to collect and submit the following data:

- Video log images: pavement (100 percent coverage) and two ROW (0.005-mile intervals or 200 images per mile) views for the entire control site.
- GPS data: latitude and longitude for the beginning of each 0.01-mile interval for the entire control site.
- IRI data: left, right and average of the wheelpaths for 0.01-mile intervals.
- Rut depth data: left, right, average, maximum, and percentage of rut measurements less than 0.5 in wheelpath for each 0.01-mile intervals. Rut depth measurements should not be spaced further than 10.56 ft. longitudinally with a minimum of five measurements every 0.01 mile.
- Faulting data: average, maximum, number, and standard deviation for each 0.01-mile interval.
- Geometric data: for each control site provide longitudinal grade, cross slope and curve radius for each 0.01-mile interval.
- Distress data: processed distress ratings for the control sites at 0.01-mile intervals.
- A detailed QC plan covering all data elements; procedures to detect malfunctions and errors; a diagnostic schedule; and error reporting and correction during data collection, processing, reduction, and delivery processes.

Control and verification sites established by ODOT must be collected once before production, and weekly during production. The agency staff will witness the site data collection from within the collection vehicle. The data and video will be analyzed, inspected, and compared to the reference values at the central office. The vendor will be notified if any issues are required to be addressed prior to continuing data collection.

Acceptance

ODOT performs quality checks during and after collection. During collection, the control and verification sites are monitored. After collection, automated checks, sampling of data and video, and GIS checks are carried out. A QA tool is utilized to identify data and distress ratings that may be out-of-range, inconsistent, or missing. The tool combines the data validation into four groups, and records suspected problems that require user adjustments or vendor re-rating.

- Preliminary checks: evaluating allowable values for general information.
- Sensor data checks: identifying duplicates and values outside the expected range for IRI, rutting, faulting and micro texture data.
- Distress rating checks: verifying expected ranges for individual distresses and combinations.
- Special checks: reviewing maximum asphalt patch length, non-matching distress types, and expected number of railroad crossings and bridges per segment.

Video images are checked through the service provided software. Video from one or two routes traversing the state are reviewed to verify segment continuity and sequence. If errors are found, the vendor would resolve them. The final QA check is done through GIS. The collected data is plotted on a base map to verify there are no missing segments or inaccurate beginning and ending points.

Quality Management Reporting

ODOT develops a yearly data quality evaluation report after acceptance quality checks are completed. The report must contain the following:

- Background: project scope, service provider information, collected network miles, and deliverables.
- General information: collection schedule, equipment used, and communication problems.
- Sensor data quality: control and verification site descriptions, reference values, procedures for initial and subsequent control and verification testing, and testing results for each data collection vehicle.
- Other sensor data quality: identified issues in location, geometric, or GPS data.
- Distress data quality: identified distress rating quality issues.
- Video quality: views collected and identified quality issues.
- Conclusions: encountered problems, corrective actions, or other resolution.
- Appendices: reference values for control and verification sites; control and verification site testing results for each data collection vehicle; IRI graphs from control site testing; and suspected quality issues identified with the QA Tool, including the investigation results and actions taken.

Corrective Actions

The agency withholds 2.5 percent of the total contract amount until final data quality acceptance. If a problem is identified during the data collection process, the service provider is required to stop collection, solve the issue, and recollect the data obtained since the last successful control or verification site was confirmed. If a problem is discovered after collection has been completed, a discussion between ODOT and the vendor is held. When problems relate to distress ratings, data is often re-assessed. Segmentation problems, special item counts, and geometric data can be corrected during data reduction. However, when data cannot be easily corrected, the vendor must re-collect the data (problematic segments may be resurveyed the following year if the same vendor is to be used).

Pennsylvania Department of Transportation

Pennsylvania Department of Transportation (PennDOT) began automated data collection in 1997 for the Systematic Technique to Analyze and Manage Pennsylvania's Pavements (STAMPP) Program. The agency maintains approximately 27,000 miles of pavement. Data collection contracts require the vendor to fulfill the agency's requirements for video images, profile testing, and roadway component location.

Data Collection

Automated data collection is performed annually on the interstate and NHS routes and biennially for all non-NHS routes. Condition assessments must meet the requirements stated in the Automated Pavement Condition Survey Field Manual Procedure (PennDOT 2011).

PennDOT conducts annual profiling on all interstate routes and all agency-maintained, newly-surfaced roads. Video logs are only required for asphalt and jointed-plain concrete pavements (JPCP). Unpaved roads, shoulders, guide rail, and drainage are manually surveyed. Table 16 summarizes the data items collected for PennDOT.

Table 16. PennDOT condition data (PennDOT 2010).

General Data	Asphalt Pavements	Concrete Pavements (distress type and extent)
• Location (determined by GPS) • County • State Route • Segment • Offset • Latitude • Longitude • Optional Data • Geometric information	• IRI • Rut depth • Transverse cracking • Fatigue cracking • Miscellaneous cracking • Bituminous patching • Raveling/weathering • Edge deterioration • Left edge joint	• Joint faulting • Broken slabs • Transverse joint spalling • Transverse cracking • Longitudinal joint spalling • Bituminous patching • Concrete patching • Rut depth

General Data	Asphalt Pavements	Concrete Pavements (distress type and extent)
• Rumble strip locations, other feature types, and locations		• IRI

Longitudinal profile is measured at least every 6.0 in. for both wheelpaths and the average of both for each 0.1-mile is reported. For jointed-plain concrete pavement, IRI data is used to determine broken slabs by analyzing data within a 20-ft. moving window. Rutting is collected and reported independently for each wheel path at a 30-ft. sampling interval. Severity levels are assigned to each sample as follows:

- Low average rut depth: less than 0.5 in.
- Medium average rut depth: between 0.5 in. and 1.0 in.
- High average rut depth: greater than 1.0 in.

Digital images are available to view on either the VideoLog or the proprietary VisiData software.

Quality Control Processes

PennDOT performs QC on more than 675 miles of those surveyed annually using the downward images from the service provider. The process includes evaluating calibration sites, blind verification sites, and randomly sampled segments (2.5 percent). Calibration site evaluation must be conducted prior to commencing data collection. PennDOT and the service provider’s data is compared and must agree within 10 percent (number of distress occurrence, severity, and extent). Whenever discrepancies are found, the service provider must re-collect the data and submit it for reevaluation. Blind verification sites are conducted during the data collection process. As the name implies, the service provider does not know the site locations—the agency discloses them after the sections have been collected. The calibration site protocol is used for blind verification sites also.

Random sites (2.5 percent of the collected data) are selected by PennDOT for evaluating the vendor’s collected data. The first batch of the vendor’s collected data are considered random sites. Collected data is compared to values determined by PennDOT in the same manner they are for calibration and blind location sites. PennDOT conducts data checks to ensure the acceptance criteria (see table 17) are met for each batch of vendor’s data received (between 750 and 5,000 miles).

Table 17. PennDOT’s acceptance criteria (PennDOT 2011).

Reported Value	Initial Criteria (within agency values)	Percent Within Limits	Action Criteria (if not met)
IRI	± 25%	95	Reject deliverable
Individual distress severity combination	± 30%	90	Provide feedback and retrain on distress definitions
Total fatigue cracking	± 20%	90	Reject deliverable

Reported Value	Initial Criteria (within agency values)	Percent Within Limits	Action Criteria (if not met)
Total non-fatigue cracking	± 20%	90	Reject deliverable
Total joint spalling	± 20%	90	Reject deliverable
Jointed concrete pavement transverse cracking	±20%	90	Reject deliverable
Location – segment and offset	Correct segment	100	Return for correction
Location – section begin	± 40 ft.	95	Return for correction and system check
Panoramic images	Legible signs	80	Report problem and reject subsequent deliverable

Individual distress data are plotted for the current and two previous years' data collection. If discrepancies are found, the data for all segments in the batch must be reviewed by the vendor. Subsequently, a comparison of required funds for maintenance is carried out. The analysis is used to observe which batches of data are more likely to have a significant difference in cost needs compared to values determined by PennDOT. The first analysis utilizes the average differences in maintenance costs calculated based on the agency and the service provider's distress ratings. The second analysis includes an evaluation of the precision of the data, this is defined as the difference between the vendor estimated maintenance needs and those determined by the agency.

Data Edits

Upon finalization of QC (including vendor discrepancies correction), PennDOT conducts the following data validation prior to uploading the data into the roadway management system.

- Duplicate checks: must be removed prior to processing additional checks.
- Survey date: year, month, and day checked to verify testing dates.
- Invalid keys: confirm there are no unexpected or incorrect values.
- Missing segment: confirm there are no missing segments.
- Construction, bridge, lane deviation, and miscellaneous flags: assure these items are properly coded in the database.
- Administrative data: verification of state route data matches service data for "turn-back" and closed to traffic roadways.
- Surface type: confirm data provider recorded surface type correctly.
- Condition versus segment length: for each segment's distresses, the severities are summed and compared to the segment length. Whenever the difference is greater than 2.7 feet, the segment must be corrected.

Summary

This section summarizes key information on quality management of pavement condition data collection in seven other state DOTs and one ministry of transportation in Canada. The literature mainly focused on the processes, protocols, and specifications employed before, during, and after data collection.

The majority of transportation agencies have well established data quality protocols for pre-production, production, and post production with specifications for both HMA and PCC pavements. Typically, throughout the literature, the measured data are ride quality (IRI), skid resistance, and pavement distresses. For pavement distresses, rutting and cracking (all forms) are the predominant condition parameters. Other distresses such as bleeding, raveling, potholes, and shoving for asphalt pavements are collected by some agencies, while cracking and faulting are commonly used for concrete pavements. Agencies track variability using different metrics. Index values reviewed by the Alabama and the New Mexico DOTs use variability measures for individual distresses. Both offer a valid evaluation to quantify the differences between production values and QA values for acceptance decisions.

Some DOTs survey their entire network on an annual basis while others do it biennially. Automated and semi-automated data collections have become the common trend in these agencies while NCDOT utilizes a combination of automated and windshield data collection methods depending on the functional classification (primary vs secondary roads) of the section. According to the analyzed literature, data reliability is a critical aspect when utilized for a PMS since its ultimate goal is to aid the agency in budget planning and decision making. It is for this reason that QMPs for pavement condition data collection have become a necessity for DOTs.

PAVEMENT MANAGEMENT MANUAL DEVELOPMENT

The *Pavement Management Manual* (PMM) shown in Appendix A consists of ten chapters and nine appendices. The purpose of the PMM is to document the procedures and protocols related to the various activities that the pavement management group is responsible for in a single reference document for use by MDOT personnel. This document serves as a comprehensive source of information that includes:

- Pavement management systems components.
- Pavement management benefits and role at MDOT.
- Pavement management program roles and responsibilities.
- Annual schedule for pavement management activities.
- Pavement management legislative and policy directives (federal and agency requirements affecting pavement management).
- Program definitions and data dictionaries.
- Data collection protocols, pavement condition assessment, and data quality.
- Performance modeling.
- Treatment decision trees and life cycle cost analysis.
- Pavement management reporting.
- Future improvements.

