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IMPROVING NMDOT'S PAVEMENT DISTRESS SURVEY METHODOLOGY AND DEVELOPING CORRELATIONS BETWEEN FHWA'S HPMS DISTRESS DATA AND PMS DATA

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16. Abstract

The New Mexico Department of Transportation (NMDOT) has a program to collect distress data through visual surveys and uses this information at the network level, together with roughness and rutting data, to calculate its pavement serviceability index. The main goal of this research study was two-fold: revise and improve the current distress evaluation protocol with the purpose of increasing the objectivity and accuracy of the distress data and methods, and develop simple procedures to estimate distress data required for Highway Performance Monitoring System (HPMS) reporting and for NMDOT's Pavement Management System (PMS). A revised protocol for visual distress surveys in flexible pavements was proposed. The variability and practicality of the proposed protocol was tested in 66 sample sections and two rounds of surveys with very good results. The interrater agreements of the current and proposed protocols were evaluated applying the Average Deviation Index method. Even though the interrater agreement was different among the distress types, the proposed protocol showed good levels of agreement for all distresses, both for severity and extent. It is recommended that the distress evaluations of rigid sections rate the same distress type but include ratings of all severity levels. Field tests consisting of detailed measurements of transverse cracks, longitudinal cracks and alligator cracking were done in 15 sample sections to determine procedures to estimate distress parameters for HPMS and PMS from raters' data of visual surveys. The Pavement Serviceability Index (PSI) was revised to accommodate the changes introduced by the proposed protocol. This report includes an implementation plan for the recommended approaches. Also included is a summary of the project goals, overview of the work performed, proposed protocol and recommendations in the format of a presentation for dissemination purposes.

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PREFACE

The research reported herein is aimed at improving the current New Mexico Department of Transportation's (NMDOT) pavement distress rating criteria and survey protocol. The main goal is to ultimately increase the objectivity and accuracy of the collected distress data. In 2010, the Federal Highway Administration (FHWA) reviewed the NMDOT's Pavement Condition Data Collection and provided recommendations and a schedule for the implementation of the recommended changes. One of the main motivations of NMDOT to review and implement changes to the pavement distress surveys was to comply with the FHWA's recommendations resulting from the 2010 review.

The NMDOT was also interested in developing methods for estimating Highway Performance Monitoring System (HPMS) data (particularly pavement distress data) to be reported annually to FHWA from the Pavement Management System's (PMS) distress data and/or distress ratings. The implementation of the recommendations of this project will provide the methodology for NMDOT to comply with the reporting requirements of the FHWA Office of Highway Policy Information HPMS regarding pavement distresses.

This document is the final report of the project sponsored by the New Mexico Department of Transportation in cooperation with FHWA. The principal investigator (PI) was Dr. Paola Bandini (New Mexico State University), and the co-principal investigators (co-PIs) were Dr. Susan Bogus Halter (University of New Mexico) and Giovanni C. Migliaccio (formerly University of New Mexico, currently University of Washington).

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DISCLAIMER

This report presents the results of research conducted by the authors and does not necessarily reflects the views of the New Mexico Department of Transportation. This report does not constitute a standard or specification.

ABSTRACT

The New Mexico Department of Transportation (NMDOT) has a program to collect distress data through visual surveys and uses this information at the network level, together with roughness and rutting data, to calculate its pavement serviceability index. The main goal of this research study was two-fold: revise and improve the current distress evaluation protocol with the purpose of increasing the objectivity and accuracy of the distress data and methods, and develop simple procedures to estimate distress data required for Highway Performance Monitoring System (HPMS) reporting and for NMDOT's Pavement Management System (PMS).

A revised protocol for visual distress surveys in flexible pavements was proposed. The variability and practicality of the proposed protocol was tested in 66 sample sections and two rounds of surveys with very good results. The interrater agreements of the current and proposed protocols were evaluated applying the Average Deviation Index method. Even though the interrater agreement was different among the distress types, the proposed protocol showed good levels of agreement for all distresses, both for severity and extent. It is recommended that the distress evaluations of rigid sections rate the same distress type but include ratings of all severity levels. Field tests consisting of detailed measurements of transverse cracks, longitudinal cracks and alligator cracking were done in 15 sample sections to determine procedures to estimate distress parameters for HPMS and PMS from raters' data of visual surveys. The Pavement Serviceability Index (PSI) was revised to accommodate the changes introduced by the proposed protocol.

This report includes an implementation plan for the recommended approaches. Also included is a summary of the project goals, overview of the work performed, proposed protocol and recommendations in the format of a presentation for dissemination purposes.

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Additionally, Robert S. Young provided background and historical information on the NMDOT's pavement condition program, pavement serviceability index and distress data of previous years, and contact information of key personnel as needed throughout the duration of the project.

The authors also acknowledge Virgil Valdez, NMDOT Research Bureau Research Analyst, for his valuable support with regard to project meetings, project logistics, technical discussions and resources.

Research assistant Gloria Kafui Ababio assisted in the distribution of the NMDOT District survey. Research assistant David Barboza assisted in the field work and compilation of the data. Dr. Rafi Tarefder provided general information on distress data needed for model calibration of the Mechanistic-Empirical Pavement Design Guide (MEPDG).

The traffic control and warning signs during the field measurements of pavement distresses were provided by the Maintenance Patrol personnel of NMDOT District 1, based in Las Cruces, NM. Their assistance is much appreciated.

This research project was sponsored by the NMDOT Research Bureau in cooperation with the Federal Highway Administration (FHWA).

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INTRODUCTION

The Pavement Serviceability Index (PSI) is used by New Mexico Department of Transportation (NMDOT) to express the serviceability level of a pavement section at the network level. The NMDOT uses PSI values to assess the condition of the state-maintained pavement network and to determine funding eligibility of projects for particular roadway sections. The PSI is calculated annually from distress ratings and automated roughness and rutting data. The distress data are gathered through visual/manual surveys on sample sections as part of the NMDOT's Annual Pavement Evaluation Program.

The goal of research project is two-fold: 1) increase the accuracy and validity of the NMDOT's pavement distress surveys by improving the objectivity and integrity of the distress rating criteria and procedures for flexible and rigid pavements, and 2) develop simple method(s) to estimate distress data for Highway Pavement Management System (HPMS) reporting and for NMDOT's Pavement Management System (PMS).

To achieve these objectives, the project included ten tasks:

- Task 1: Perform literature review and state Departments of Transportation (DOTs) survey.
- Task 2: Obtain existing NMDOT pavement condition data files.
- Task 3: Perform data pre-processing.
- Task 4: Revise distress rating criteria and protocol.
- Task 5: Perform data analysis for revising the PSI formula.
- Task 6: Evaluate the revised PSI formula using the proposed protocol.
- Task 7: Carry out field measurements of transverse cracking and fatigue cracking.
- Task 8: Correlate raters' data from visual surveys and field measurements to estimate HPMS data.
- Task 9: Determine whether network-level distress data and methods satisfy Mechanistic-Empirical Pavement Design Guide (MEPDG)'s model calibration needs.
- Task 10: Prepare reports and deliverables.

This report includes a summary of the literature review of pavement distresses, distress evaluation and reliability measurements, and a description of the NMDOT's Pavement Data Collection program. The results of the state DOTs are summarized and discussed. This survey focused on learning about the state of practice in these agencies regarding HPMS distress data collection and use. The report continues with the description and comparison of the NMDOT's current and proposed distress evaluation protocols for visual distress surveys. This section includes a description of the sample sections used to evaluate the protocols and the analysis to assess the variability of these methods. A review of the PSI formulation is also described.

To address the project objectives, methods to estimate distress data for HPMS reporting and NMDOT's PMS parameters from raters' data of visual distress surveys are proposed. A section describing briefly the potential use of visual surveys' distress data for MEPDG model calibration is also included. The report finally provides the conclusions and recommendations for NMDOT resulting from this study. In addition, this report includes an implementation plan for recommendations of the project and a presentation for report dissemination.

LITERATURE REVIEW

PAVEMENT DISTRESS DEFINITIONS AND CAUSES

Flexible Pavement Distresses

With asphalt concrete (AC) pavements, there are eight major distresses that the majority of state DOTs (including NMDOT) concentrate on rating in flexible pavements. Guidelines from the Distress Identification Manual for the Long Term Pavement Performance (LTPP) program (1) are used in defining and describing the following major distresses. The causes of these distresses are described in detail in the NMDOT's Pavement Maintenance Manual (2). Below is a list of the distresses and their descriptions.

1. *Raveling and Weathering:* Wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. Raveling ranges from loss of fines to loss of some coarse aggregate and ultimately to a very rough and pitted surface with obvious loss of aggregate. Raveling is caused by oxidation or aging of a paved surface, bad workmanship or materials. Raveling is aggravated by hot and wet weather which causes oxidation and stripping of the asphalt binder.

2. *Bleeding:* Excess bituminous binder found on the pavement surface, usually in the wheel paths. Bleeding may range from a local discoloration relative to the remainder of the pavement, to a surface that is losing surface texture because of excess asphalt, to a condition where the aggregate may be obscured by excess asphalt with a shiny, glass-like, reflective surface that may be tacky to the touch. Bleeding is usually caused by too much asphalt binder in the pavement mix, excessive prime coat or tack coat or by too low air void content in the pavement mix. Bleeding is aggravated by hot weather, which causes the softening and expansion of the asphalt binder.

3. *Rutting:* A rut is a longitudinal surface depression along the wheel path. It may have associated transverse displacement of the asphalt material (shoving). Rutting is a permanent deformation of any layer due to weakened support layers, poorly compacted layers and unstable wearing surface or overloading. Severe rutting is often caused by excessive asphalt binder in the pavement mixture. Aggregates in these mixtures do not have aggregate-on-aggregate contact so the material flows instead of being locked in place. Rutting is aggravated by hot weather which causes the softening of the asphalt binder.

4. *Longitudinal Cracking:* Cracks predominantly parallel to the pavement centerline (or traffic direction). The location of longitudinal cracks within the lane (wheel path versus non-wheel path) is important. If the cracks occur on the centerline or outside of the wheel path, the cause is usually a poorly constructed paving joint. If longitudinal cracks occur in the wheel path, they are caused by excessive deflection due to loading or loss of foundation support probably due to water, insufficient pavement structure or weak support material. Longitudinal cracks within the wheel path are much more serious and are indicative of early-stage fatigue cracking.

5. *Transverse Cracking:* Cracks that are predominantly perpendicular to the pavement centerline. These are caused by pavement expansion and contraction due to temperature changes or shrinkage of asphalt binder with age.

6. *Alligator/Fatigue Cracking:* Occurs in areas subjected to repeated traffic loadings, especially the wheel paths. In early stages of development, it can appear as a series of interconnected cracks. Eventually, it develops into many-sided, sharp-angled pieces, usually less than 1 foot on the longest side, characterized by a chicken wire/alligator skin pattern, in later stages. The primary causes of fatigue cracking are inadequate structural design, poor construction (inadequate compaction), inadequate structural support due to higher than normal traffic loadings, normal loadings on aged and brittle pavement or excessive deflection due to loading or loss of foundation support due to water infiltration, and insufficient pavement structure or weak support material. Small, localized fatigue cracking is indicative of a loss of subgrade support. Large fatigue cracked areas are indicative of general structural failure.

7. *Edge Cracking:* Applies only to pavements with unpaved shoulders. Crescent-shaped cracks or fairly continuous cracks that intersect the pavement edge and are located within 2 feet of the pavement edge, adjacent to the shoulder. Longitudinal cracks outside of the wheel path and within 2 feet (0.61 m) of the pavement edge are included. Edge cracking is caused by loss of foundation support due to water, insufficient pavement structure, weak support material or unstable shoulder.

8. *Patch Condition:* Portion of pavement surface, greater than 4.0 in^2 (25.8 cm^2), that has been removed and replaced or additional material applied to the pavement after the original construction. The patches may have been placed for any number of reasons, such as utility work, potholes, or adjacent construction, and evaluated only to determine the condition or intactness of the patch.