MDOT supplied many source documents that were used to develop the Manual. The PMM also references and contains several appendix documents that provide supplemental information regarding pavement management practices. The appendixes are independent and may change with some regularity as new data collection contracts are entered and data quality practices change. The PMM is formatted to be a stand-alone manual used by MDOT to conduct routine department wide operations.

QUALITY MANAGEMENT PLAN DEVELOPMENT

The QMP referenced in Appendix E of the *Pavement Management Manual* (Appendix 1) of this *Final Report* was developed following the *FHWA Practical Guide for Quality Management of Pavement Condition Data Collection* according with the information provided by MDOT. Best practices and quality management plans from successful DOTs (from a data quality management stand point) were considered when developing the end product. The plan includes responsibilities for each stakeholder in the process (e.g., the agency pavement management office, the data collection team) to complete during collection phases (e.g., pre-production, during production, and post production.) Any identified gaps in the information provided were consulted with MDOT prior to completing the plan. The key features present in the QMP are detailed below:

- The data collection deliverables subject to quality review, along with protocols and quality standards used to determine a successful outcome for a deliverable.
- The quality control activities utilized to monitor, provide feedback, and verify that deliverables meet the defined quality standards.
- The acceptance testing that determines if quality criteria are met and what corrective actions should be taken whenever the criteria are not met.
- The quality-related personnel roles and responsibilities per activity.
- The process and format for documenting completion of all QM activities (quality standards, quality control, acceptance, and corrective actions).

The QMP document is formatted to be included in the MDOT data collection contract if desired, and is housed as an appendix to the PMM.

CONCLUSIONS AND RECOMMENDATIONS

This project produced two important forms of documentation for pavement management personnel at MDOT. The PMM documents existing pavement management practices and lists the models incorporated into the PMS. As MDOT faces routine staff transitions to new roles, the *Manual* serves as a benchmark to facilitate the transitions as smoothly as possible. A second document, the QMP, outlines the quality control and acceptance criteria that should be followed to ensure that the most reliable data possible is loaded into the PMS.

Applied Pavement Technology recommends a series of tasks for the agency to carry out in the future to further strengthen its pavement management practices. These tasks listed below will promote agency development through collaboration from the respective divisions.

- Develop statistics based on the reports from the QMP that allow for their inclusion in data collection contracts. Statistics were previously collected for smoothness, faulting, rutting, and friction. These are used for comparison to control site data to qualify the data acceptance. This recommendation will allow data driven updates on the default specification included in the QMP and an overall improvement in data quality.
- Collect blind section distress using three different replicates: MDOT, the selected contractor, and a verification contractor (independent data collector). The latter collector will aid in verifying “true” values for every section as well as settling disputes between the DOT and the contractor.
- Implement a protocol for streamlining pavement management data throughout MDOT. Regardless of the collection cycles, or sections a division is accountable for, data collection processes, quality control, and quality assurance should be consistent throughout the agency.
- Review performance models every 3 years. Quality data leads to more accurate performance models, therefore it is necessary to calibrate new performance models as new data becomes available.
- Review and revise the data QMP in 3 years. Collecting comparison data for two cycles should provide variability statistics that can then be incorporated into the data collection contract. Since the contract and QMP complement each other, both should be revised as better statistics allow.

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APPENDIX 1: MISSISSIPPI PAVEMENT MANAGEMENT MANUAL

PAVEMENT MANAGEMENT MANUAL

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CHAPTER 1. INTRODUCTION

Purpose of the Manual

The Mississippi Department of Transportation (MDOT) is responsible for collecting, managing, analyzing, and reporting pavement-related data on the State's highways that drives key decisions. The purpose of the *Pavement Management Manual* (PMM) is to document the procedures and protocols performed by the Research Division's pavement management group in a single reference document.

Contents

The PMM consists of ten chapters (including this introductory chapter) and nine appendices. A brief summary of the contents of each chapter is provided in table 1-1.

Table 1-1. Pavement Management Manual content.

Chapter	Contents
1. Introduction	• Purpose and How to Use the Manual
2. Pavement Management Fundamentals	• Introduction and Benefits to Using Pavement Management • Role of Pavement Management at MDOT
3. Pavement Management Program Overview	• MDOT Pavement Management Roles and Responsibilities • Annual Schedule for Pavement Management Activities
4. Pavement Management Legislative and Policy Directives	• Federal Requirements Impacting Pavement Management • Agency Requirements Impacting Pavement Management
5. Program Definitions and Data Dictionaries	• Network Tier Definitions • Distress Identification References • Pavement Condition Index Calculation References • Data Dictionary References
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10. Future Improvements	• Planned Improvements, Responsibilities, and Deadlines
Appendix A	Distress Classification Guide
Appendix B	Data Dictionary
Appendix C	Pavement Condition Index Calculation Manual
Appendix D	Current Data Collection RFP
Appendix E	Data Quality Management Plan
Appendix F	Prediction Model Development Guide
Appendix G	Performance Models Used in PMS
Appendix H	Treatment Decision Trees
Appendix I	MDOT Reports

How to Use the Manual

This document is intended to be used as a reference guide, with each chapter being a stand-alone section that the reader can refer to for specific information. The document is intentionally brief, providing pointed guidance and information on key pavement management activities at MDOT. The target audience for the manual includes MDOT management and executives, MDOT field staff who participate in developing pavement projects, and the pavement management group who may use the manual as a reference to orient new staff or other stakeholders.

The first five chapters provide general background information on the fundamentals of pavement management, role of pavement management at MDOT, legislative and policy directives, and definitions. Information on the data collection-related activities can be found in chapter 6. Chapters 7 and 8 provide information on pavement performance modeling and treatment selection. Reporting requirements and templates are discussed in Chapter 9. Chapter 10 provides an overview on the planned improvements.

The PMM is intended to be periodically updated to address changes in staff roles and responsibilities, additional or different data collection and management practices, improved processes, and to maintain alignment with agency objectives.

CHAPTER 2. PAVEMENT MANAGEMENT FUNDAMENTALS

Introduction to Pavement Management

State highway agencies are responsible for maintaining their pavement infrastructure in a cost-effective manner. Careful management of the pavements has become increasingly important as road networks continue to age and there is increasing competition for funding. To manage the pavement network under these conditions, agency personnel seek answers to the following types of questions.

- What pavements should we address first?
- What is the best use of available funds?
- What annual budget do we need to keep our pavement network at its current condition over the next few years?
- How are our pavement conditions performing over time?
- Are we better off spending our money on pavements in very poor condition or letting those bad pavements deteriorate while we concentrate on keeping good roads in good condition?

To answer these type of questions, pavement management practitioners developed the first pavement management system (PMS) in the 1970s. In simple terms, a PMS is a systematic process that: 1) assesses the current pavement condition, 2) predicts future pavement condition, 3) determines maintenance and rehabilitation needs, and 4) prioritizes these needs to make the best use of anticipated funding levels (i.e., maximizing benefit while minimizing costs).

The importance of identifying not only the best repair alternative but also the optimal time of repair has been documented in U.S. Army Corps of Engineers, Construction Engineering Laboratory (USACERL) Technical Report M-90/05 and is summarized in figure 2-1 (Shahin and Walther 1990[1]). This figure shows that over the first 75 percent of the pavement life, approximately 40 percent of the pavement condition deterioration takes place. After this point, the pavement deteriorates much faster, with the next 40 percent drop in pavement condition occurring over the next 12 percent of the pavement life. The financial impact of delaying repairs until the second drop in pavement condition can mean repair expenses four to five times higher than repairs triggered over the first 75 percent of the pavement life.

MDOT implemented Deighton's Total Infrastructure Management System (DTIMS) as their pavement management system in 2016. The new system used data collected and incorporated models developed under the legacy PMS to maintain consistency and compatibility.

[1] Shahin, M.Y and J. A. Walther. 1990. *Pavement Maintenance Management for Roads and Streets Using the PAVER System*. USACERL Technical Report M-90/05. Construction Engineering Research Laboratory, US Army Corps of Engineers, Champaign, IL.

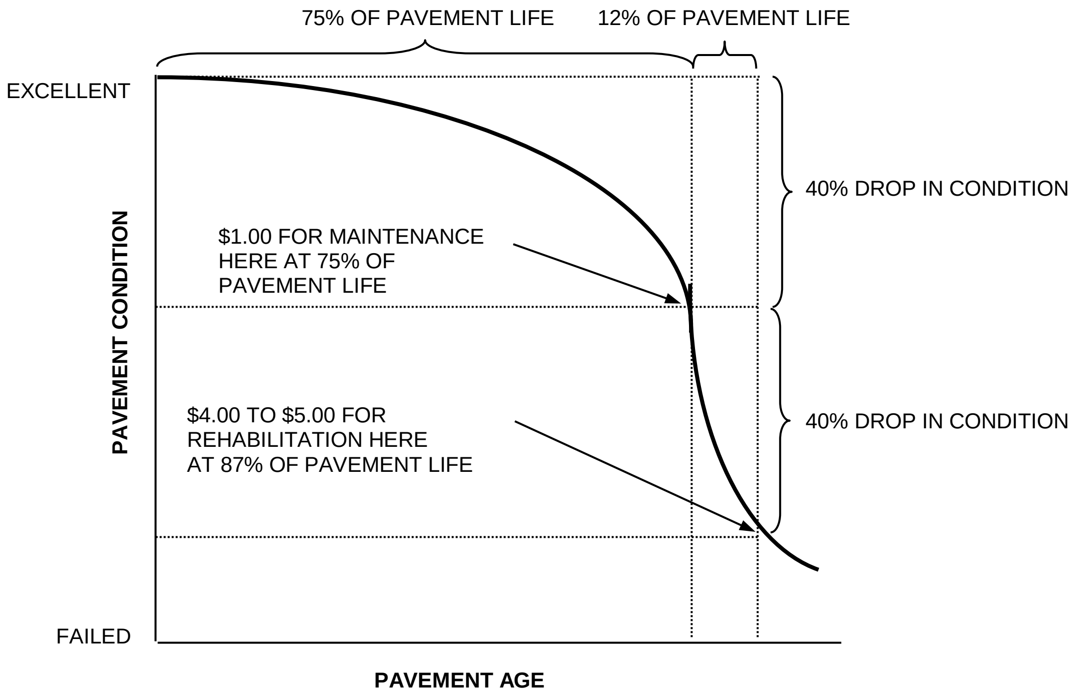

Figure 2-1. Typical pavement condition life cycle (Shahin and Walther 1990).