Rigid Pavement Distresses

Rigid pavements are those roads comprised of Portland Cement Concrete (PCC). There are eight different distresses the NMDOT currently evaluates. The definitions and causes of these distresses are described in more detail in the Distress Identification Manual (1) and the NMDOT's Pavement Maintenance Manual (2).

1. *Corner Break:* A portion of the slab separated by a crack that intersects the adjacent transverse and longitudinal joints at an approximately 45 degree angle. The lengths of the sides are from 1 foot (0.305 m) to one-half the width of the slab, on each side of the corner. Cracks extend vertically through the entire slab thickness. Corner breaks are caused by loss of support often due to infiltration of water through cracks and damaged joints.

2. *Faulting of Transverse Joints and Cracks:* A difference in elevation across a joint or crack usually associated with undoweled Jointed Plain Concrete Pavement. Usually

the approach slab is higher than the leave slab due to pumping. Faulting is noticeable when the average faulting in the pavement section reaches about 0.1 inch (2.54 mm). Most commonly, faulting is a result of slab pumping. Faulting can also be caused by slab settlement, curling, warping and loss of support often due to infiltration of water through cracks and damaged joint seals. Faulting is aggregated by loading, pumping, inadequate drainage and erosion.

3. *Joint Seal Damage:* Any condition that allows incompressible materials or water to infiltrate into the joint from the surface. Types of joint seal damage include joint sealant stripping, joint sealant extrusion, weed growth, hardening of filler, and loss of bond to slab edges or absence of joint sealant. The most common causes are deterioration or damage to joint seals due to improper installation, incompatibility with the concrete, or contamination.

4. *Lane-to-Shoulder Drop-Off or Heave:* Difference in elevation between the edge of the slab and outside shoulders; it typically occurs when the outside shoulder settles. Causes include settlement or heave of roadway and/or shoulders due to different rates of settlement and compaction.

5. *Longitudinal Cracking:* Cracks that are predominantly parallel to the pavement centerline. Longitudinal cracking is caused by unbalanced loading on slabs as traffic transverses the pavement.

6. *Patch Deterioration:* Bowl shaped openings in the pavement surface where the patch has deteriorated. The most common cause of patch deterioration is water seeping under a patch during wet, freezing weather. The water freezes, expands, and pushes up from below the cracked area. The vibration of vehicle tires over the cracked area and stresses to the pavement by the weight of trucks causes the patch to break up and come out of the pavement.

7. *Spalling of Joints and Cracks:* Cracking, breaking, chipping or fraying of slab edges within 2 feet (0.61 m) of longitudinal or transverse joints or cracks. Spalling does not extend vertically through the slab, but angles through the slab to the joint or crack. It results in loose debris on the pavement, roughness, generally an indicator of advanced joint/crack deterioration. Spalling is caused by localized areas of scaling, weak concrete, clay balls or high steel, dowel bar misalignment or lock-up due to misalignment or corrosion; disintegration of the PCC from freeze-thaw action, durability cracking or alkali-aggregate reactivity; reinforcing steel that is too close to the surface; inadequate air void system; excessive stresses at the joint/crack caused by infiltration of incompressible materials and subsequent expansion or weak PCC at a joint caused by inadequate consolidation during construction.

8. *Transverse and Diagonal Cracking:* Cracks that are predominately perpendicular to the pavement centerline. Medium or high severity cracks are working cracks and are considered major structural distresses. The main cause is unbalanced loading on slabs as traffic traverses the pavement.

PAVEMENT DISTRESS MEASUREMENTS AND RATING

Transportation agency managers need comprehensive and timely information on the conditions of their existing pavements to make budgeting, planning, construction, and maintenance decisions. To characterize the conditions of existing pavements, pavement condition surveys are conducted in one or more of the four areas: roughness, distress, structural capacity, and friction (3). Pavement surface distresses, either alone or together with other condition measures, are an important input for a composite condition index that indicates the overall condition of existing pavements and presents a useful tool for budgeting and planning maintenance and rehabilitation strategies.

The methods used to collect distress data range from manual surveys based on human visual inspection to semi-automated and automated surveys using a system based on 35mm or digital photography, video cameras, or sensors. While some agencies have adopted automated technology to conduct distress surveys (for example, see Reference 4), other agencies use manual or visual methods including walking surveys, shoulder surveys, and windshield surveys. Manual/visual distress survey procedures range from very detailed measurement and mapping of specific distress types to rating the overall surface deterioration of the road (5). Manual distress surveys commonly rely on individual evaluators' visual inspection, interpretation and judgment of the extent and severity of all distresses found on each pavement section (Figure 1).

FIGURE 1 NMSU student technicians performing distress ratings and data compilation (NMSU Photos by D. Phillips and P. Bandini)

Due to factors such as the raters' own bias, experience, exposure to various types of distresses, and training received (6) even experienced raters may not always give the same severity-extent rating for any given section or two different test sections in a similar condition. Thus, manual distress evaluations or ratings contributed by more than one rater are potentially subject to variability between raters (7). This variability between raters is what has been termed reproducibility (8), which indicates the capability of different raters of producing identical ratings for the same pavement section.

The reproducibility described above is distinguished from another kind of variability that may be revealed during quality control procedures such as random resurvey. In random resurvey, each individual rater evaluates a set of pavement sections in several rounds over a relatively short period. If the rater re-evaluates the same section to be in a far worse or better condition than indicated in the previous rounds of evaluation, this indicates inconsistency of the rater's evaluations, which could lead to potentially large variability in distress data contributed by the rater. According to Livneh (8), this variability between different rounds of evaluation by the same rater is termed repeatability.

Bianchini et al. (9) studied the reproducibility of raters and crews relevant to manual/visual pavement distress measurements. They proposed a new approach to estimate the inter-rater or inter-crew reliability for manual or semi-automated distress data collection. This approach is especially useful when there are two variables to be rated (for example, distress extent and severity) that are dependent on each other. Their analysis acknowledged that a certain degree of variability in the visual distress ratings is likely to occur and, thus, minimum acceptable values of complete and partial agreements of the crews or raters were suggested. The statistical approach to validate the level of agreement between the ratings of two raters or crews was based on the use of the chi-square distribution to test hypotheses about multinomial experiments. Bogus et al. (10) also studied the reliability of manual distress surveys and rater training using inter-rater agreement measures to test for reproducibility and regression analysis to test for repeatability. These measures were found to provide objective evaluations of manual distress data.

An annotated bibliography of the pavement distress manuals and methods developed and used by state DOTs and other agencies, research on reliability of distress surveys and data and other related research is included in Appendix A.

PAVEMENT MANAGEMENT SYSTEMS

Highway pavement management systems (PMS) are used throughout the United States (U.S.) to identify which roads and pavement sections require repair, maintenance or reconstruction. They are also used by the Federal Highway Administration (FHWA) to allocate federal money to the state transportation agencies for the maintenance of roadways. Pavement management seeks to improve the efficiency of decision making regarding pavement design, maintenance, and repair and increase its consistency (11).

As a way to ensure that roadways will receive the maintenance they require, the FHWA developed the Highway Performance Monitoring System (HPMS). The HPMS was developed in 1978 as a national highway transportation system database. It contains data that reflect the extent, condition, performance, use, and operating characteristics of the nation's highways. The HPMS database includes limited data on all public roads, more detailed data for a sample of the arterial and collector functional systems, and certain statewide summary information (12). The HPMS data are used for assessing highway system performance under FHWA's strategic planning process and for many statistics such as fatality and injury rates, and are the source of a large portion of information included in FHWA's annual Highway Statistics and other media and publications. Some state transportation agencies use the HPMS data for assessing highway condition, performance, air quality trends, and future investment requirements. By June 15th of each year, state transportation agencies must report their HPMS data for the previous year to FHWA headquarters using the HPMS submittal software (12).

The *Highway Performance Monitoring System (HPMS) Field Manual* (13) outlines the data requirements, format and specifications. Required data related to pavement management include:

- International Roughness Index (IRI),
- Present Serviceability Rating (PSR),
- surface type,
- depth of rutting,
- average vertical displacement due to faulting,
- percentage of area of fatigue cracking, and
- length of transverse cracking.

Besides the HPMS at the national level, most states have their own pavement management systems and models. Examples of the overall indices being used by the state transportation agencies include (14):

- Pavement Condition Index (PCI),
- Present Serviceability Index (PSI),
- Pavement Distress Index (PDI),
- Pavement Quality Index (PQI),
- Remaining Service Life (RSL), and
- others (e.g., Overall Condition Index, Distress Score, Surface Distress Index, etc.).

From the literature review, the most common index used for overall pavement condition was the RSL. The NMDOT calculates PSI for both flexible and rigid pavements in the state.

NMDOT'S PAVEMENT CONDITION DATA COLLECTION

The NMDOT has collected pavement condition data, i.e. surface distresses, rutting and roughness, during the last two decades along the New Mexico State Highway and Routes System. Until 2009, NMDOT collected pavement distress data on more than 15,500 lane-miles of pavement in their statewide route system mostly on an annual basis. In 2010 and 2011, distress, rutting and roughness data were not collected in New Mexico (Robert S. Young, personal communication, July 2011). The condition of existing pavements is evaluated in two measures: roughness and surface distresses. Combining the two measures, a pavement condition index called Pavement Serviceability Index (PSI) is calculated. This index indicates the overall condition of each pavement section. The NMDOT also uses PSI values to determine the funding eligibility of projects for particular roadway sections.

The NMDOT currently uses automated methods to measure pavement roughness, expressed in terms of the standardized International Roughness Index (IRI) and pavement rutting. Surface distress data are collected through manual/visual surveys. Until 2009, NMDOT's annual pavement condition data collection program included automated rutting measurements and ratings of severity and extent of rutting from manual surveys. More than 98% of the NMDOT-maintained pavements in New Mexico are flexible pavements.

Pavement condition data are not measured or collected on shoulders or turning lanes, passing lanes, unpaved roads, bridges, or roadways under construction. Distress, rutting and roughness data are always collected in the far-right driving lane. On two-lane highways (one lane in each direction), data are collected in the positive direction only. [Note that for highways with predominant east-west orientation, the positive (P) direction is the east-bound lane and the minus (M) direction is the west-bound lane. For highways with predominant north-south orientation, the positive direction is the north-bound lane and the minus direction is the south-bound lane.] On multilane highways (four or more through lanes), pavement condition data are collected in both directions.

MANUAL PAVEMENT DISTRESS RATINGS

Prior to 2006, NMDOT's district construction personnel carried out the pavement distress rating work. In 2006, NMDOT entered into professional service agreements with New Mexico State University (NMSU) and the University of New Mexico (UNM) to carry out the NMDOT's annual pavement distress evaluation program. The program managed by the universities was very successful in 2006; therefore, NMDOT contracted the two universities to collect the statewide pavement distress data in 2007 through 2009. As part of this agreement, university students from NMSU and UNM have worked as raters in the manual distress surveys to evaluate pavement distresses for NMDOT at approximately 15,500 sample sections along state-maintained routes throughout New Mexico.

As part of NMDOT's Annual Pavement Evaluation Program, pavement distresses are evaluated through visual (walk) surveys conducted on a sample segment of each 1-mile long pavement. For the sole purpose of the pavement distress surveys, a sample section is defined by NMDOT as an area extending one tenth of a mile (0.1 mile = 528 ft = 161 m) in length and having a width equal to the right driving lane. The pavement sample units were approximately located at 1-mile intervals, starting or ending at each highway milepost marker (for the positive and negative directions respectively), except for those that restrict accessibility of raters or do not permit safe inspection. During distress surveys, evaluators (or raters) individually perform visual inspection on the sample segment and identify distresses found on the section (Figure 2).