General PMS Components

A PMS is comprised of six basic components, as shown in figure 2-2. To illustrate the general concepts of the PMS approach, each of these different components is discussed in more detail below.

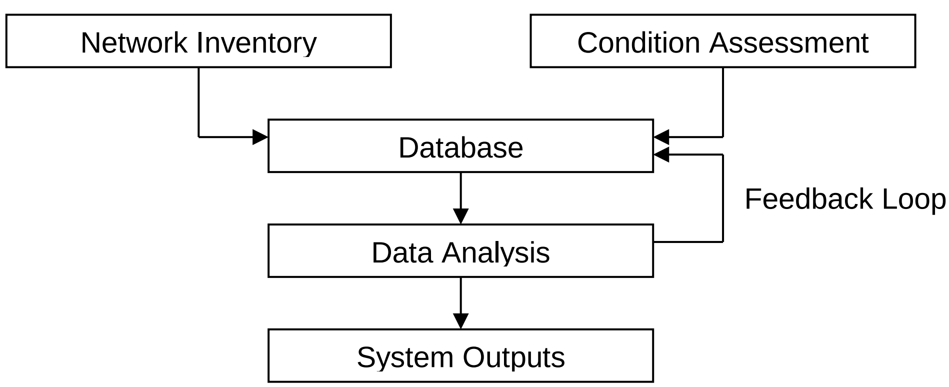

Figure 2-2. Basic components of a PMS.

Figure 2-3 was developed to highlight the PMS process in use by MDOT.

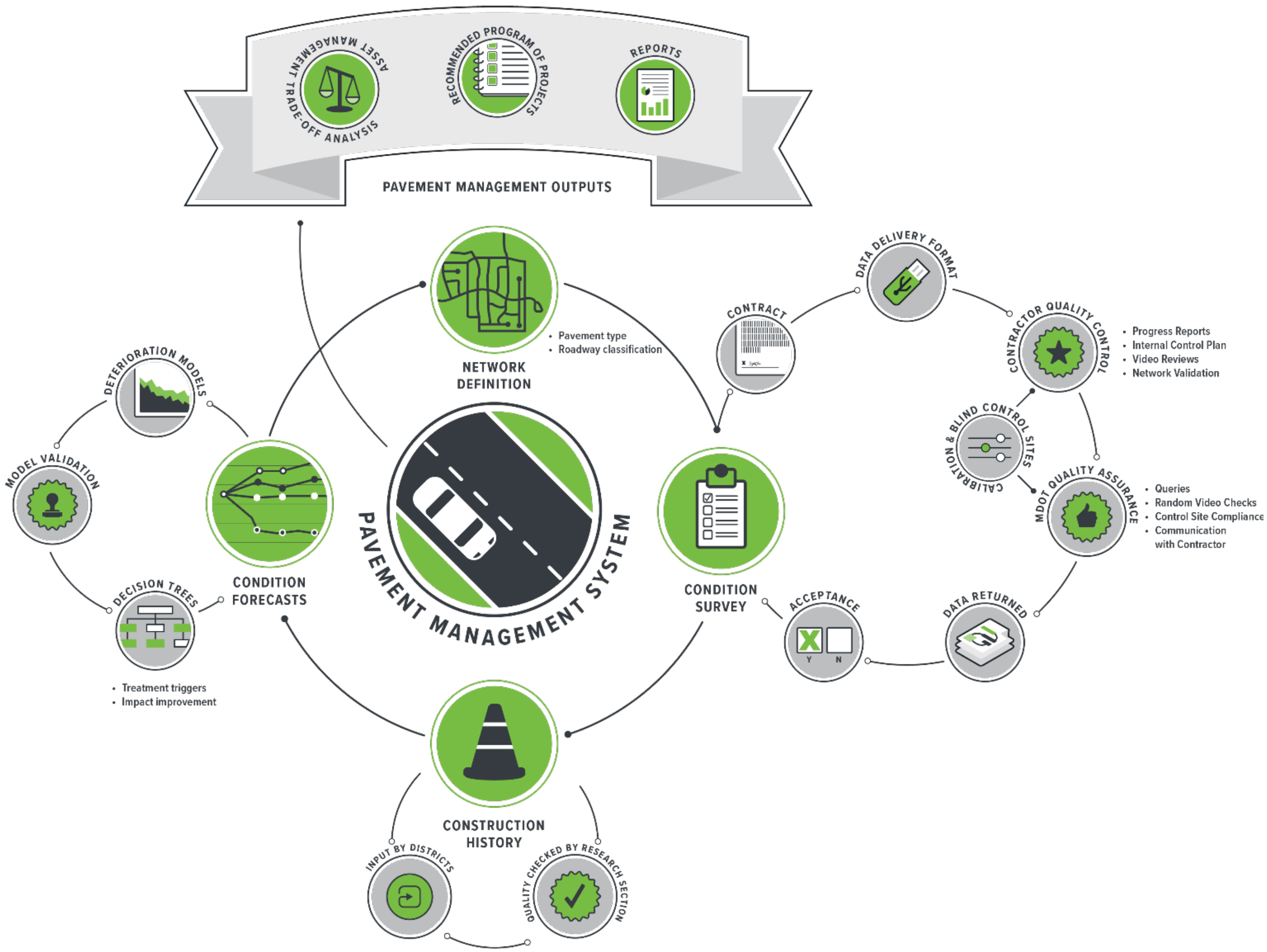

Figure 2-3. Characteristics and benefits of a pavement management.

Network Inventory

Network inventory is used to define the physical pavement characteristics being managed. Typically, the collected information includes construction, maintenance, traffic, and condition data. Although there is flexibility in the amount of information that must be collected and the manner in which it is stored in a PMS database, there are some types of information that are mandatory. The following list outlines the types of information that must be collected in order for the system to operate correctly:

- *Pavement location*—Physical pavement locations in the field.
- *Pavement dimensions*—Pavement section length, width, and/or area.
- *Surface type*—Describes the pavement surface/structure (e.g., asphalt, concrete)
- *Construction history*—Date of original construction, last major rehabilitation, such as reconstruction or an overlay.

Examples of other information that is beneficial to record in a PMS database are included in the following list (note that this list is not comprehensive, nor does MDOT have all these elements):

- *Pavement cross-section*—Information on the thicknesses and material types of each pavement layer.
- *Traffic*—Types and levels of traffic.
- *Maintenance history*—Date, type, and cost of maintenance activities performed on the pavements.
- *Testing data*—Coring, boring, deflection, friction, roughness data, and so on.
- *Drainage facilities*—Type and location of drainage facilities.
- *Shoulders or curbs*—Type and location of shoulders or curbs.

Condition Assessment

Pavement management decisions depend on some method of pavement evaluation. The method selected to evaluate pavement condition is extremely important because it is the basis of project and treatment selection recommendations. For that reason, it is critical to select an objective and repeatable procedure so that PMS recommendations are reliable. Pavement managers must evaluate their needs when determining not only the type of condition data to collect, but also how often to collect the data. A data quality management plan is structured to ensure that condition data is collected in accordance with defined processes and only accepted after a review for quality.

Database

Once the network inventory and pavement condition data have been collected, a database can be established to store and use the information. Although a manual filing system may be possible for a small network, the efficiency and cost-effectiveness of storing data on a computer makes an automated database the most practical alternative, especially with the size and complexity of a state pavement network.

Data Analysis

Data analysis can occur at the network- or project-level. At the network level, potential system preservation and rehabilitation needs are evaluated and prioritized for planning and scheduling within budget constraints over a multi-year period. The objective of a network-level analysis is to evaluate systemwide treatment needs to determine the best use of limited funds available for maintenance, preservation, and rehabilitation. After the recommendations have been made during the network-level analysis, the information in the database can be used to supplement a project-level analysis. At the project-level, more detailed information about the project can be used to design the appropriate treatment.

System Outputs

Results of planning analyses are useful only if the information provided can be easily conveyed. There are a number of different methods for presenting the analysis results, including tables, reports, graphs and maps. Due to the voluminous information contained in a PMS, graphical reports are generally more effective than comprehensive project reports for people who need to quickly evaluate large amounts of data.

Many agencies have found value in linking their PMS to maps to display information through geographical information systems (GIS). As with the graphical display, this capability has greatly enhanced the usefulness of PMS data within agencies that need to convey complex information in a short period of time. GIS links are perhaps most useful in displaying the funded projects in each analysis year and for displaying pavement condition results along with planned work or maintenance needs for other assets being managed by the department to help with cross-asset project scoping decisions.

Feedback Loop

An often-overlooked component of a PMS is the development of a feedback loop. The feedback loop establishes a process by which actual performance and cost data are input back into the models used in the pavement management analysis. For example, the PMS may use models that estimate the life of an asphalt overlay at 12 years. Actual performance data may show that the life of the agency's overlays is closer to 8 to 10 years. This type of information should be used to update the pavement management models so that the system recommendations remain reliable and become improved with time.

Benefits of Pavement Management

Figure 2-4 summarizes the main characteristics and benefits of pavement management.

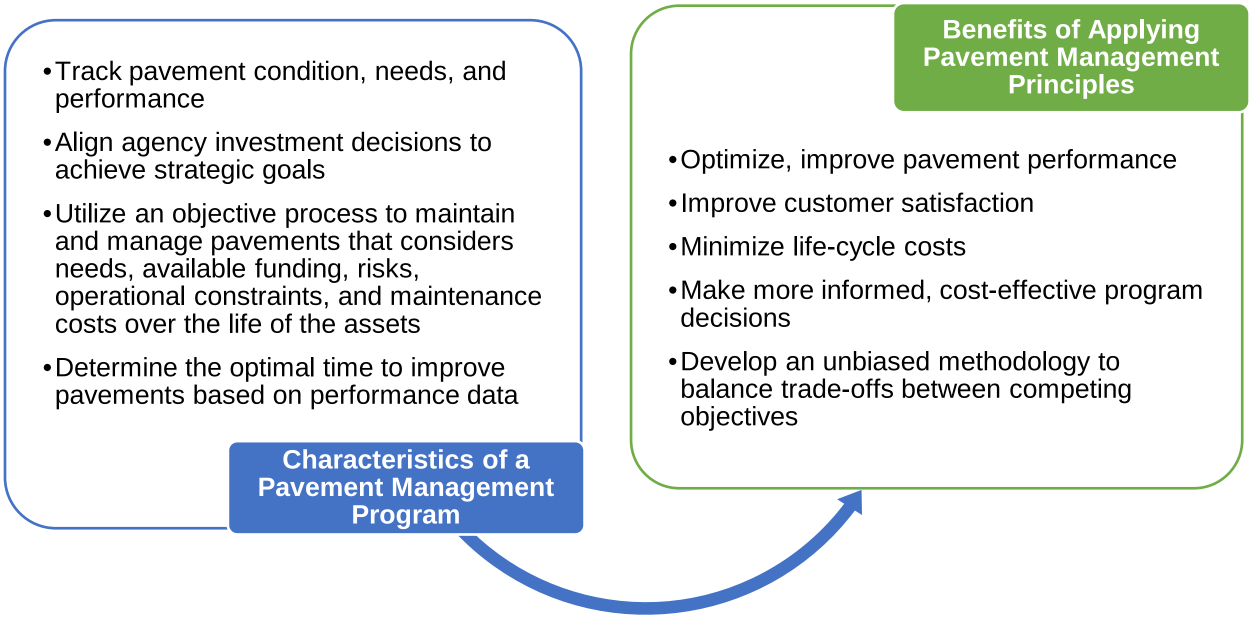

Figure 2-4. Characteristics and benefits of pavement management

Role of Pavement Management at MDOT

Pavement management data is collected and maintained to aid MDOT in making decisions regarding pavement project priorities, funding, and program development. Some of the main applications of MDOT's pavement management data are summarized below:

- Deflection data is used to recommend overlay thicknesses to Districts.
- Construction history and material property information are used to analyze conditions on various research projects.
- Pavement condition data at project level is used to develop standards for job acceptance.
- Condition data at project level is used to monitor the warranty jobs.
- Condition data is used to aid the maintenance division on the prioritization of the interstates' 3-year maintenance plan.
- The Chief Engineer uses PMS data to show funding needs and expected pavement conditions deterioration over time if maintenance is not done.
- PMS data supports long-term investment decisions and maintaining the pavement network at the lowest life cycle cost.