Between 2002 and 2009, NMDOT evaluated eight distress types for asphalt (or flexible) pavements and another set of eight distresses for concrete (or rigid) pavements. The current NMDOT's *Distress Evaluation Chart for Flexible Pavements* and *Distress Evaluation Chart for Rigid Pavements* are shown in Appendix B. This set of criteria was used in the distress surveys until 2009. Distresses identified from each sample section are evaluated in their severity and extent. Severity represents the degree of pavement deterioration. The extent of a particular distress is rated by estimating the area of the sample unit on which the distress was present and is qualitatively described by the severity levels of low, medium and high.

In reference to *NMDOT's Distress Evaluation Chart for Flexible Pavements* (Appendix B), the extent is rated as low when the distress appears in 30% or less of the sample unit area, medium if the distress is on 31 to 60% of the sample unit area, or high if the distress is on an area that extended more than 60% of the sample unit. Values of 1, 2 or 3 are assigned to severity and extent that are rated as low, medium or high, respectively. The extent is rated only for the highest severity rating in a pavement sample unit. For a given distress type, severity and extent ratings of zero indicate that the distress is not present on the surface of the sample unit. The current NMDOT's protocol assigns a minimum rating of severity equal to 1 and extent equal to 3 for the distress of weathering and raveling

The distress survey procedure described in this section corresponds to the current NMDOT protocol, which was evaluated in this research project for possible changes and improvement. The test sections are 161 m (0.1 mile) long, generally starting or ending at each highway milepost, and are spaced at 1.6 km (1 mile) intervals. The survey crews are composed of two people, both are trained to serve as rater or safety person. A crew travels to the assigned location or milepost and drives the vehicle off the shoulder to a safe parking position, with the vehicle emergency flashlights, strobe and light bar turned on. After safely parking, the crew members get out of the vehicle with the equipment and materials necessary for the distress evaluation and safety and walk 161 m (0.1 mile) along the roadway (or on the shoulder when possible) starting at the milepost marker when the test section is in the positive direction or ending at the milepost marker when the test section is in the negative direction.

The rater performs a preliminary evaluation while walking away from the vehicle by observing the conditions of the pavement surface and identifying the types of distresses present. The other crew member (safety person) walks a few feet behind the rater watching for any unsafe conditions and alerting the traveling public with a "slow" sign or flag. Once the raters arrive to the end of the test section, one of them starts the evaluation (by rating the severity and extent of each distress type present) and the other watches for traffic and potential hazards on the road (Figure 3), while both walk back toward the starting point and their vehicle. Sometimes the location of the test sections has to be moved 161 m to 323 m (0.1 to 0.2 miles) forward or backward, at the discretion of the raters, when unsafe or hazardous conditions exist or due to the presence of a bridge or ramp within the length of the test section to be evaluated.

FIGURE 2 NMSU student technician rates pavement distresses in a rigid section in Southern New Mexico

FIGURE 3 Two-person crew carries out a pavement distress survey in a flexible pavement section

TRANSITION FROM MANUAL TO AUTOMATED RUT DEPTH MEASUREMENTS

Until the pavement distress data collection cycle of 2009, the rut depth was visually/manually assessed by the raters using a 1.2-m (4-ft) long straightedge or rut bar (e.g., 4-ft oak bar or aluminum level) on both wheel paths at 6 to 9 locations along the pavement section. Adopting the recommendations of Project NM08SAF-02 "*Transition from Manual to Automated Rutting Measurements: Effect on Pavement Serviceability Index Values*" (15), NMDOT's Pavement Distress Evaluation Program will no longer collect rutting data as part of the visual/manual surveys starting in 2012. The average rut depth will be obtained automatically and converted to equivalent ratings of severity and extent to be used in the PSI calculations throughout the highway network.

AUTOMATED RUT DEPTH AND ROUGHNESS MEASUREMENTS

The NMDOT's Pavement Evaluation Section is in charge of collecting automated data of pavement roughness and rut depth in interstate and other highway routes in New Mexico. In the 1980's, NMDOT used a Tech West Photo Log to measure pavement roughness (16). From 1991, roughness and rutting data were collected with an Automatic Road Analyzer (ARAN) van for data collection. In 2000, NMDOT started measuring roughness and rutting data with a K. J. Law Dynatest T6600 High Speed Profilometer mounted on a van. A second T6600 Profilometer and van were acquired in 2003 for the data collection activities (16). Roughness data are collected according to the "*Standard Practice for Determination of International Roughness Index (IRI) to Quality Roughness of Pavements*" (17). This equipment uses three infrared displacement sensors and two precision accelerometers. The sensors are set at 68 in. The rut depth data are stored in "raw data" files at user-defined intervals, such as 0.5, 1, 2 or 3 ft. Using the raw data, the rut depth is currently averaged and reported every 161 m (0.1 mile).

In addition to automated rut depth measurements, NMDOT also collects roughness data using two NMDOT-owned 3-point profilometers. According to NMDOT, roughness is measured each year on 99% of the New Mexico State Highway System as well as other Principal and Rural Minor Arterials, FL Designated Routes and Off-Interstate Business Loops. NMDOT did not collect or contract out automated rut depth and roughness data in 2010 and 2011 (Robert S. Young, personal communication, July 2011). The frequency of the IRI measurement is every 0.02 mile. The mathematical simulation used for IRI computation is quarter car (i.e., average of two wheel paths). Pavement roughness and automated rut depth data are not collected on some very short state routes and some very short highway segments. Automated pavement rutting and roughness data are not collected on unpaved roads because these measurements would not be meaningful in those cases.

NMDOT'S PAVEMENT SERVICEABILITY INDEX (PSI)

The NMDOT uses the Pavement Serviceability Index (PSI) as a measure of pavement condition at the network level. The PSI applies to both flexible and rigid pavements. This index ranges from 0 (very poor condition) to 5 (very good condition). For flexible pavements, the NMDOT's PSI is calculated (until 2010) from pavement roughness data and distress ratings (including rutting), through one of the following empirical expressions:

$$\text{PSI} = 0.041666\ \text{X}, \quad \text{if X} \leq 60 \tag{1}$$

or

$$\text{PSI} = [0.0625(\text{X} - 60)] + 2.4999, \quad \text{if X} > 60 \tag{2}$$

where X is given by

$$\text{X} = 100 - \left[\frac{0.6(\text{IRI} - 25) + (0.4\text{DR})}{2.9} \right] \tag{3}$$

where IRI is International Roughness Index, and DR is the Distress Rate defined as

$$\text{DR} = \sum_{i=1}^{n} \left[(\text{Severity Rating}_i)(\text{Extent Factor}_i)(\text{Weight Factor}_i) \right] = \sum_{i=1}^{\text{n}} (\text{DR}_i) \tag{4}$$

in which *i* denotes one of the eight types of distresses of flexible or rigid pavements (n = 8), and DR_i is the component of the distress rate (DR) value corresponding to the distress type *i* for a given pavement section. The extent factors and weight factors for the eight distress types in flexible pavements currently used by NMDOT for the calculation of DR and PSI are given in Table 1.

TABLE 1 Factors for Extent Ratings and Weight Factors for Flexible Pavements According to the Current NMDOT Methodology (15)

Distress Type	Weight Factor	Extent Level	Extent Rating	Extent Factor
Raveling and Weathering	3	Low	1	0.3
		Medium	2	0.6
		High	3	1.0
Bleeding	2	Low	1	0.3
		Medium	2	0.6
		High	3	1.0
Rutting and Shoving	14	Low	1	0.5
		Medium	2	0.8
		High	3	1.0
Longitudinal Cracking	20	Low	1	0.7
		Medium	2	0.9
		High	3	1.0
Transverse Cracking	12	Low	1	0.7
		Medium	2	0.9
		High	3	1.0
Alligator Cracking	25	Low	1	0.7
		Medium	2	0.9
		High	3	1.0
Edge Cracking	3	Low	1	0.5
		Medium	2	0.8
		High	3	1.0
Patching	2	Low	1	0.3
		Medium	2	0.6
		High	3	1.0

The NMDOT ranks the condition of the highway pavement network in New Mexico based on the calculated PSI values. The higher the PSI value, the better the pavement condition. The NMDOT considers that interstate highways with PSI lower than 3.0 are in deficient condition and those with PSI of 3.0 or greater are in non-deficient condition. For non-interstate highways, the limiting PSI value between deficient and non-deficient conditions is 2.5. The ranking criteria are given in Table 2. The value of DR typically ranges from 0 to 400.

For a given year, the NMDOT calculates PSI values according to Equations 1 through 4 using distress ratings from the year's manual distress surveys and IRI data collected during the previous year (or previous pavement condition data collection cycle). Note that automated roughness data were not collected in 2006, 2010 and 2011.

TABLE 2 NMDOT's Ranking of Pavement Condition Based on PSI Values at the Network Level (15)

New Mexico PSI Range	Pavement Condition		
	Condition Ranking	Interstate Highways	Non-Interstate Highways
4.0 ≤ PSI ≤ 5.0	Very Good	Non-deficient	Non-deficient
3.0 ≤ PSI < 4.0	Good	Non-deficient	Non-deficient
2.5 ≤ PSI < 3.0	Fair	Deficient	Non-deficient
1.0 ≤ PSI < 2.5	Poor	Deficient	Deficient
0.0 ≤ PSI < 1.0	Very Poor	Deficient	Deficient

COMPARISON OF MANUAL DISTRESS DATA COLLECTION PROTOCOLS

METHODOLOGY

The primary objective of this research study was to improve NMDOT's current distress data collection protocols for flexible and rigid pavements to reduce variability in the distress ratings and allow for collection of data for HPMS reporting. This section describes the current protocol and the proposed protocol for visual distress surveys and distress evaluation criteria for flexible and rigid pavements.

Description of Current Distress Data Collection Protocol

The procedure used to rate a pavement section under the current NMDOT protocol consists of the following: walk from the vehicle 161 m (0.1 mile) while scanning for distresses, then evaluate/rate the distresses while walking back to the vehicle. The evaluation of the distress severity and extent is based on the rater's judgment to apply the rating criteria and own assessment.

If a distress type is present, the rater identifies the highest severity level, i.e. Low (1), Medium (2), or High (3), and the extent of that severity as a percentage of the test section affected, Low (1 to 30%), Medium (31 to 60%) or High (61 to 100%), according to the *NMDOT's Distress Evaluation Charts for Flexible and Rigid Pavements* in Appendix B. For rigid pavements, the thresholds for some of the extent ratings are given in number of cracks instead of percentage of section.

In this method, the raters would only note the highest severity present for any particular distress. For example, if multiple transverse cracks were found within a test section, and only one crack fell into the High severity criterion, then only that one crack is considered for rating the extent of transverse cracks, as a High Severity (3) but Low Extent (1), disregarding any of the lesser severity cracks. In this situation, more information is available than is reported, and is one of the limitations of the current NMDOT protocol. In addition, the current protocol for flexible pavements assumes that the distress of raveling and weathering adopts minimum severity and extent ratings of 1 and 3, respectively, regardless of the road condition, surface type or age of pavement.

The only change to the current protocol used in this research project was the elimination of rutting and shoving as a manually collected distress for flexible pavements. Because rutting and shoving data will be collected automatically in the future, this distress was not evaluated as part of the current protocol (Robert S. Young, letter dated July 27, 2010).

Description of Proposed Distress Data Collection Protocol

The current NMDOT distress evaluation protocol for visual surveys was revised to identify areas that needed improvements, such as vague criteria, discrepancies and unclear definitions, and type/format of data that could allow information to be used for HPMS reporting. Thus, the proposed protocol for visual surveys incorporates the needs of HPMS data reporting as well as revised/new needs of the NMDOT's pavement management system (PMS).

Flexible Pavements

In 2009, the Federal Highway Administration (FHWA) reviewed the NMDOT's Pavement Management System, including the NMDOT's Pavement Evaluation Program. The revision focused mainly on flexible pavements. Following FHWA's recommendations resulting from the 2009 review, NMDOT has specified that for flexible pavements, rutting and shoving will be collected using an automated system; patching is to be eliminated entirely; longitudinal cracking occurring in the wheel path is to be combined with alligator cracking, as these phenomena are both caused by cyclic loading of pavements and fatigue of pavement; and longitudinal cracking outside the wheel path is to be combined with edge cracking (Robert S. Young, letter dated July 27, 2010).