CHAPTER 3. PAVEMENT MANAGEMENT PROGRAM OVERVIEW

Roles and Responsibilities

Table 3-1 identifies the MDOT pavement management roles and responsibilities.

Table 3-1. Pavement management roles and responsibilities.

Team Role	Assigned Resource	Responsibilities
State Research Engineer	Cynthia Smith	• Oversees pavement management program. • Assures Quality Management Plan (QMP) is followed. • Establishes QMP update schedule.
Assistant State Research Engineer	Rhea Vincent	
State Pavement Management Systems Engineer	Marta Charria	• Manages pavement condition survey data contract. • Manages activities of District Coordinators. • Manages skid testing for construction acceptance. • Migrates the automated pavement condition data entry into the pavement management system. • Reviews 100 percent of delivered data for completeness and reasonableness. • Reviews calibration results. • Reviews weekly and monthly vendor status reports. • Sends letter of final acceptance to the service provider. • Provides Summary QA reports.
Field Operations Engineer	Alex Collum	• Collects and processes warranty data, and develops reports on contractor-maintained pavement projects. • Oversees technicians responsible for State collection of FWD, DCP, and coring on secondary routes.
	Alex Middleton	• Oversees profiler technician. • Manages smoothness construction acceptance specification/contractor profiler certification.
District Project Entry Personnel	District technical assistance staff (materials lab or maintenance area).	• Maintains project history of overlays or treatments and alerts PMS linear referencing system if changes occur.
Profiler Technician	Alan Hatch	• Maintains field control sites and verifies vendor's weekly reports are within tolerance. • Conducts contractor certification for smoothness acceptance of new construction. • Conducts distress ground truth and blind site measurement (future assignment).
Skid Technician	Derrick Noel	• Conducts skid testing for field control and blind sites during data collection. • Collects friction data on new construction projects and special requests.
Automated Data Collection Vendor Quality Control	Vendor	• Collects the pavement condition survey. • Implements Vendor Quality Control Plan. • Assures personnel certification training, validation of equipment accuracy and precision, daily QC procedures, and routine QC procedures. • Provides weekly calibration schedule and maintain records of calibration.

Schedule for Pavement Management Activities

Table 3-2 summarizes the schedule for pavement management activities at MDOT.

Table 3-2. Schedule for pavement management activities.

Activity	Schedule
Data Collection	End of January
QC/QA	April
Data Delivery	August
Data Analysis	September
Program Recommendations	All year, upon request
Reports	All year, as needed, upon request

CHAPTER 4. FEDERAL REQUIREMENTS FOR PAVEMENT MANAGEMENT

Background

In 2017, the Federal Highway Administration (FHWA) published certain rules and regulations that would drive the pavement data collection and management activities at MDOT. The two rules that are directly related to the pavement management activities are:

- 23 CFR Part 490: *National Performance Management Measures: Assessing Pavement Condition for the National Highway Performance Program and Bridge Condition for the National Highway Performance Program*.
- 23 CFR Part 515 and 667: *Asset Management Plans and Periodic Evaluations of Facilities Repeatedly Requiring Repair and Reconstruction Due to Emergency Events*.

These rules include detailed information on data to be collected for the pavements on the National Highway System (NHS) along with guidelines on federal reporting requirements. The rules also provide minimum standards for developing and operating pavement management systems. A summary of the national pavement performance measures and minimum requirements for pavement management systems are summarized in this chapter.

Pavement Performance Measures

The proposed national measures to assess the condition of pavements on the NHS are summarized in figure 4-1.

Pavements

Condition Thresholds

Metric	Good	Fair	Poor
IRI (in/mile)	<95	95–170 95–220*	>170 >220*
Cracking (%)	<5	5–10	>10
Rutting (in) **[asphalt-surfaced pavements only]**	<0.20	0.20–0.40	>0.40
Faulting (in) **[concrete-surfaced pavements only]**	<0.05	0.05–0.15	>0.15

***Urbanized Areas**

Performance Measures

Good	Poor
All metrics rated "Good"	≥ 2 metrics rated "Poor"

Performance measures are calculated for pavements in the Highway Performance Monitoring System (HPMS). Targets are expressed as:

- Percentage of pavements on the Interstate System in Good condition.
- Percentage of pavements on the NHS (excluding the Interstate System) in Good condition.
- Percentage of pavements on the NHS (excluding the Interstate System) in Poor condition.

Figure 4-1. Summary of proposed pavement condition thresholds and performance measures.

Using the pavement performance measures summarized in figure 4-1, the rules also set a minimum condition requirement indicating no more than 5 percent of the Interstate pavements can be in *Poor* condition.

Minimum Standards for Pavement Management Systems

To support asset management, pavement management systems should include documented procedures for the following:

- Collecting, processing, storing, and updating inventory and condition data for all NHS pavement assets.
- Forecasting deterioration for all NHS pavement assets.
- Determining the life-cycle cost benefits to evaluate alternative actions (including no action decisions) for managing the condition of NHS pavement assets.
- Identifying short- and long-term budget needs for managing the condition of all NHS pavement assets.
- Determining strategies for identifying potential NHS pavement and bridge projects that maximize overall program benefits within financial constraints.
- Recommending programs and implementation schedules to manage the condition of NHS pavement assets within policy and budget constraints.

Transportation Asset Management Plan Timeline and Reporting Requirements

The timeline associated with the target setting and transportation asset management plan (TAMP) development is summarized in figure 4-2.

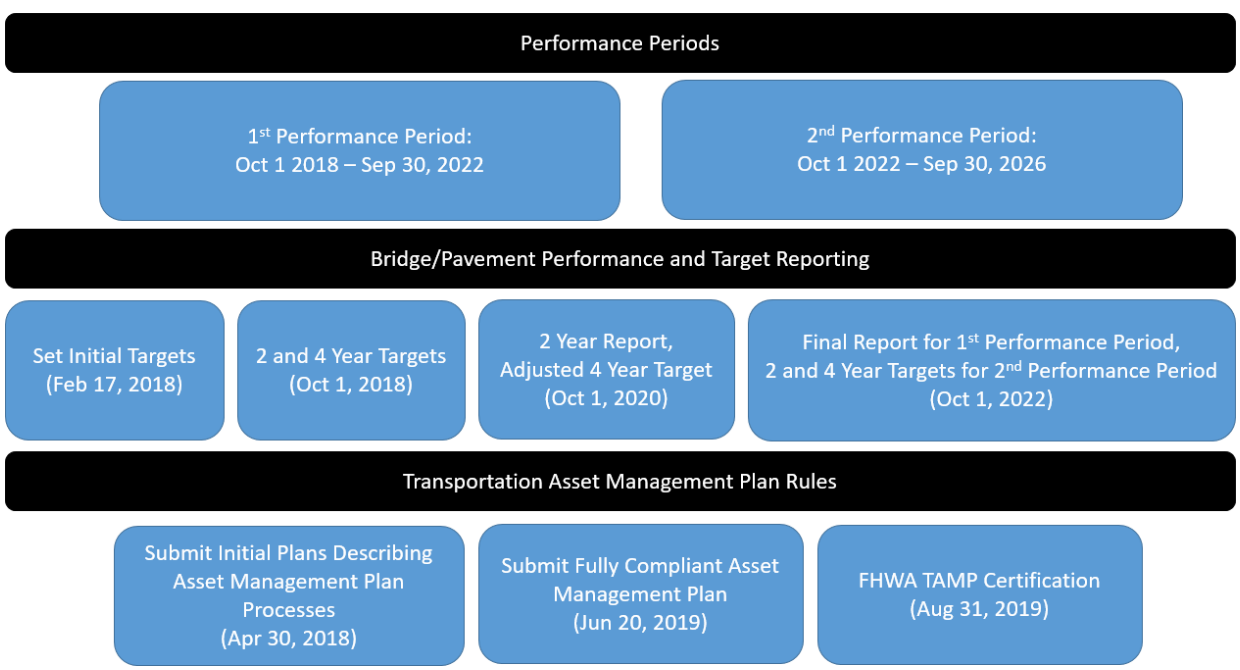

Figure 4-2. Federal target setting and asset management timeline.

The key requirements related to performance-based management of pavements are summarized below.

- State DOTs and MPOs shall **establish statewide and metropolitan planning area wide performance targets** (based on the established national performance measures), respectively, for:
  - Condition of pavements on the Interstate System.
  - Condition of pavements in the NHS (excluding Interstate System).
  - Condition of bridges on the NHS.
- **Baseline condition/performance**: States are required to report performance derived from the latest data collected through the beginning date of the performance period specified for each target.
- **Discussion on how established targets support expectations** documented in longer-range plans such as the TAMP should be provided.
- **Demonstrate lowest life-cycle cost.** States are also required to develop a life cycle cost, risk management plan and a financial plan according to TAMP development process.
- **The Mid Performance Period Progress Report (2-year report**) due **Oct 1, 2020** should include:
  - Evaluation of 2-year condition/performance. The actual condition/performance from latest data collected.
  - Discussion of progress towards achieving established 2-year targets.
  - Comparison of actual 2-year conditions with established targets and documented reasons for differences.
  - Discussion of investment strategy effectiveness.
  - Target adjustment discussion (when applicable): Submit adjusted 4-year target. If adjustment is submitted, discuss basis for adjustment and how adjusted target supports expectations in long-range plans. State DOT may only adjust a 4-year target at the midpoint and by reporting the change in the Mid-Performance Period Progress Report.
  - Discussion of progress made towards achievement of all 2-year targets established for National Highway Performance Program (NHPP) measures. Include discussion on prior accomplishments and planned activities for remainder of performance period to make significant progress towards 4-year NHPP targets.
  - When applicable, discussion of any extenuating circumstances that prevented the State DOT from making 2-year significant progress towards achieving NHPP targets.
  - If FHWA determines that the DOT has not made significant progress towards NHPP targets in the biennial evaluation, then the DOT should provide a description of actions that will be undertaken to achieve targets.
- **Full Performance Period Progress Report (4 year report): Oct 1, 2022**

Discuss all items under bullets listed for the mid-year report.