Another important change dictated by NMDOT is that, for each distress type, the extent of each severity will be rated to provide a more complete representation of the conditions of pavements in New Mexico. Previously, "severity ruled extent," that is, only the worst severity and its corresponding extent were to be reported. The change to rating all severities and their corresponding extents for all distresses is consistent with FHWA's 2009 recommendations.

In revising and modifying the current protocol, the focus was on including procedures to allow direct and simple HPMS reporting as well as handling the needs of the NMDOT's PMS. For flexible pavements, HPMS only requires three items to be reported:

- Rutting (Item # 50)
- Fatigue cracking (or alligator cracking – Item # 52),
- Transverse cracking (Item # 53).

The NMDOT needs data collection of the following distress types in flexible pavements:

- Raveling and weathering,
- Bleeding,
- Alligator cracking,
- Transverse cracking,
- Longitudinal cracking,
- Rutting and shoving (also refers as rutting).

As previously mentioned, rutting will be evaluated automatically only, effectively removing it from this list. The proposed protocol for visual distress surveys in flexible pavements concentrates on fatigue and transverse cracking for the HPMS system and on simplifying the other distresses required by the NMDOT.

The 2010 "*HPMS Field Manual*" (13) provides detailed descriptions of each distress type, photos of example sections, and sample methods of data collection in order to achieve consistent results over all state agencies. This was the primary reference used to develop the proposed protocol, along with the rating manuals obtained from other state DOTs that collect distress data through visual/manual surveys. By reviewing NMDOT's current criteria and simplifying some of the descriptions for pavement distresses, new criteria were written to reduce subjectivity.

Every method detailed here assumes manual/visual collection of information and data from the roadside, through walk surveys. In training, the pavement raters calibrate their paces to be able to estimate length of cracks and distress areas without actually having to measure them. This will improve safety by allowing the rater to stay out of traffic lanes, and will save time and money by not requiring road closures or traffic interruptions during evaluations or measurements.

The description of the revised criteria to identify and rate the five distresses of the proposed protocol is next. The proposed *Distress Evaluation Reference Chart for Flexible Pavements* for NMDOT is in Appendix C, both the criteria and the rater's field version.

1. *Raveling and weathering*: This item is not needed for HPMS reporting, but it is required for NMDOT's PMS. Based on analysis of NMDOT's historical data from 2006 through 2009 for raveling and weathering (Figure 4), this distress, if occurs, is most likely present along the entire test section. The data showed that 87.5% of the sections were rated with extent of 3 (High) for raveling and weathering, 9.2% with extent of 1 (Low) and 3.3% with extent of 2 (Medium). Therefore, the proposed protocol for raveling and weathering only requires the pavement raters to indicate the severity of the distress on the field forms. The extent for raveling and weathering will be assumed as 3 (High) when the severity is 1, 2 or 3. A pavement section could be rated with severity and extent of 0 for raveling and weathering when the pavement surface has not been weathered and does not meet the minimum criteria for severity 1 (Low).

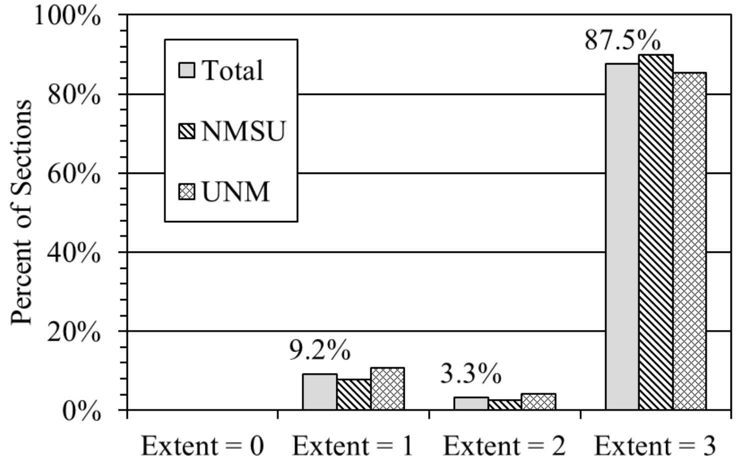


FIGURE 4 Percentage of pavement sections with distress of raveling and weathering. Average of data from 2006 through 2009

2. Bleeding: This item is not required for HPMS reporting, but it is required for NMDOT's PMS. Based on analysis of NMDOT's historical data from 2006 through 2009 for bleeding (Figure 5), this distress, if it occurs, is predominantly rated with an extent of 1 (Low). The data showed that 65.8% of the sections were rated with extent of 0 (no bleeding), 21.8% with extent of 1 (Low) for bleeding, 5.4% with extent of 2 (Medium) and 7.0% with extent of 3 (High). Therefore, the proposed protocol requires that bleeding be evaluated as "Present/Not Present" for each level of severity. The extent for this distress will be assumed as 1 (Low).

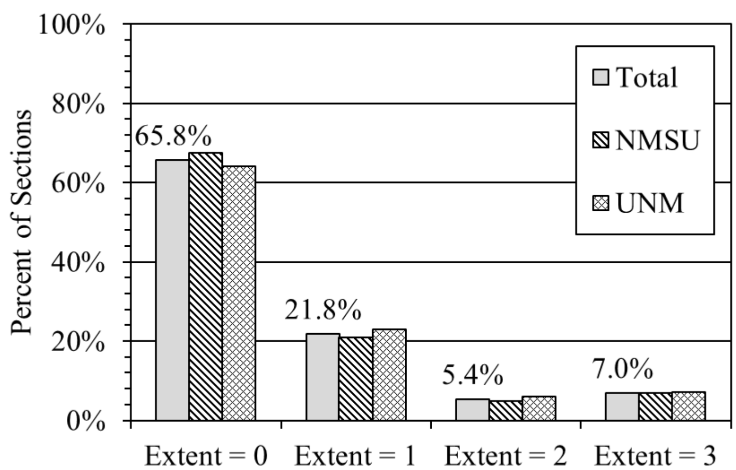


FIGURE 5 Percentage of pavement sections with distress of bleeding. Average of data from 2006 through 2009

3. Alligator (fatigue) cracking: This item represents alligator cracking and longitudinal cracking located within the wheel path, which is also referred to as fatigue cracking. The HPMS requires a percentage of total sectional area affected by this type of distress be reported to the nearest 5%. In order to ensure that any instance of this distress be captured, the percent area will be rounded up. This will ensure that even a small area of alligator cracking will be reported. To obtain the data, the pavement rater will "pace off" the lengths along the section that display this distress, recording the pace count and the number of wheel paths (either 1 or 2) on their field forms.

   The 2010 "*HPMS Field Manual*" (13) assumes that fatigue cracking only appears in the wheel paths and that each wheel path is 2 feet wide. These assumptions will be used to estimate the area of fatigue cracking for HPMS reporting. From the raters' data, the extent rating for each severity level will be also assessed for use in the NMDOT's PMS.

4. Transverse cracking: The HPMS requires that transverse cracking be reported in linear feet per mile. To obtain these data, the raters will count the number of transverse cracks that are "at least 6 feet long" for each severity level and record the totals on the field forms. To be conservative, a half lane-width crack counts as a whole lane-width crack. The NMDOT requires that each severity be reported for use in its PMS; however, the *total* (aggregated) number of transverse cracks across all severities will be used for HPMS reporting, as severity is not considered.

5. Longitudinal cracking: This item is not required for HPMS, but it is required by NMDOT for its PMS. This distress refers to longitudinal cracks outside the wheel path, located anywhere within the test section, and edge cracks. The NMDOT has requested that these two distress types be combined into one rating, to comply with the FHWA's 2009 recommendations (Robert S. Young, letter dated July 27, 2010). In the proposed protocol for visual surveys, longitudinal cracking will be evaluated similarly to the current protocol, with the exception that the extent ratings of all severities present will be assessed and recorded in the field forms.

The top three distresses on the field form of the proposed protocol (Appendix D) are Raveling and Weathering, Bleeding, and Alligator Cracking. The pavement rater should focus on these three distresses "on the way out," that is, while walking away from the vehicle. The rater should be able to easily and quickly evaluate raveling and weathering and indicate the worst severity on the field form. This leaves the trip out to the other end of the section to concentrate on pacing alligator cracking, which has a larger impact on the overall pavement condition, and indicating if it occurs in one or both wheel paths. Instances of bleeding can be noted quickly in the field form, as only severity levels need to be marked and reported.

The last two parts on the field form are to be filled out on the return trip to the vehicle: Transverse Cracking and Longitudinal Cracking. Because Edge Cracking and Longitudinal Cracking are now combined into a single category and not needed for HPMS data reporting, the concentration will be on transverse cracking, which is used for both HPMS and the NMDOT's PMS. As the raters walk back to the vehicle, they will count and record the number of transverse cracks that occur on each severity level. The criteria of the current protocol for rating severity and extent of longitudinal cracking (limited to cracks outside the wheel path) and edge cracking will be applied for evaluating the longitudinal cracking of the proposed protocol as a single distress type.

Separating the distress rating into two different time frames is believed to eliminate some guesswork from the evaluation process. Raters will not be overwhelmed by roads in poor condition that display all or most of the distress types if they are to concentrate on only a few at a time. As mentioned earlier, the field form for distress data collection and the distress rating criteria of the proposed protocol for flexible pavements are included in Appendices D and C respectively.

Rigid Pavements

The current protocol for rigid pavements evaluates eight distresses. Considering the recommendations for flexible pavements of the 2010 FHWA's review of the NMDOT Pavement Distress Data Collection, it is proposed to maintain the same distress types and rating criteria of severity and extent, but collect data for all severity levels present in the section. The current protocol for rigid pavements is comprehensive and collects important information related to the pavement condition and serviceability.

In addition, to obtain information for HPMS reporting, the raters will report the number of concrete slabs with fatigue cracking and the total number of slabs in the sample section. This information will be used to calculate the percentage of slabs with fatigue cracking in each section. The revised field form for rigid sections to be used with the proposed protocol is enclosed in Appendix D.

Sample Sections, Training and Evaluation Approach

The proposed (new) protocol was tested in the field with several student technicians in sample sections and with field measurements in test sections. The field evaluations of the protocols included four separate evaluations of any particular milepost or sample section. The first two evaluations were performed using the current protocol and the last two evaluations were performed using the proposed (new) protocol. Two evaluations for each protocol were required to evaluate the consistency of the raters for each protocol. Because one objective of this project was to improve the accuracy and validity of the data collection protocols, this research design was necessary.

In order to achieve the amount of data needed to validate the recommendation of the proposed protocol for flexible pavements, it was decided to conduct field evaluations in both northern and southern New Mexico. In northern New Mexico, 24 sample sections were used for comparing the current and proposed protocols. In southern New Mexico, 42 sample sections were used to compare both protocols. A total of 66 sample sections for flexible pavements are listed in Table 3. Six additional sample sections were rigid pavements. The sample sections included high and low volume roads, different types of pavement structures and materials, New Mexico routes, US highways and interstate highways. Rutting was not rated when applying the current protocol for flexible pavements.

The student technicians were first trained on the current protocol. Three NMSU raters had extensive experience applying the current protocol because they had previously worked as raters one or two summers in the distress surveys for NMDOT. They also received instruction and retraining on the current protocol. After the raters completed the two rounds of distress surveys according to the current protocol, the crews received classroom and field training on the proposed (new) protocol. Once they felt confident on the new procedures and criteria, the raters proceeded with the field tests. A graduate research assistant (Kelly Montoya), who led the training and data collection at UNM, also contributed to the training of the NMSU raters on the proposed protocol. This practice helped provide consistency on the training of both groups of raters (Figure 6).