CHAPTER 5. DEFINITIONS AND DATA DICTIONARIES

Highway Systems

The Mississippi highway network has been divided into several classification systems for applying design criteria and for determining the funding sources that can be used for maintenance and rehabilitation. The *Planning Division* maintains and updates the maps for the functional classification system, Federal-aid system, and the various jurisdictional systems. The following sections describe each of the three systems.

Functional Classification

The highway design criteria are based on the functional classification that groups the highways by the character of service they provide. The two primary considerations in classifying the public highway network are access to property and mobility.

Arterials

Arterial highways are characterized by a limited access to abutting properties and a capacity to quickly move relatively large volumes of traffic. In rural areas, arterials provide connections between the major urban areas and provide a level of service suitable for statewide or interstate travel. In urban areas, the arterial system serves the major centers of activity within the urban area, carries the highest traffic volumes and longest trip movements, and serves both major intra-city and through trips. For design purposes, the arterials are divided into the following categories:

1. **Freeways**. This is the highest level in the arterial system. These facilities are characterized by full control of access, high design speeds, and a high level of driver comfort and safety.

2. **Principal and Minor Arterials**. Principal arterials provide high traffic volumes and the greatest trip length. Many of these are divided facilities which may have partial control of access. Minor arterials provide a mix of interstate and inter-county travel service in rural areas and provide intracommunity connections in urban areas. Minor arterials, as compared to principal arterials, provide relatively lower travel speeds, trip lengths, and traffic volumes, but they provide more access to property than the principal arterial system.

Collectors

Collector routes are characterized by an approximately even distribution of their access and mobility functions. Traffic volumes and speeds are typically lower than those of arterials. In rural areas, collectors serve intra-county travel needs and provide connections to the arterial system. In urban areas collectors act as intermediate links between the arterial system and points of origin and destination.

Local Roads and Streets

All public roads and streets not classified as arterials or collectors are classified as local facilities. Local roads and streets are characterized by their many points of direct access to adjacent properties and their relatively minor value in accommodating mobility. Speeds and volumes are usually low and trip lengths short.

Federal-Aid System

The Federal-aid system consists of those routes within Mississippi that are eligible for the categorical Federal highway funds.

National Highway System

The National Highway System (NHS) consists of the Interstate highway system, logical additions to the Interstate system, selected other principal arterials, and other facilities that meet the requirements of one of the subsystems within the NHS. The NHS includes the following sub-systems:

1. **Interstate**. A network of controlled-access highways under the NHS.
2. **Other Principal Arterials**. Highways in rural and urban areas that provide access between an arterial and a major port, airport, public transportation facility or other intermodal transportation facility.
3. **Strategic Highway Network**. The network of highways that are important to the United States' strategic defense policy and which provide defense access, continuity, and emergency capabilities for defense purposes.
4. **Major Strategic Highway Network Connectors**. Highways that provide access between major military installations and highways which are part of the Strategic Highway Network.

Roadway Network Jurisdictional Systems

There are approximately 72,000 miles of public roads in the state of Mississippi. The roadway network is classified into several systems based on the organization responsible for highway and street improvement, for maintenance, and for traffic enforcement.

State Highway System

The State highway system consists of all highways under the jurisdiction of the Mississippi Department of Transportation. The system equals approximately 14.6 percent, or 10,500 center-line miles of all public highways in Mississippi. These routes are typically the most significant highways in the State, carry the greatest traffic volumes, and operate at the highest speeds. Six State highway districts conduct maintenance work on the State system.

County Road System

Mississippi has eighty-two counties, and the county governments are responsible for all rural roads within their boundaries which are not on the State highway system. There are approximately 53,000 miles of county-maintained roads in Mississippi. Of the county-maintained roads, approximately 50 percent are paved. The Office of State Aid Road Construction is responsible for administering both State and Federal-aid funds, which are available for highway improvements on part of the county road system.

Municipal System

The municipal system consists of most urban roads and local city streets within the corporate limits. The extension of these routes outside the corporate limits, but still within the urban area, are generally the responsibility of the county.

Data-Related Reference Manuals

MDOT has published various reference manuals and guidance documents that establish the various procedures, protocols, and activities being conducted by the pavement management group for pavement inventories and condition assessment. A summary listing of these documents is provided below. Copies of these documents are included in the appendices.

- Appendix A: **Distress Classification Guide** (2016)**—**Definitions and rules for pavement distress classification.
- Appendix B: **Data Dictionary** (2017)**—**Structure of MDOT's pavement management system and description of various terms used in the database.
- Appendix C: **Pavement Condition Rating (PCR) Calculation Manual—**This manual is currently undergoing revisions and once complete, it will be included in Appendix C.

CHAPTER 6. PAVEMENT MANAGEMENT DATA COLLECTION

Background

There are approximately 27,500 lane-miles of state-maintained roads in Mississippi. MDOT collects and manages data on 13,800 lane-miles, consisting of the right most lane in both directions for divided highways. On undivided highways, data is collected in the right-most lane for the north or east directions. A quick overview of the PMS statistics is provided in table 6-1.

Table 6-1. Statistics on PMS Data collected/managed by MDOT.

Total State-Maintained Mileage	10,500 Center-Line Miles 27,500 Lane-Miles
Total Mileage Surveyed in PMS	13,800 Miles
Analysis Sections evaluated to develop performance models	6,000
Construction Projects included in the Construction History	3,145
Rehabilitation/ Maintenance Projects included in the Construction History	10,966
Distress Records housed within PMS	25,223,783
Number of Distress records completed in a typical survey	6,000,000

Types of Data in the PMS

A summary of the general data types housed in the MDOT PMS is provided below.

- **Inventory**: This information includes geometric, lane, and crossing route data. This type of data depicts each pavement section's location on the state-maintained system, as well as a physical description of its lane configuration. Geometric data consists of uniquely identifying features, such as county, route name, direction of data accumulation, beginning and ending log-mileage, measured length, and number of lanes. Lane information specifies type of lane (such as lane 1, lane 2, or right turn lane), lane widths, and shoulder widths. Crossing route data shows the mileage points associated with intersecting routes. Inventory/history data are collected and updated by the District offices when a project is completed. District personnel currently use a distance measuring instrument (DMI) to determine log-mileage along the route; however, in the future, GPS will be used to match with Planning Division's linear referencing system (LRS).

- **Construction**: Construction history, both original and subsequent projects, are stored in the PMS. Original construction data includes date of construction, termini, total number of layers, total thickness, and thickness and material properties of each layer (i.e., surface course, base, and subgrade). The PMS also tracks rehabilitation projects, such as overlays, milling, punch-out repair, and slab replacements, performed on each section. The data includes date and type of rehabilitation and/or resurfacing, as well as the thicknesses and material properties of each course. Construction and rehabilitation project data are maintained by the Districts.

- **Pavement Condition**: A pavement condition survey of the state-maintained highway system is performed every two years. The contractor collects both condition and distress data in order to monitor the overall shape of the state's roadways. Condition data includes the following: International Roughness Index (IRI), Pavement Condition Rating (PCR), roughness rating, rut depth, faulting, and texture. Through the 2008 survey, distress data such as cracking, potholes, patching, punchouts, and joint deterioration were collected on 500-foot samples within each analysis section. Beginning with the 2010 survey, MDOT began to have the vendor collect 100 percent of the lane rather than samples.

- **Other Data**: Other data collected, typically at District request for specific projects, includes falling weight deflectometer (FWD) and skid/friction data on selected sections. Also, traffic data and project cost (financial) data are contained in the PMS. Traffic and project data are not collected by pavement management personnel. Traffic data comes from the Planning Division, and project data comes from the Financial Management and Contract Administration Divisions.

Distress Data Collection

Pavement condition and distress data are collected by a contractor every two years. The longitudinal profile is collected using a South Dakota profiler that uses laser sensors for measurement. Roughness, rutting, faulting, and texture measurements are collected on 100 percent of the state-maintained system.

The data collection vehicle is mounted with five video cameras to capture images of the shoulders, wheel paths, and the right-of-way. The images are then digitized into frames for analysis purposes with one frame represents approximately 50 feet. The data collection vehicle is also equipped with a GPS receiver to log coordinate data. Distress evaluation is then performed on the digitized image. A random sampling of approximately 20 percent is used for the distress evaluation.

The various distress types and severity levels included in MDOT's pavement condition evaluation procedure are summarized in table 6-2. Detailed information about each of the distress types is available in Appendix A.

Table 6-2. Distress types and severities.

Pavement Type[1]	Distress Type	Severity Levels[3]	Measurement Unit
Flex, Comp, JCP, CRCP	Longitudinal Cracking	L, M, H	Length (ft.)
Flex, Comp, JCP, CRCP	Transverse Cracking	L, M, H	Width (ft.)
Flex, Comp, JCP, CRCP	Patching[2]	L, M, H	Area (sq. ft.)
Flex, Comp, JCP, CRCP	Lane-to-Shoulder Drop-off	L, M, H	Height (in.)
Flex, Comp	Potholes[2]	L, M, H	Quantity (count)
Flex	Alligator (Fatigue) Cracking	L, M, H	Area (sq. ft.)
JCP, CRCP	Durability (D) Cracking	L, M, H	Area (sq. ft.)
JCP, CRCP	Longitudinal Spalling	L, M, H	Length (ft.)
JCP	Corner Breaks	L, M, H	Quantity (count)
JCP	Transverse Spalling	L, M, H	Height (in.)
JCP	Slab Replacement[2]	L, M, H	Quantity (count)
JCP	Faulting of Transverse Joints	L, M, H	Height (in.)
CRCP	Punchouts	L, M, H	Quantity (count)
CRCP	Punchout Repair[2]	L, M, H	Quantity (count)

[1]Flex: Flexible (asphalt) pavements, Comp: Composite pavements (flexible over concrete), JCP: Jointed Plain/Reinforced Concrete Pavements, CRCP: Continuously Reinforced Concrete Pavements

[2]Severity level determined by area, not intensity.

[3]L: Low, M: Medium, H: High

Information on the data collection protocols and the scope of pavement data collection activities is available in Appendix D.