TABLE 3 Sample Sections of Flexible Pavement Used to Evaluate the New Distress Protocol for Visual Surveys

Route	Sample Sections (Mileposts, MPs)	Direction	General Location	Number of Sample Sections
NM0006	0.0 [a], 1.0, 2.0, 3.0	P	Northern NM	4
NM0014	0.0, 1.0, 2.0, 3.0	P	Northern NM	4
NM0028	10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0	P	Southern NM	11
NM0185	4.0, 5.1, 6.0, 7.1, 8.0, 9.0, 10.0	P	Southern NM	7
NM0041	0.0, 1.0, 2.0, 3.0, 29.0, 30.0, 31.0, 32.0	P	Northern NM	8
NM0556	12.0, 13.0, 14.0, 15.0	M	Northern NM	4
US0070	142.0, 143.0, 144.0	P	Southern NM	3
US0070	142.0, 143.0, 144.0	M	Southern NM	3
US0550	0.0, 1.0, 2.0, 3.0	P	Northern NM	4
I00010	125.0, 126.0, 127.0, 128.0, 129.0	P	Southern NM	5
I00010	125.0, 126.0, 127.0, 128.0, 129.0	M	Southern NM	5
I00025	14.0, 15.0, 16.0, 17.0	P	Southern NM	4
I00025	14.0, 15.0, 16.0, 17.0	M	Southern NM	4

[a] The legal definition of Milepost 0.0 was not used. Milepost 0.0, according to the *NMDOT's Black Book*, is located north of the I-40 off-ramp. This piece of roadway is not traveled; it ends in dirt and is literally crumbling with weeds and grasses growing through the cracks. A managerial decision was made to use the first 1/10 mile (161 m) south of the off-ramp to get more realistic distresses to be used in comparing evaluation methods.

FIGURE 6 Graduate research assistant Kelly Montoya trains a group of raters on how to apply the proposed (new) protocol for visual distress surveys

Safety and General Procedures

The approaches to the pavement section and safety procedures were the same in both the current and proposed protocols. The main instructions and steps are discussed below:

1. A crew composed of two people must perform the visual surveys. One will serve as the distress rater while the other will serve as the safety person (also referred as safety spotter) to watch for hazards on and off the road. The two crew members will take turns in both roles. While in the section, the safety spotter should alert the rater of any hazard and should alert the traveling public of their presence.
2. Approach mile marker where survey location is to begin; anticipate this location because you will have to slow to a stop at the milepost (MP) marker or begin of the section. Approximately 0.5 miles (0.8 km) from the MP marker, turn on your emergency light bar and/or strobe and right-hand turn signal. Slow gradually to a stop well off the pavement adjacent to the MP marker (for positive direction). For minus direction, park 0.1 mile (161 m) before the MP marker. Turn on the emergency flashers on the vehicle (hazard lights). Leave the vehicle running (power for light bar and/or strobe).
3. Safely exit the vehicle looking for traffic from the rear. Put on required NMDOT safety vest and cap or hat, if not already wearing them. Obtain all necessary safety and evaluation equipment for conducting the distress survey.
4. The rater should have the following equipment: clipboard and pen, field form, and steel rule. The safety spotter should have the following equipment: slow/slow sign and/or orange flag, and any necessary equipment to mark off 528 ft (161 m) and to locate the end of the sample section.

5. Mark off about 528 ft (161 m) to the front of the vehicle (with traffic flow). As the safety spotter is marking off the distance, the rater will start the initial part of the evaluation and rating (Figure 7).
6. When arriving to the end of the sample section, both crew members should return toward the parked vehicle. The rater should complete the last part of the visual survey and fill out the rest of the field form (Figure 7), while the safety spotter watches for traffic and advises the rater of adverse conditions that may imperil either of their safety.
7. The safety spotter shall use the "Slow/Slow" sign or orange flag as necessary to warn the traffic. (Using a flag can be safer and more practical than a sign when strong winds are present.) The safety spotter shall continuously monitor oncoming traffic as the crew returns toward the parked vehicle and remains along the edge of the road with the "Slow/Slow" sign (or flag) facing traffic and between the safety spotter and the travel lane. The safety spotter should stay even with the rater. In rare cases where there is limited sight distance, the safety spotters may position themselves further up the road (toward the oncoming traffic) to improve their view of oncoming traffic. In no instance shall the safety spotter be outside of voice range of the rater.
8. Upon return to the parked vehicle, store all measurement and safety gear and data form. Secure safety belts and slowly move down the shoulder to the next milepost. If the shoulder is not wide enough or contains debris, then drive the vehicle into the traffic lane safely and to the next milepost (or sample section) to repeat the distress rating protocol. Remember to use flashing hazard lights until up to speed.
9. At the end of a major sample section and/or at the end of the day, the light bar, strobe (if used) and hazard lights must be turned off. At end of the workday, all equipment must be properly accounted for and stowed in motel and or vehicle trunk. Account for all equipment at the beginning of each workday. Check vehicle per daily vehicle check list each morning.

Data Comparison Method

There are currently several methods available for testing interrater agreement. One of the simplest and most robust is the average deviation (AD) Index. The AD index is actually a measure of disagreement (18), such that a value of zero means that there is zero disagreement, or total agreement. This measure was developed for use with multiple evaluators rating a single target on a variable using an interval scale of measurement. This index estimates agreement in the metric of the original scale of the item (i.e., it has the same units as the item targeted) and, therefore, can be considered a pragmatic measure (19). The AD index may be estimated around the mean (AD_M) or median (AD_{Md}) for a group of evaluators rating a single target, such as a sample section of pavement on a single item such as severity or extent of a pavement distress. Each rating is compared to the others in a group, and the deviation from the median is calculated, giving a relative "distance" from the expected value.

FIGURE 7 An NMSU rater performs visual distress survey of a flexible pavement section, walking from (left) and to (right) the vehicle

The AD_{Md} values are computed as follows:

$$AD_{Md(j)} = \frac{\sum_{n=1}^{N} \left| x_{jk} - Md_j \right|}{N} \tag{5}$$

where $AD_{Md(j)}$ = average deviation from the median computed for an item j, N = number of judges, raters or observations (consequently, the total number of deviations for an item), x_{jk} = k^{th} rater's score on item j, and Md_j = median for item j. The scale $AD_{Md(J)}$ is computed as:

$$AD_{Md(J)} = \frac{\sum_{j=1}^{J} AD_{Md(j)}}{J} \tag{6}$$

where $AD_{Md(J)}$ = average deviation computed from the median for J essentially parallel items, and $AD_{Md(j)}$ is defined as above. Although AD_M and AD_{Md} scale values can be computed directly from respective scale means and medians, these values are based on composite scores and cannot be directly interpreted in terms of response options or units of the original measurement scale (19).

Because there is rarely total agreement among evaluators, a cut-off value of c/6 can be used to determine whether there is a consensus among evaluators, where c represents the number of response options. This c/6 was developed by assuming 0.7 as a lower cut-off limit and rearranging the correlation coefficient, selecting a uniform distribution for the likelihood of an inexperienced rater choosing any possible value from the set and adjusting the results for average deviation (20). Values lower than the cut-off point mean acceptable levels of consensus, and a value that falls over the cut-off point indicates a problem of consensus among evaluators.

Following the current protocol, only the highest severity of each distress type is reported along with its extent. For every distress type, the range of severity and extent values that is available for selection in the current protocol is 0 through 3, giving 4 choices. Therefore, c = 4, and the cut-off value is c/6 = 4/6 = 0.67. The smaller the deviation from the median, the better; any AD index above 0.67 is considered a problem, and the underlying issues should be resolved to correct it. Full discussion and application of this approach to visual surveys can be found in (20) and (10).

The proposed (new) protocol involves changing the format or rating criteria of the data collected for all the distress types except longitudinal cracking. The method used to compare the interrater agreement was the same, the Average Deviation about the Median, but certain values were adapted to the format in which that the data were reported.

It is important to note that the raters' data for each distress need not be identical among raters because there is an expected inherent variability among raters. The main point of the visual surveys is to assess whether a distress is present and attempt the most accurate evaluation possible. If the severity and extent ratings reported by several raters for a given section are similar, then the distress evaluation has succeeded in giving a valid reference point for the general condition of the sample section. The application of the method for each distress will be explained next.

1. Raveling and weathering: This data item requires that only the worst severity be reported, as it is assumed that this distress affects the entire section based on the cause of the problem. Consequently, it receives an extent rating of 3 (High) regardless of the severity level. The analysis for this item is as follows: compare directly the severity ratings reported by each rater because the only available options are 0, 1, 2, and 3. The number of alternatives will be 4, and the cut-off coefficient will remain c = 0.67 for this distress.

2. Bleeding: This distress will be evaluated somewhat similar to the distress of raveling and weathering. Because more than one severity can be reported within a sample section, the sum of the observed severities will be compared among raters. For example, if one rater finds severities 1 and 2 on a sample section, the sum will be 3. If another rater finds severity 2 only, the sum is 2. The possible numbers reported are 0, 1, 2, and 3, in a combination of none or all severities, so the number of different alternatives is seven: 0, 1, 2, 3, 4, 5, and 6. The cut-off coefficient for this distress will be c = 1.17.

3. Alligator cracking: This distress will be evaluated by pacing off the lengths of each severity of alligator cracking located within the sample section. In order for this value to be compared among raters, it will be converted to a percentage of area of the

section. (Each rater will most likely have a different pace length.) The percentage of area will be rounded to the nearest 5%, according to HPMS requirements, and compared among raters. The number of alternatives will be 36, because the highest possible alligator cracking area within a sample section will be 33.3% and, due to the rounding, will be reported as 35%. It was decided to use the range of 0 to 35% as opposed to multiples of 5 (i.e., 0, 5, 10, 15, 20, …, etc.) to avoid an exaggeration of 5 times the actual deviation, which could skew the results negatively. The cut-off value here will be c = 6.0.

4. Transverse cracking: This distress is evaluated by counting the number of cracks that occur within a sample section for each severity level. The HPMS requires this data item be reported in linear feet per mile; therefore, the number of cracks is multiplied by 12 feet (the assumed lane width) to obtain a length, and is multiplied again by 10 to convert the 0.1 mile-long sample section that is evaluated to a full 1.0 mile-long section. Hence, the number reported to HPMS will be a multiple of 120. For the sample sections considered in this study, the average greatest number of cracks (all severities) in a given section reported by UNM and NMSU raters for rounds 1 and 2 was 51. This value was adopted as the upper limit of number of transverse cracks (6 ft or longer). Therefore, the number of alternatives will be 6,121 (= 51 × 120 = 6,120, plus 1 for the option of no transverse cracks). Again, it was decided to use a continuous range rather than multiples of 12 to avoid skewing results. The cut-off value in this case is c = 1,020.

5. Longitudinal cracking: This distress type is reported in each severity along with the corresponding extents. In order to obtain a single index value to be used for comparison, it has been decided that a level of distress should be calculated. This level of distress consists of the sum of each severity multiplied by the extent of that severity. This distress is not required for HPMS reporting, so it will be used entirely for NMDOT's PMS purposes. The number of alternatives is the sum of each possibility of combinations, from 0 through 18, giving a total of 19 possibilities. The cut-off value is c = 3.17.

PSI Comparison and Statistical Methodology

The modifications to the distress rating criteria and protocol of visual surveys resulting from this research will affect the format and type of input distress data available to calculate DR and PSI with Equations 1 through 4. Because PSI values are used annually to assess the overall condition of the highway network in the state and for other PMS and reporting purposes of NMDOT, it was important to address this issue. The NMDOT provided direction in regard to potential changes to PSI calculation. The direction was focused on minimizing the overall effect of the change of protocol on the PSI values. In other words, the PSI calculated with distress data obtained with the proposed protocol should be as closed as possible to the PSI calculated with distress data obtained with the current protocol of visual distress surveys.

The following approach was applied to revise the PSI calculation to accomplish this goal.

1. PSI with Current Protocol:
    - 1.1 Only distress ratings obtained in round 2 of visual surveys (both current and proposed protocols) were used in these analyses. Sixty six sample sections of flexible pavements were considered.
    - 1.2 Because there were individual ratings obtained by three or four raters for each sample section (current protocol), then a DR value (Equation 4) was calculated for each rater; these values were then averaged for each section (current protocol).
    - 1.3 For each sample section, a PSI value was calculated with Equations 1 through 3 using the averaged DR (current protocol).