Friction and Deflection Data Collection

Skid testing is performed using a skid rig manufactured by K. J. Law on new construction projects at the request of the District office. For newly constructed pavement sections, skid testing is performed approximately three months after the facility is open to traffic. Skid testing is also performed biannually and included in the data collection contract.

At the District's request, for overlay thickness recommendations, pavement deflection data is collected using a Dynatest Falling Weight Deflectometer (FWD). The deflection data is collected and analyzed by the Research Division to determine pavement layer properties and recommend overlay thickness.

Quality Control/Quality Assurance of Contractor-Collected Data

Quality Control/Quality Assurance (QC/QA) on the condition data is performed by the Pavement Management Data Coordinator from the Research Division, who works closely with the Pavement Management Analyst in each District office.

Control sites are established in each district based on the pavement type, and the calibration of the contractor's equipment is performed using MDOT's South Dakota Profiler, rut bar, and the Georgia Fault Meter.

QC/QA on the condition data is performed according to MDOT's quality management plan. Detailed information on MDOT's quality management procedures are documented in Appendix E.

CHAPTER 7. PAVEMENT PERFORMANCE MODELING

Background

Pavement management involves forecasting needs based on pavement performance predictions. By determining the rate at which the condition will change over time, a meaningful life-cycle strategy can be developed to maximize the effectiveness of preventive maintenance and rehabilitation activities. In addition to identifying the most economical type of repair, the optimal time for applying treatments can be estimated. Typically, the optimal repair time is the point at which a gradual rate of deterioration begins to increase at an accelerated rate. It is critical to identify this point in time to schedule repairs before higher maintenance and rehabilitation costs are incurred due to extensive deterioration.

Many methods of predicting condition are available, but the method used by MDOT's PMS involves the use of Markov transition probability matrices that are used to predict the progression of distress extents from one condition state to another. The use of Markov models to predict pavement performance assumes that future condition state of a pavement is a function of the present state and not dependent on past performance of the pavement. Markov models are developed by compiling data on the observed performance of large numbers of pavement sections in order to determine the probability of condition transitions over time. When adequate data exists, using this approach will provide accurate models of individual distresses; the method also recognizes the severity of condition changes over time, transitioning from low severity to higher severity as time progresses.

Pavement Families

The MDOT PMS groups pavements into one of the following three facility types for modeling purposes: Interstate (IN), 4-Lane (4L), and 2-Lane (2L). For each of these three roadway classifications, the PMS assigns one of four pavement types: Flexible (FL), Composite (CO), Jointed Plain Concrete / Jointed Reinforced Concrete (JCP), and Continuously Reinforced Concrete (CRCP). For each pavement type, the last treatment applied is categorized as: New, Preventive Maintenance (PM), Minor Rehabilitation (Minor), or Major Rehabilitation (Major). The combination of roadway classification, pavement type, and last previous treatment are used in the PMS to define pavement families (e.g., groups of pavements with similar deterioration patterns). The list of possible pavement families in the PMS is available in Table 4 of Appendix F. Due to the lack of mileage with JCP and CRCP pavement types, all JCP and CRCP performance models were developed without regard to the roadway classification.

Transition Probability Matrices

To predict pavement performance, transition probability matrices (TPM) are defined for each type of distress in the PMS. The TPM identifies the probability that a distress condition will change from one state to another in terms of severity from time (t) to time (t+1) years. The TPMs will be used in the PMS to predict the propagation of distresses from known states, through time, to future condition states. Four condition states exist for each distress based on the severity of the distress. The condition states are as follows:

- N: Null
- L: Low
- M: Medium
- H: High

The probability that a distress condition state transforms from one state to another is quantified in the TPMs for each distress. An example TPM for reflective longitudinal cracking on an interstate composite pavement is shown in table 7-1.

Table 7-1. Example transition probability matrix.

	N (Null)	L (Low)	M (Medium)	H (High)
N (Null)	0.924	0.065	0.011	0.000
L (Low)	0.000	0.905	0.088	0.007
M (Medium)	0.000	0.000	0.925	0.075
H (High)	0.000	0.000	0.000	1.000

To interpret the TPM, a user must identify a current time (t) distress state in the first column and a transition time (t+1) distress state in the table heading. The intersecting cell implies that the probability of the distress state at time (t), L, for example, to a time (t+1) distress state of M is 0.088 (8.8%). Since pavements don't improve without treatment, the probability is 0 (zero) that a pavement with a condition of L at time (t) can transition to a state of N at time (t+1).

Constructing the probability matrix requires an appropriate amount of pavement history, project records and corresponding distress measures in order to have confidence in the accuracy of the prediction. MDOT has collected pavement condition data on a bi-annual basis since 1991 and possesses a pavement history database tracking over 5,700 pavement sections which contributed to the matrix development. The historical data collected by MDOT was used to design the TPM.

Some data infill is typically required to fill gaps where pavement condition data is missing. This is common practice in the development of probability matrices and was used primarily to provide pavement condition ratings in the years between bi-annual data collection years. For the MDOT PMS, a simple duplication of the previous year's condition was used to provide continuous annual pavement distress record for the TPM construction process.

Details on the step-by-step procedure involved in the definition of the TPM is provided in Appendix F. The performance models currently being used in MDOT's PMS are provided in Appendix G.

Schedule for Updates

The performance models used in dTIMS will be reviewed every 1-2 years by the *State Pavement Management Systems Engineer* and updated as needed based on an analysis of the historical performance of pavement sections in the various categories defined by MDOT.

CHAPTER 8. TREATMENT SELECTION

Background

At the time of this writing, MDOT is completing the implementation of a new enterprise pavement management system software program—Deighton Total Infrastructure Management System (dTIMS). Homogenous pavement management sections are defined in the PMS based on uniform physical characteristics (e.g. county, route, soil type, pavement structure, and lane configuration). A simplified illustration depicting how the PMS works is shown in figure 8-1.

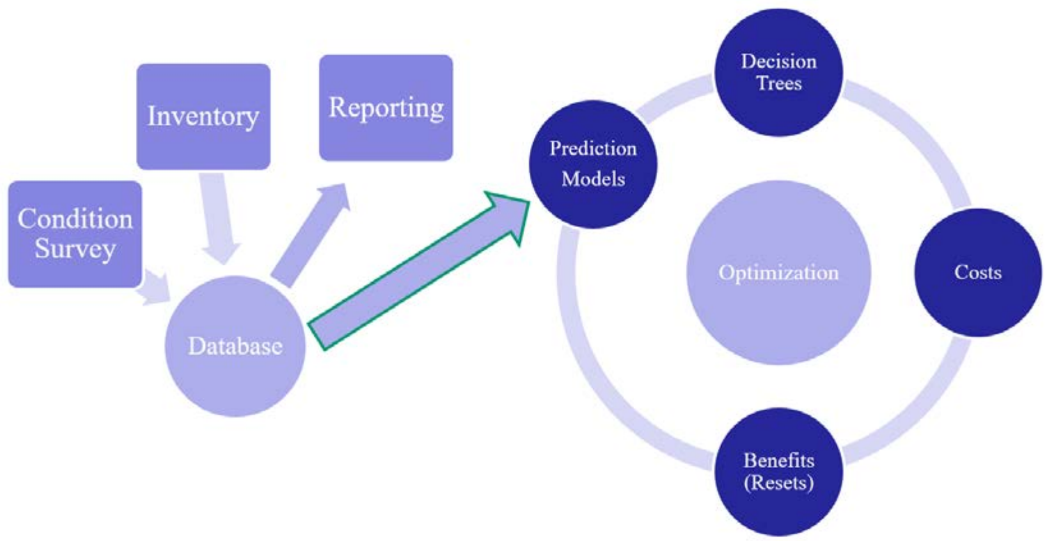

Figure 8-1. Simplified illustration of PMS operation.

Inventory and condition data (discussed in Chapter 6) are used in conjunction with the pavement performance prediction models (discussed in chapter 7) and the treatment selection decision trees in the optimization routine to develop treatment recommendations. The treatment costs and impacts (i.e., benefit/condition resets) are considered during the optimization process to determine the most cost-effective treatment for each section over the analysis period. Treatment decision trees and the optimization process are discussed in more detail in the following sections.

Treatment Decision Trees

MDOT has developed a series of decision trees for treatment selection based on facility type (two-lane, four-lane, interstate), pavement type (flexible, JCP, CRCP, composite), and, for two-lane routes, a distinction for truck weight limits of 57,000 and 80,000 pounds. The first version of the decision trees date back to 1993 and included rehabilitation techniques that were common in the late 1980s and early 1990s. The decision trees were updated in 2013 to include newer rehabilitation techniques such as full depth reclamation, scrub seals, and thin asphalt overlays. The treatment recommendations in the decision trees currently being used are based on an assessment of a number of pavement distresses (such as cracking, rutting, roughness, etc.), AADT, age, etc., to determine the level of repair needed. The treatment level is defined as one of the following three categories: preventive maintenance, minor rehabilitation, or major rehabilitation.

Preventive maintenance typically involves minor maintenance and preservation activities that are applied to pavements that are already in good condition with minimal structural deterioration. Minor rehabilitation activities (e.g., mill and 1.5 inch overlay) are generally applied to pavements that have started exhibiting structural distresses. Major rehabilitation activities are generally required for pavements in poor condition where the distresses have progressed to an extent that requires more substantial treatments (e.g., three-inch overlay, full depth reclamation on flexible pavements, or rubblization and overlay on concrete pavements) to restore the structural integrity of the pavement structure.

MDOT is currently working on refining the impact rules for treatment applications (treatment resets) and these will be used to update/refine the decision trees and performance models as required.

Table 8-1 presents a general summary of the various treatment options typically used by MDOT. The most current version of the decision trees that include specific details on the type of treatment applicable by facility type and condition are available in Appendix H.

Table 8-1. Summary of various treatment options used by MDOT.