2. PSI with Proposed Protocol:
    - 2.1 The terms in the total distress rate (DR) (Equation 4) corresponding to the distresses of edge cracking and patching were eliminated.
    - 2.2 Data from three raters were available for each sample section. For the severity ratings of raveling and weathering, bleeding and longitudinal cracks, the lowest and highest ratings were dropped and the remaining rating for each distress type (and its corresponding extent ratings) was used.
    - 2.3 The averages of number of transverse cracks and alligator area from the data of the three raters were used to deduce extent ratings for each severity level. The applied methodology will be described in later sections.
    - 2.4 A multivariable optimization analysis was performed in terms of PSI. The weight factors for raveling and weathering, bleeding, transverse cracks, alligator cracking and longitudinal cracks were determined.

The analysis used IRI and automated rut depth data collected in the 2009 data collection cycle for most sample sections. For some of the sample sections in the southern part of the state, 2009 IRI data were not available and thus 2008 IRI data were used in those cases. The IRI and automated rut depth data were not collected in 2010 and 2011.

The statistical analyses sought to minimize the difference (or error) between the PSI values calculated using distress data applying the current protocol and the PSI values calculated using distress data applying the proposed protocol. The method of least squares was applied for the data fitting, so that the sum of squared residuals was minimized. In this problem, for a given sample section, the sum of squared residuals (SSE) was defined as the squared difference between the PSI value calculated with data from the current protocol (observed value, $PSI_{Current.Prot}$) and the PSI value calculated with data from the proposed protocol (value provided by the model, $PSI_{Proposed.Prot}$):

$$\text{Minimize} \quad SSE = \sum_{i=1}^{ND} (PSI_{\text{Current Prot}} - PSI_{\text{Proposed Prot}})^2 \tag{7}$$

where ND is the number of PSI values in the data set (number of observed values).

NMDOT DISTRICT SURVEY

The main objective of this study was to revise the NMDOT's current procedures for pavement distress evaluation in order to meet requirements of HPMS reporting and its PMS needs. A survey was sent to NMDOT's district maintenance engineers and/or assistant maintenance engineers of the six NMDOT Districts to learn how much familiar they were with the current distress data collection procedures and how/if they were using the PSI values in their maintenance planning activities at the district level. Another important aspect of this survey was to know how important the distresses of Raveling and Weathering and Bleeding were to planning their pavement maintenance activities. This could be useful for the revision of the PSI equation and weights.

The survey was composed of 13 questions; the thirteenth question asked to volunteer any information the responder would want to share with the project team. As of the time of this report, responses were received from Districts 1, 2, 3, 4 and 6, with District 4 providing two responses. Numerous calls were placed to District 5 engineer listed as the contact for this position, but the project research assistants were not able to obtain a response to the survey from this district. Appendix E contains the survey questionnaire and the responses from the districts.

When asked how familiar they were with the NMDOT's Annual Pavement Distress Data Collection procedures and rating criteria, 4 of the maintenance engineers responded that they were very familiar with the procedures and criteria and 1 maintenance engineer expressed to be somewhat familiar. They also indicated that they had access to the flexible distress data and PSI for the sample sections located in their districts. Three of the districts stated they use the PSI computed from distress surveys and roughness data to plan and prioritize their maintenance works. The other two said they do not use the PSI values.

The responder of District 3 said that this District collects its own distress data. The responder of District 3 also mentioned that their method of evaluation of distresses differs from that applied by the Universities (which is the official NMDOT protocol for pavement distress rating) and had questions about how the PSI values are computed. District 6's responder stated that the distress evaluations are carried out on sample sections for which the PSI values are calculated; hence, the PSI values do not reflect what is actually on the field.

One of the questions was for the districts to rate six pavement distresses in terms of pavement serviceability. Table 4 summarizes the ratings of the distresses in determining pavement condition or serviceability in terms of their capacity to carry traffic loads. Overall, rutting and shoving and alligator cracking were the distresses rated higher as good or excellent indicators of the pavement condition and structural capacity of the pavement by the District maintenance engineers. In this survey, transverse cracking and edge cracking were rated mostly as not good indicators of pavement serviceability by the districts.

Though the districts said they had access to the distress data collected in their districts, 4 of them said they collected their distress information on an annual basis on New Mexico routes and interstate highways and this information indicated to them which routes needed to be maintained. One district, however, responded that it only does visual inspections.

The districts were asked to state the criteria that they used in determining which routes needed maintenance. The following are some of the criteria mentioned: route type (interstate, US routes, etc.), history of last work performed on roadway, severity of distresses, types of distress, condition of the roadway, availability of funding, requests and complaints from the public and/or others, pavement age, volume of heavy commercial traffic, past knowledge and performance of roadway, and how quickly the roadway is deteriorating.

The survey also indicated that maintenance activities by the districts were not being scheduled for pavements with bleeding alone, which may indicate that bleeding does not have a high weight on district planning of maintenance activities. In cases where maintenance activities were to be planned due to bleeding, the severity and extent are used in prioritizing which routes need to be maintained.

With regard to raveling and weathering, the districts said that information on the portion of the section that shows medium and high severity levels was very important to them. Two of the responders said that data was useful to them if information was available for the whole mile and not just 0.1 mile (which is the length of the sample section). However, some stated that the extent ratings and percentage of the 0.1 mile (161 m) long section that showed high and medium severity levels were the information needed.

TABLE 4 Rating of Pavement Distresses by NMDOT Districts in Terms of Pavement Serviceability

Raveling and Weathering	Bleeding	Rutting and Shoving	Alligator cracking	Transverse Cracking	Edge Cracking
2	2	1	1	3	3
1	1	1	1	4	4
4	3	1	1	4	3
3	4	3	2	2	3
2	4	2	2	2	3

Note: Rating legend

1: Distress type is an excellent indicator of the pavement condition/serviceability
2: Distress type is a good indicator of the pavement condition/serviceability
3: Distress type has some relationship with the pavement condition/serviceability
4: Distress type is NOT a good indicator of the pavement condition/serviceability

DATA ANALYSIS AND RESULTS

Variability of Current and Proposed Protocols Using Average Deviation Index

Current Protocol

Four UNM student technicians and three NMSU student technicians were trained and assigned to perform visual surveys according to the current NMDOT distress rating protocol (except rutting and shoving data). Each rater independently evaluated each sample section twice, in two rounds of visual surveys. The first and second rounds of surveys were separated in time by two to four weeks and were completed before the raters were trained on the proposed protocol.

The Average Deviation (AD) Index method was applied to assess quality and variability of the data obtained with the current protocol. Ideally, the differences in average deviations about the median would be 0, but anything under c = 0.67 was considered acceptable. Figures 8 through 11 show the average deviation about the median for each distress in rounds 1 and 2 of distress surveys by distress severity and extent for UNM and NMSU raters, respectively. Note that the segmented lines in these figures represent c = 0.67, which is the cut-off value for agreement.

All distresses may be shown on the same graph because they are all rated in the same manner according to the current protocol, with both severity and extent having a range from 0 to 3 and the same number of alternative choices. The overall trend of the data for each raters group (NMSU and UNM) between rounds 1 and 2 is similar, even though the values are slightly different. This confirms that there is stability in the rating methods. Overall, the agreement between raters is good to very good. Only the distress of bleeding reported by the UNM group had values slightly above the cut-off for severity and extent. Previous research has shown that bleeding in the current protocol had the greatest variability overall, both among student raters and between student raters and expert raters (10). Bleeding tends to be difficult for inexperienced raters to evaluate, whereas alligator cracking is a distress that is both repeatable and reproducible (10). These trends have been confirmed through this exercise.

The NMSU raters showed greater level of agreement among their ratings. This could be partially attributed to the prior experience and familiarity of these raters about the current NMDOT protocol because they all had previously worked either one or two summers in a full-time basis as distress raters applying this method.

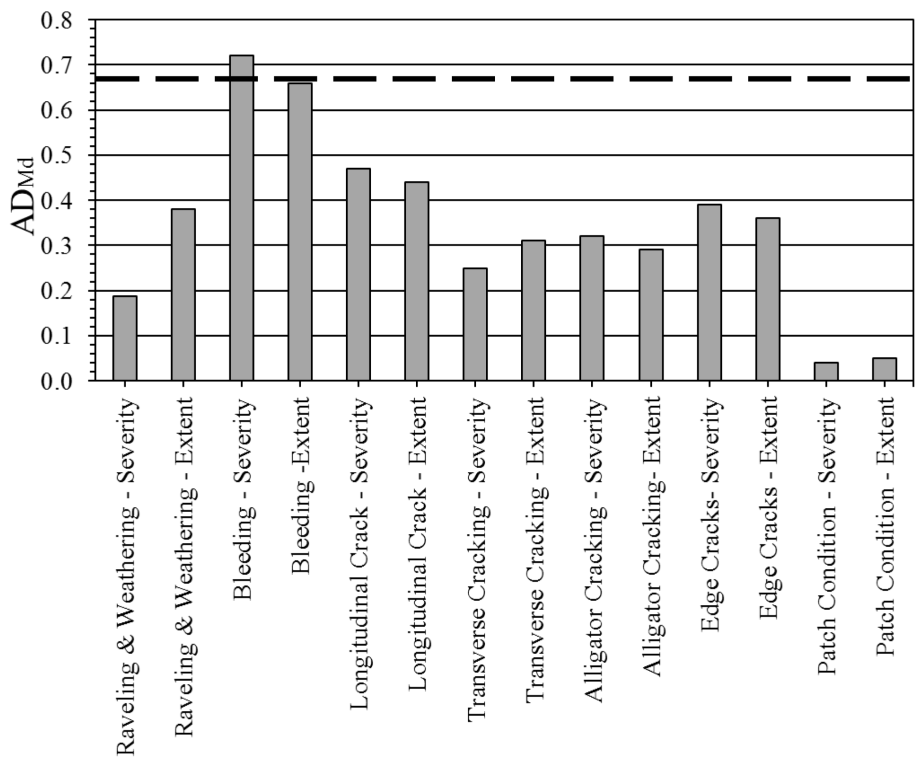


FIGURE 8 Results of AD Index method for UNM raters' data of round 1 of visual surveys (c = 0.67) applying the current protocol

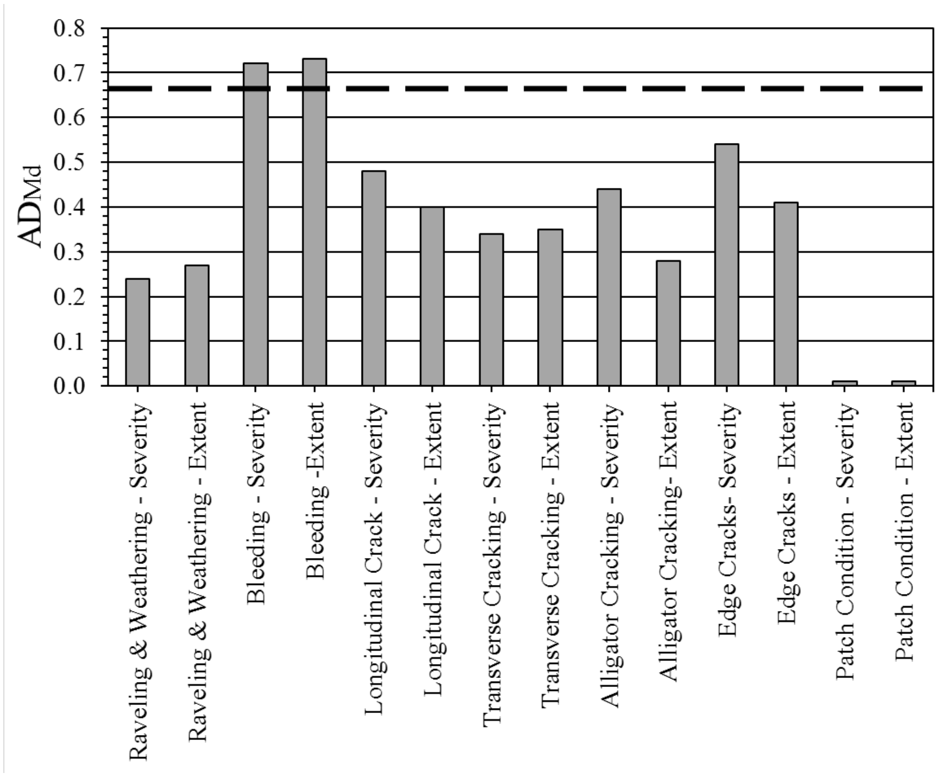


FIGURE 9 Results of AD Index method for UNM raters' data of round 2 of visual surveys (c = 0.67) applying the current protocol