System	Pavement Type	Preventive Maintenance	Minor Rehabilitation	Major Rehabilitation
Two-Lane	Flexible	Spot Level Rejuvenate Fog Seal Crack Seal/Fill Spot Mill Chip Seal Ultra-Thin Overlay Scrub Seal 1.5-inch Overlay	Spot Level & Chip Seal Spot Mill/Level & 1.5 inch Overlay Spot Level & Scrub Seal	Spot Level & 1.5 inch Overlay Base Repair and/or Mill & 3-inch Overlay
	JCP	Grinding Joint Seal Crack Seal Partial Concrete Pavement Restoration [CPR] (e,g., grind, joint seal, crack seal, spall repair, dowel-bar retrofit)	Partial CPR (e.g., undersealing, slab replacement, 1.5 inch overlay, dowel-bar retrofit)	Extensive CPR (e.g., grind, dowel-bar retrofit, slab replacement) 3-, 4.5-, or 6- inch overlay
	CRCP	Grinding Crack Seal Spall Repair	Punchout Repair Spall Repair 1.5 inch overlay	Punchout Repair Spall Repair 2-, 3-, 4.5-, or 6- inch overlay Rubblize and 8-inch overlay
	Composite	Spot Level Rejuvenate Fog Seal Crack Seal/Fill Spot Mill Chip Seal Ultra-Thin Overlay Scrub Seal 1.5-inch Overlay	Repair Reflective Cracks Spot Mill/Level & 1.5 inch Overlay Spot Level & Scrub Seal	Base Repair and/or Mill & 3-inch Overlay
Four-Lane	Flexible	Spot Level Micro Mill Fog Seal Crack Fill/Seal Level 1.5 inch Overlay	3 inch overlay	Base Repair 3-, 4.5-, or 6- inch overlay Full Depth Reclamation

System	Pavement Type	Preventive Maintenance	Minor Rehabilitation	Major Rehabilitation
	JCP	Grinding Joint Seal Crack Seal Partial CPR	Partial CPR 1.5 inch Overlay	Extensive CPR 3-, 4.5-, or 6- inch overlay
	CRCP	Grinding Crack Seal Spall Repair	Punchout Repair , Spall Repair, and 1.5 inch overlay	Punchout Repair Spall Repair 3-, 4.5-, or 6- inch overlay 2-, 3-, 4.5-, or 6- inch overlay Rubblize and 8-inch overlay
	Composite	Spot Level Rejuvenate Fog Seal Crack Seal/Fill Spot Mill Chip Seal Ultra-Thin Overlay Scrub Seal 1.5-inch Overlay	Repair Reflective Cracks Spot Mill/Level & 1.5 inch Overlay Spot Level & Scrub Seal	Base Repair 3-, 4.5-, or 6- inch overlay 3/4.5/6 inch Overlay Full Depth Reclamation
Interstate	Flexible	Spot Level Micro Mill Fog Seal Crack Fill/Seal Level 1.5 inch Overlay	2-, or 3 - inch overlay	Base Repair 3-, 4.5-, or 6- inch overlay Full Depth Reclamation
	JCP	Grinding Joint Seal Crack Seal Partial CPR	Partial CPR and 1.5 inch Overlay	Extensive CPR 3-, 4.5-, or 6- inch overlay
	CRCP	Grinding Crack Seal Spall Repair	Punchout Repair Spall Repair and 1.5 inch overlay	Punchout Repair Spall Repair 2-, 3-, 4.5-, or 6- inch overlay Rubblize and 8-inch overlay
	Composite	Spot Level Rejuvenate Fog Seal Crack Seal/Fill Spot Mill Chip Seal Ultra-Thin Overlay Scrub Seal 1.5-inch Overlay	Repair Reflective Cracks Spot Mill/Level & 1.5 inch Overlay Spot Level & Scrub Seal	Base Repair 3-, 4.5-, or 6- inch overlay Full Depth Reclamation

Life-Cycle Cost Analysis

Life-cycle cost analysis in dTIMS is conducted in two parts:

- First, the treatment strategies are generated for each analysis section in the roadway network.
- Next, the best strategy for each analysis section is selected as a part of the optimization process.

The optimization routine built into dTIMS uses an incremental benefit/cost (IBC) technique that maximizes the benefits under a constrained budget. The treatment strategies generated in the first phase are sorted by IBC ratios and the optimization routine then starts at the highest IBC ratio to check if the budget is available to implement the suggested treatment and moves down the list in the descending order of IBC ratios.

For each subsequent treatment strategy, the optimization routine will:

1. Determine if the treatment can be selected based on budget available.
2. Determine if strategy has already been selected for the analysis section.
   a) If no strategy is selected, the optimization routine will select a suitable strategy.
   b) If a strategy has already been selected, the optimization routine will select a new strategy only if the budget is available and the new strategy has a higher IBC ratio.

      If the optimization routine has switched the previous strategy selected for a new one, the routine will return to the top of the list and repeat the process. If the optimization routine did not select a strategy due to funding deficiency, the routine will move to the next strategy.
3. Finally, the routine will terminate when there are no more treatment strategies to check against the budget or when no more funding is available.

Analysis Outputs

Once the optimization process is complete, the treatment recommendations on a year-by-year basis for each PMS section are summarized into a spreadsheet and various visualization/reporting options are available to view and present the data. An illustration of an example summarizing the results of the analysis is shown in figure 8-2.

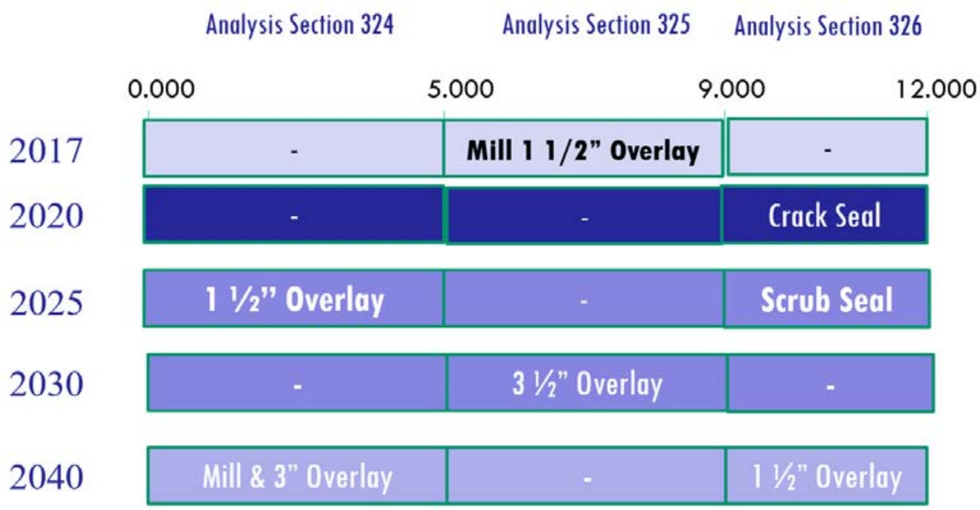

Figure 8-2. Example of illustration of analysis results from dTIMS.

Schedule for Updates

The treatment costs used in dTIMS will be reviewed every 1-2 years by the *State Pavement Management Systems Engineer* and updated as needed based on an analysis of as-built costs from recent construction projects.

CHAPTER 9. PAVEMENT MANAGEMENT REPORTING

Reports

As a part of standard internal reporting practices, MDOT produces a variety of reports using the data from the PMS. These reports are in addition to the highway performance monitoring system (HPMS) reporting requirements for the Federal Highway Administration (FHWA). The reports produced by MDOT for internal reporting are discussed in the following sections. Appendix I includes examples of all the reports discussed in this chapter.

Report Books

"Report Books" is a standard report that is generated by each district containing the basic inventory and work history information for each PMS analysis section. The information included in this report includes: county, route, section ID, length, mile points, lanes, pavement type, overlay history, and construction history. An example screenshot of this report is show in in figure 9-1.

County Adams [1] **Route** 61 **DDA** N **Pvmt Type** OFLEX **Section #** 2513
Beg Mi 14.031 **End Mi** 14.378 **Length** 0.347 **Lanes in Section** 2 **Total Lanes** 4 **Divided** Y
Begin N end of St Catherine Cr Bridge **End** Hospital
Svy Date 2/26/2012 **PCR** 78 **Rut:** 0.18 in **IRI:** 122.3 in/mi **Fault:** N/A in

Overlay #	Date	Resurface Type	Rehab Type	Tot Thk (in)	Mill Thk (in)
5	9/9/2010	50 - ACP	0 - N/A	1.50	N/A
4	7/30/2002	50 - ACP	0 - N/A	1.50	1.50
3	3/1/1991	50 - ACP	0 - N/A	2.00	N/A
2	10/1/1978	50 - ACP	0 - N/A	1.50	N/A
1	12/1/1967	50 - ACP	0 - N/A	2.50	N/A

Original Construction Date	Total OC Structure Thickness	Total OC Surface Thickness	OC Surface Type	Total Present In-Place Structure Thickness	Total Present In-Place Surface Thickness
1/1/1960	21.50 in	4.50 in	D30 - Orgnl Surface AC Surface	27.50 in	10.50 in

County Adams [1] **Route** 61 **DDA** N **Pvmt Type** COMP **Section #** 2514
Beg Mi 14.378 **End Mi** 15.836 **Length** 1.458 **Lanes in Section** 2 **Total Lanes** 4 **Divided** Y
Begin Hospital **End**
Svy Date 2/26/2012 **PCR** 82 **Rut:** 0.10 in **IRI:** 83.64 in/mi **Fault:** N/A in

Overlay #	Date	Resurface Type	Rehab Type	Tot Thk (in)	Mill Thk (in)
4	9/9/2010	50 - ACP	0 - N/A	1.50	N/A
3	7/30/2002	50 - ACP	0 - N/A	1.50	1.50
2	3/1/1991	50 - ACP	0 - N/A	2.00	1.38
1	10/1/1978	50 - ACP	0 - N/A	1.50	N/A

Original Construction Date	Total OC Structure Thickness	Total OC Surface Thickness	OC Surface Type	Total Present In-Place Structure Thickness	Total Present In-Place Surface Thickness
1/1/1964	14.00 in	8.00 in	D50 - Orgnl Surf PCC Contin	16.12 in	10.12 in

Figure 9-1. Example screenshot from "Report Books."

Interstate Rating Committee Reports

MDOT documents the condition of the Interstate pavement sections in the "Rater Sheet" report (see figure 9-2) that includes the following information: location, distresses, pavement condition rating (PCR), survey year, project number (if the section is recommended for work). Along with the "Rater Sheet", MDOT also documents the list of recommended projects for the biennium in the "Interstate Rating Committee Recommended Projects" report (see figure 9-3). These reports are generated by each of the districts.

INTERSTATE RATING COMMITTEE 2017-RATER SHEET

District 1

County [Number]	Route	Begin Mile	End Mile	Sect ID	Avg Rut (in)	Avg Fault (in)	Avg IRI (in/mi)	PCR	Pvmt Type	Survey Year	Priority In 2016	Last Work Done	Project No	FY	Termini	Old Rating	New Rating
Lee [41]	22 E	7.654	8.565	2853	.14	N/A	98.31	73	FLEX	2016	10	10/29/2004	107327	FY18	I-22 Lee Co from US 45 to Itawamba CL (9.7 Mi)	2Y	

Section: 1 Corresponding Opposite Section(s) 31, 32

Section Length 0.911

Beg landmark @ 45 / 78 Interchange **End landmark** 1/2 Mi. West of Veteran Comments from Rating Committee

	Low	Med	High		Low	Med	High
Rut %	33.33	62.5	0.6	Fault%			

Past Comments

County [Number]	Route	Begin Mile	End Mile	Sect ID	Avg Rut (in)	Avg Fault (in)	Avg IRI (in/mi)	PCR	Pvmt Type	Survey Year	Priority In 2016	Last Work Done	Project No	FY	Termini	Old Rating	New Rating
Lee [41]	22 E	8.565	8.833	2854	.16	N/A	99.2	76	FLEX	2016	10	10/29/2004	107327	FY18	I-22 Lee Co from US 45 to Itawamba CL (9.7 Mi)	2Y	

Section: 2 Corresponding Opposite Section(s) 30, 31

Section Length 0.268

Beg landmark 1/2 Mi. West of Veterans **End landmark** Just West of Mud Creek B Comments from Rating Committee

	Low	Med	High		Low	Med	High
Rut %	19.05	80.95	0	Fault%			

Past Comments

County [Number]	Route	Begin Mile	End Mile	Sect ID	Avg Rut (in)	Avg Fault (in)	Avg IRI (in/mi)	PCR	Pvmt Type	Survey Year	Priority In 2016	Last Work Done	Project No	FY	Termini	Old Rating	New Rating
Lee [41]	22 E	8.833	11.149	2855	.15	N/A	107.93	76	COMP	2016	10	10/29/2004	107327	FY18	I-22 Lee Co from US 45 to Itawamba CL (9.7 Mi)	1+Y	

Section: 3 Corresponding Opposite Section(s) 29

Section Length 2.316

Beg landmark Just West of Mud Creek B **End landmark** Near Auburn Rd. Exit Comments from Rating Committee

	Low	Med	High		Low	Med	High
Rut %	26.19	65.95	5.48	Fault%			

Past Comments

Figure 9-2. Example screenshot of "Rater Sheet".

INTERSTATE RATING COMMITTEE RECOMMENDED PROJECTS FOR FY2018-2020

Route 55 **Priority Number** 1

County	Direction	Begin Mile	End Mile	Length	Begin Landmark	End Landmark	Pvmt Type	Rating	Rater Comment	Avg Rut/Fault (in)	PCR	Most Recent Project Date
Hinds [25]	N	19.964	22.201	2.237	0.644 MI N of Rankin Co	0.631 MI N Of S Abut RR	COMP	6		0.11	79	6/2/2007
Hinds [25]	N	22.201	23.717	1.516	0.631 Mi N of S Abut RR	0.985 Mi N of SR25	COMP	6		0.12	73	6/2/2007
Hinds [25]	N	23.717	25.053	1.336	0.985 Mi N of SR25	S Br Abut Over Canton Ma	COMP	6		0.18	73	6/2/2007
Hinds [25]	N	25.053	26.738	1.685	S Br Abut Over Canton Ma	0.286 MI N Of Beasley Rd	COMP	6		0.19	71	6/2/2007
Hinds [25]	N	26.738	27.465	0.727	0.286 Mi N Of Beasley Rd	Madison Co Line	FLEX	6		0.18	55	6/2/2007
Hinds [25]	S	22.288	19.91	2.378	0.631 MI N. of S Abut RR	0.486 MI N of Rankin Co	COMP	6		0.16	76	6/2/2007

Figure 9-3. Example screenshot from "Interstate Rating Committee Recommended Projects".

Two-Lane/Four-Lane Project Recommendations

The project recommendations by district for the two-lane and four-lane highways are documented in a separate report that includes the distresses recorded, category of treatment recommended (preventive maintenance, minor rehabilitation, or major rehabilitation), and type of treatment recommended. An example screenshot from the “Two-Lane/Four-Lane Project Recommendations” report is shown in figure 9-4.

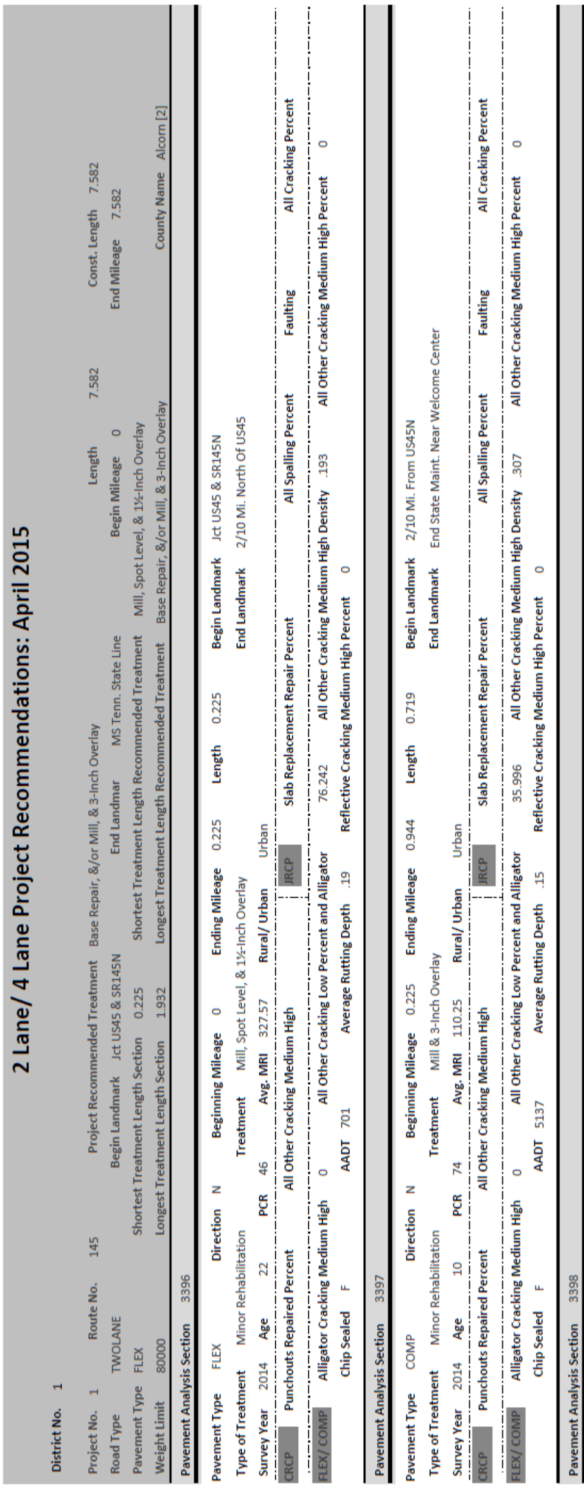

Figure 9-4. Example screenshot from the “Two-Lane/Four-Lane Project Recommendations” report.

RDD680 Report

The RDD680 report is generated for each analysis section in the PMS and it includes detailed information on the location, construction history (original construction and future overlay/resurfacings/rehabilitations), roadway condition, and traffic. A screenshot of the RDD680 report is shown in figure 9-5.

Mississippi Department of Transportation
Transportation Management Information System
RDD680 Report Analysis Section ID: 2258

Date: 08/08/2016
Time: 10:22:40

County:	Carroll [8]	Begin Distance:	0.000 mi	DDA:	N	Federal Functional Class:	01
Route:	55	End Distance:	7.156 mi	District:	2	National Highway System:	Y

Pavement Type:	Overlay Flexible	Number of Lanes in Section:	2	Plan Length:	7.120 mi
Structure Number:	4.68	Total Number of Lanes:	4	Measured Length:	7.156 mi
Divided Highway:	Y	Total Lane Width:	24.0 ft / 7.32 m	Paved Shoulder:	N
		Left Shoulder Width:	8.0 ft / 2.40 m		
		Right Shoulder Width:	12.0 ft / 3.60 m		

Begin Station No.:	124+98.40	Begin Latitude:	33.230302	Begin Longitude:	-89.807783
End Station No.:	501+00	End Latitude:	33.329754	End Longitude:	-89.775857
Begin Landmark:	Holmes/Carroll County Line				
End Landmark:	+ 0.5 Mile South SR 35				
Memo:					

Overlay/Resurfacing/Rehabilitations (continued...)

Overlay Number:	2	Milling Thickness:	1.50 in	Pave Fabric:	N
Project Number:	P9988	Rehab Thickness:	0.00 in	Edge Drain:	N
Project Detail Number:	1	Resurfacing Type:	50 - ACP	% of Surface Area:	0
Date Updated:	08/24/1992	Rehab Type:	0 - N/A		
Completion Date:	09/01/1986	Historical Project #:	I-55-3(53)		

Layer	Material Type	Material Property 1	Material Property 2	Thickness (in)
1	SC-1	TYPE VIII		1.50

Roadway Condition

Data Orientation:	F	Roughness Rating:	86	Left Texture Number:	0.00
Year Data Collected:	1991	Distress Rating:	93	Center Texture Number:	0.00
Survey Date:	08/15/1991	Pavement Condition Rating:	85	Right Texture Number:	0.00
Number of Faults:		Survey Pavement Type:	Flexible		

Start Tape Set Nmbr:	208	Start Video Frame:	00:01:13:02	End Video Frame:	00:08:45:01
End Tape Set Nmbr:		Start Video Frame:		End Video Frame:	

IRI Average:	65.89 (in/mi)		Rutting Average:	0.17 in		Faulting Average:	
Low:	0 %	0 <= x <= 100	Low:	0 %	0.13 <= x <= 0.250	Low:	
Medium:	0 %	100 < x <= 150	Medium:	0 %	0.25 < x <= 0.500	Medium:	
High:	0 %	x > 150	High:	0 %	x > 0.500	High:	

Figure 9-5. Example screenshot from the RDD680 report.

CHAPTER 10. FUTURE IMPROVEMENTS

Road Map for the MDOT PMS

This chapter summarizes the future improvements to the pavement management processes at MDOT. Figure 10-1 summarizes the *Road Map* for the next three years, beginning in 2017. The Road Map is reviewed and updated every three years. The Research Division is largely responsible for initiating and completing the initiatives listed.

District Updates/ Training	• Train District personnel in project data entry and updates • Timeline: Fall 2017, prior to 2018 condition surveys
Optimization	• Complete dTIMS implementation and integration with Districts • Run budget and optimization scenarios • Engage MDOT upper management and gain insights into their vision on how the PMS data is to be used in the decision-making process
Project Cost Updates	• Update project costs annually based on a 3-year running average of projects let to contract and calculate costs for each treatment type • As more recent costs are available, the oldest cost data in the 3-year running average will be excluded
QA Improvements	• Collect more cracking verification sites • Continue to participate in distress data quality pooled fund study • Continue to automate QA queries and checks when possible
Monitor Emerging Technologies	• Monitor and evaluate use of emerging technologies such as 3D mapping, unmanned aerial systems (UAS), and machine learning to management data collection, management and processing
Data Visualization	• Improve skills in "telling the story" • Investigate better options for communicating the data and analysis results from the PMS to upper management and elected officials • Design graphics/reports/maps that communicate the message in a succinct and effective manner

Figure 10-1. Road map for PMS improvements.