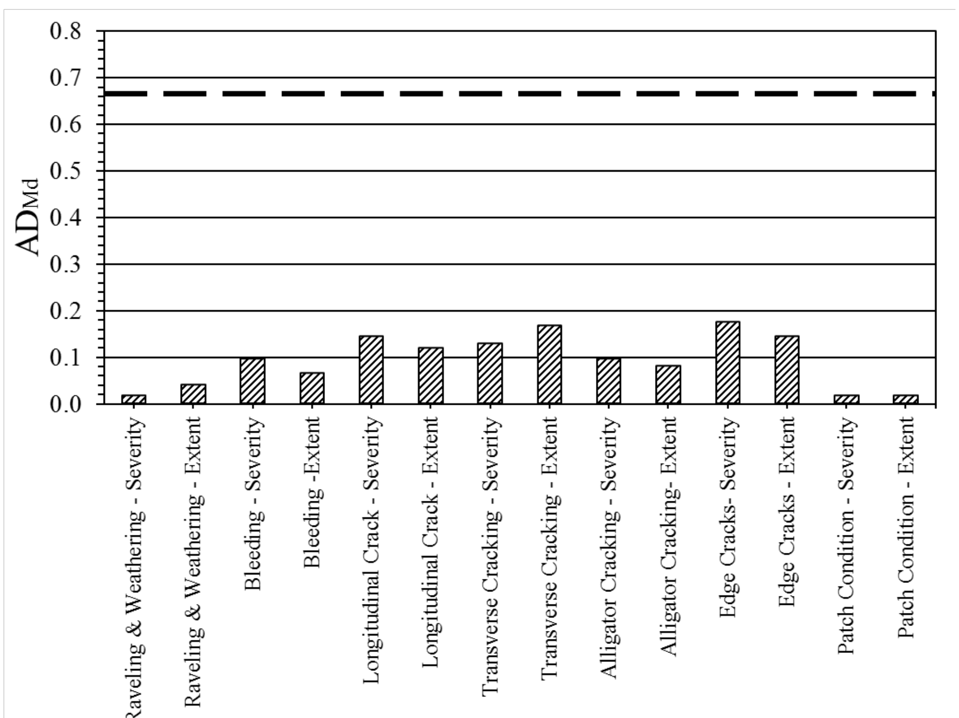


FIGURE 10 Results of AD Index method for NMSU raters' data of round 1 of visual surveys (c = 0.67) applying the current protocol

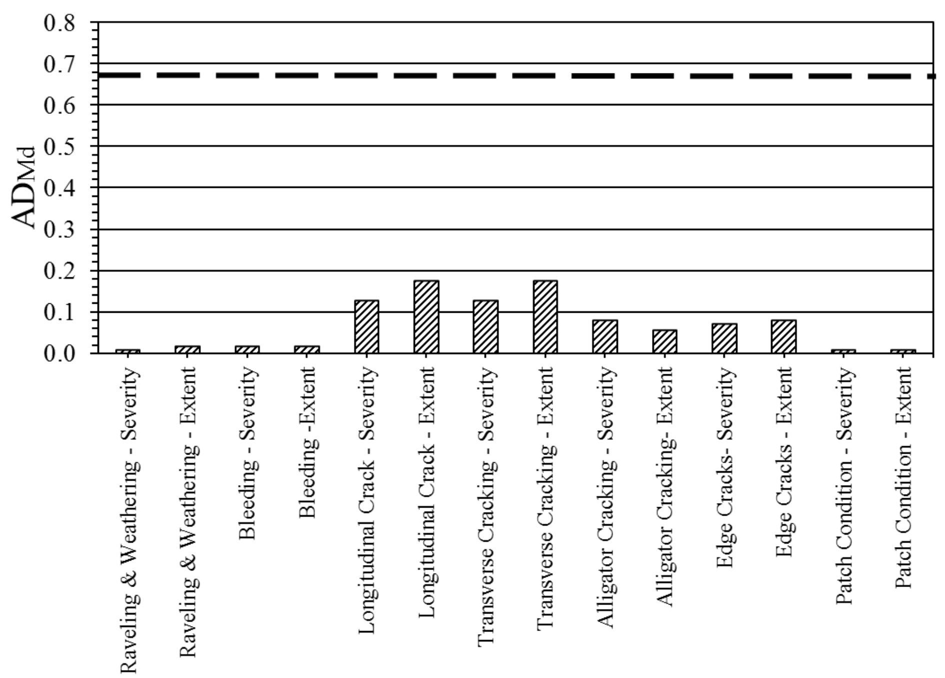


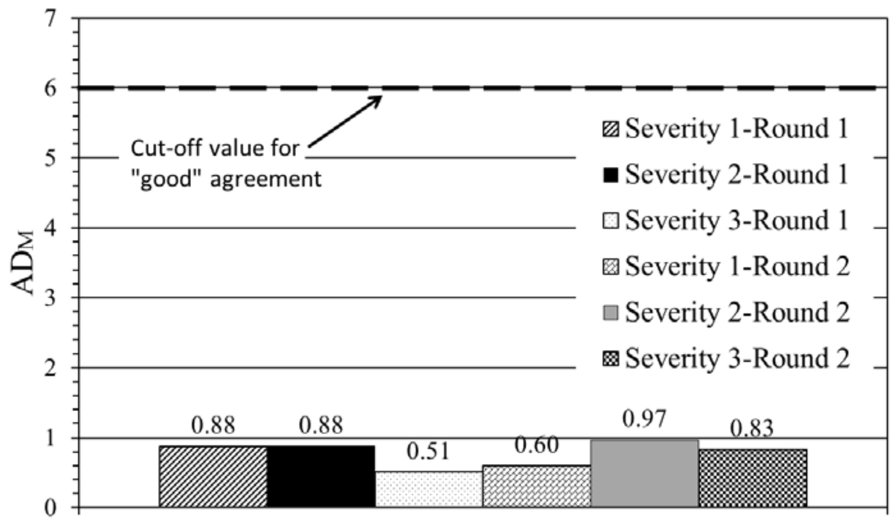
FIGURE 11 Results of AD Index method for NMSU raters' data of round 2 of visual surveys (c = 0.67) applying the current protocol

Proposed Protocol

Each distress according to the proposed (new) protocol must be evaluated separately because of the differences in the ranges of scores and numbers of alternatives for the various distress types. However, the same method of analysis was applied based on the average deviation among the mean (AD_M) and average deviation among the median (AD_{Md}). Each severity level was evaluated separately to determine whether the criteria describing each severity were adequate, clear and repeatable. The assessment per distress type is described next.

Alligator cracking. In addition to the individual severities, an analysis was performed on the total alligator cracking reported per sample section as another test of the proposed protocol. If any individual severities of alligator cracking reported had large variability but the total did not, it could indicate a potential problem with the severity criteria or training. If the total alligator cracking had large variability, it could indicate a potential problem with rating the extent of the distress. Figures 12 through 14 show the results from the data analysis for alligator cracking. In these figures, the cut-off value for good agreement was c = 6.0, indicated by the segmented line. Figures 12 and 13 show the average deviations about the mean and the median by individual severity.

Finding large variability in Figures 12 and 13 would have indicated that the criteria to rate severity levels are unclear or that individual raters were having difficulty rating consistently this distress in terms of the severity. However, the values were very close together, and very small (well below the cut-off value), which showed that in general alligator cracking could be rated consistently and with relatively small variation among raters.



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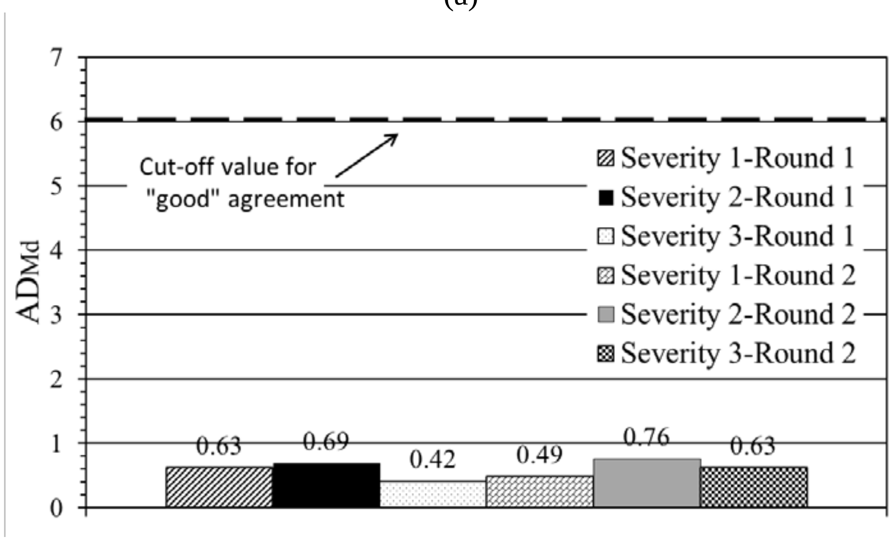
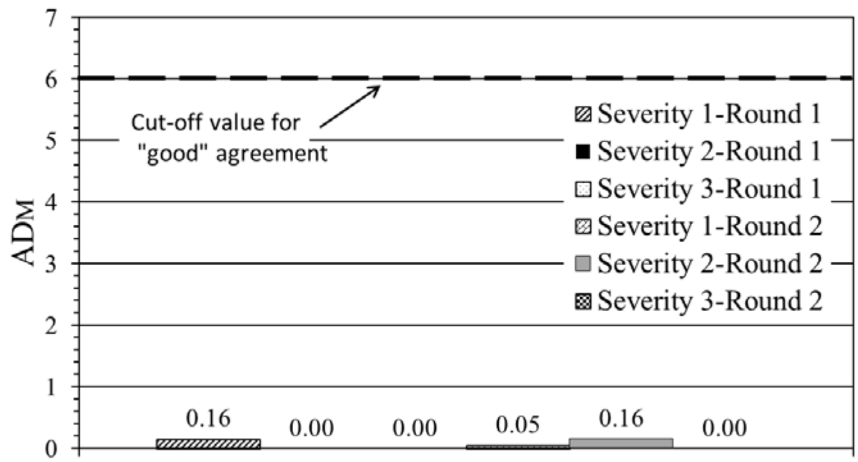


(b)

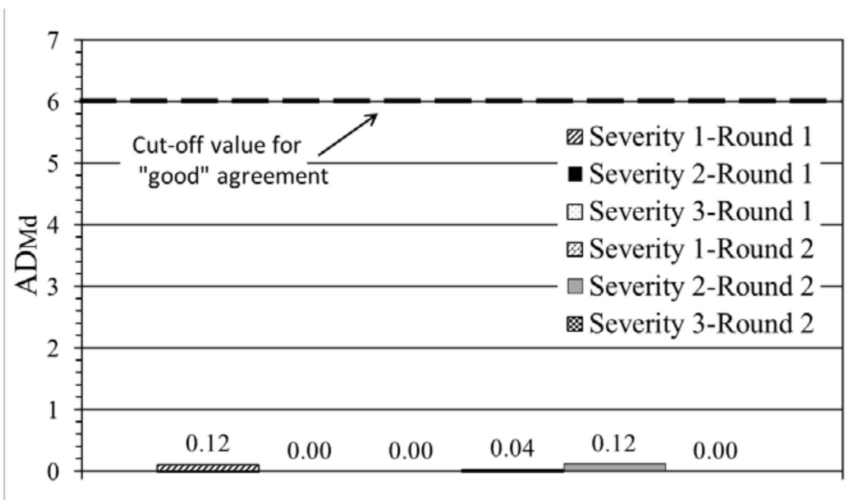
FIGURE 12 Results for severity ratings of alligator cracking (c = 6.0) applying the proposed protocol based on UNM raters' data: a) AD_M and b) AD_{Md}

Figure 14 shows the average deviations about the mean and median for alligator cracking (aggregate of all severities) found in a given sample section. Figures 14a and 14b combined all severity levels present. The average deviations of the total (aggregated) alligator cracking for rounds 1 and 2 were slightly lower than the individual severity deviations. This observation could indicate that the raters had more difficulty (more variability) determining the severity of the distress than deducing the length of the sample section affected by the distress.

A possible explanation for this observation is the location of the distress on the pavement surface. A primary assumption in rating alligator cracking in the proposed protocol is that it occurs only in the wheel path, but distinguishing the exact lateral limits of the wheel paths from the rest of the lane can be difficult depending on lane width, configuration (i.e., a curve in the road), pavement condition, and the type of route being rated (busier roads with more traffic could make evaluating the pavement more challenging). Because the location of longitudinal cracks may be hard to determine from the shoulder, it is possible that some longitudinal cracks in the wheel path (which should be rated as alligator cracking of severity 1 were reported as longitudinal cracking outside the wheel path, or vice versa.

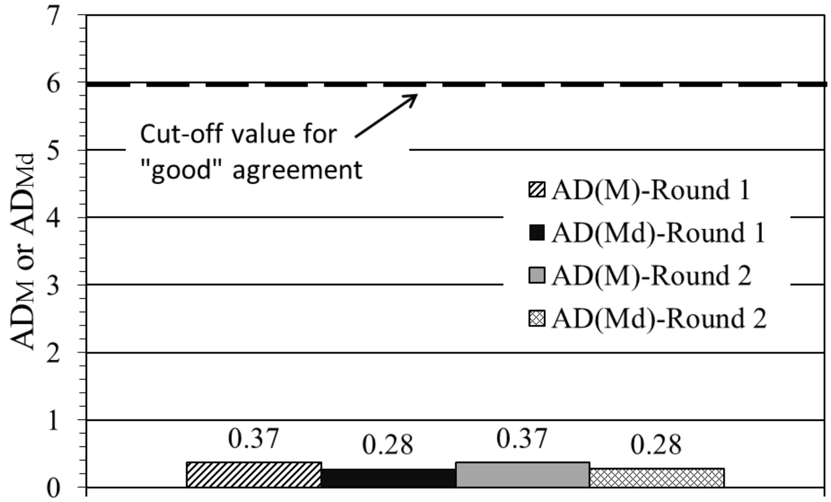


(a)

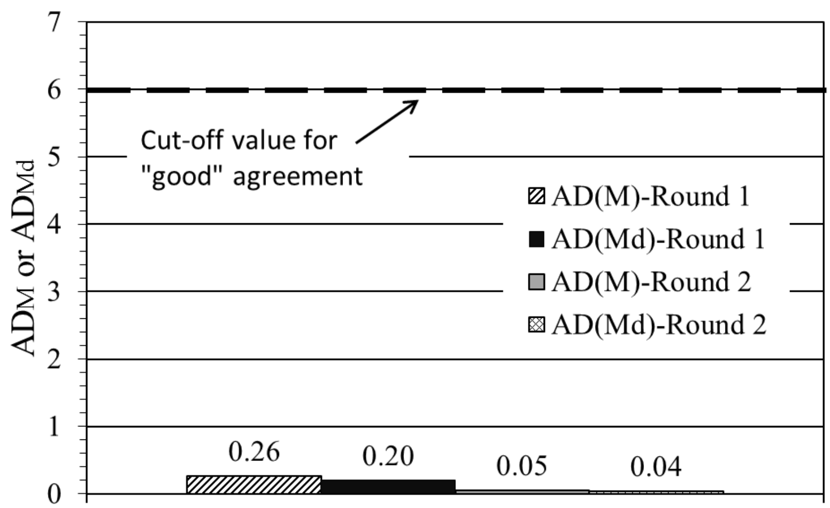


(b)

FIGURE 13 Results for severity ratings of alligator cracking (c = 6.0) applying the proposed protocol based on NMSU raters' data: a) AD_M and b) AD_{Md}



(a)



(b)

FIGURE 14 Results of AD_M and AD_{Md} for aggregated (all severities) alligator cracking (c = 6.0) applying the proposed protocol: a) UNM raters and b) NMSU raters

Transverse cracking. This distress was analyzed in a similar manner as alligator cracking. Figures 15 and 16 show the average deviations about the mean and median, respectively, across two rounds of visual distress surveys. The cut-off value for good agreement is 1,020 and is indicated by the segmented line in these figures. Figures 17 and 18 show the average deviations about the mean and median for transverse cracking as an aggregate value (all severities).

The average deviations of the total number (aggregate of all severities) of transverse cracking for survey rounds 1 and 2 were slightly higher than the individual severity deviations. This observation could indicate that the raters had some difficulty (more variability) distinguishing among severity levels than counting the number of cracks. A possible explanation for this observation is that the rater has to apply own judgment in deciding the severity level of each single crack, while tracking the crack counting and keeping up with other parts of the surveys in an entire lane with traffic interrupting the view.

New to this protocol is also the "10% Rule," which states that if at least 10% of a crack can be rated as a higher severity, then it shall be rated based on that highest severity regardless of the severity level(s) of the rest of the crack length. Another possibility of variability in general may be that the rater must decide whether a transverse crack reaches halfway across the lane in order to be counted ("6 ft or longer") in the proposed protocol. This apparently simple judgment call becomes much more challenging when a sample section is in poor condition and exhibits several distress types and various severity levels throughout and in which it is difficult to determine where one crack ends and another begins.

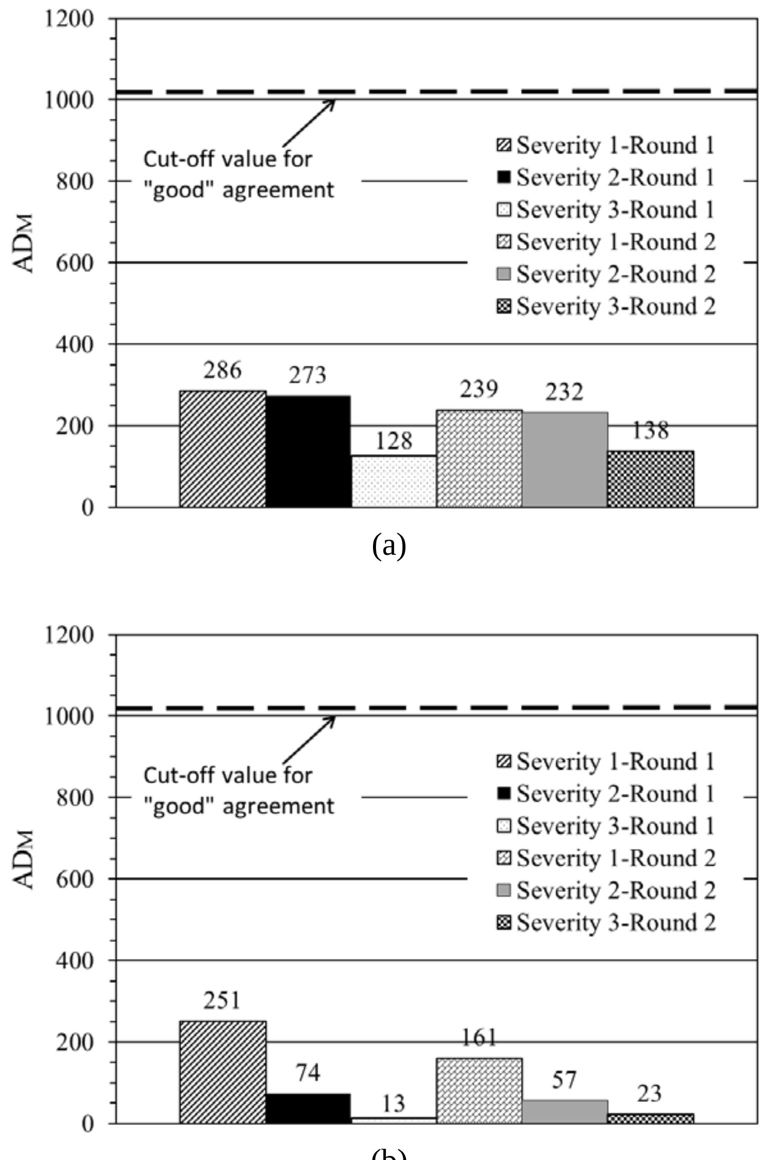
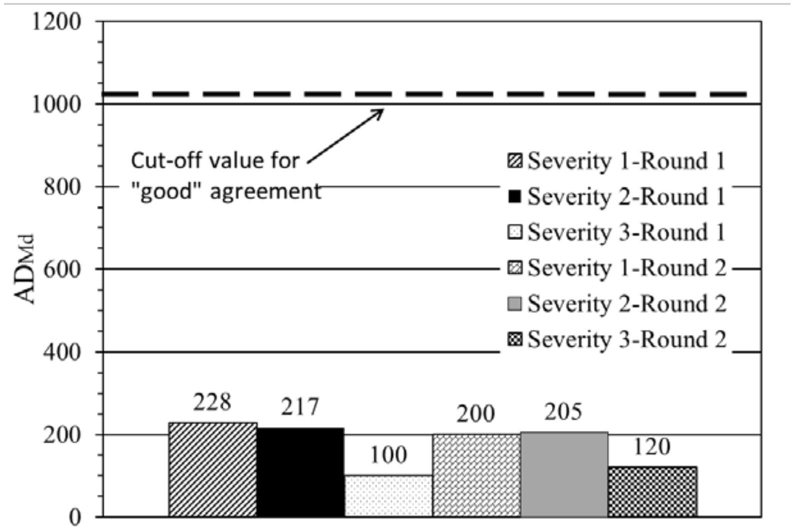
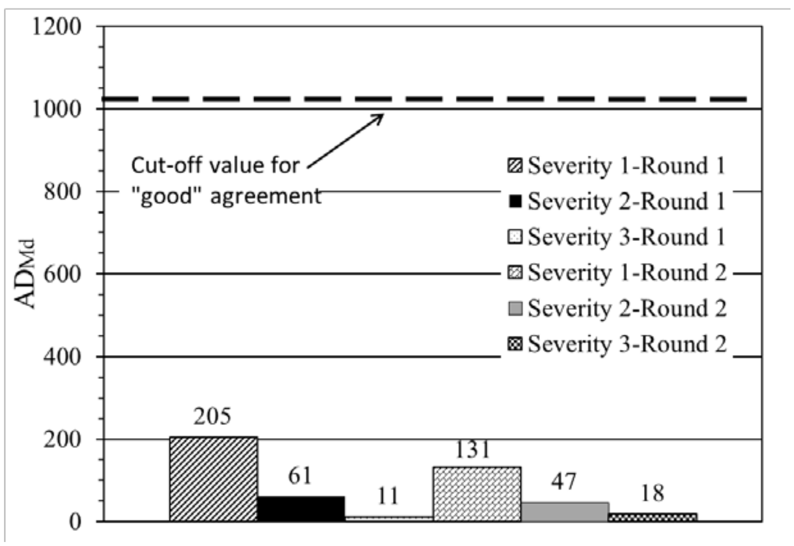


FIGURE 15 Results of AD_M for severity ratings of transverse cracking (c = 1,020) applying the proposed protocol: a) UNM raters and b) NMSU raters



(a)



(b)

FIGURE 16 Results of AD_{Md} for severity ratings of transverse cracking (c = 1,020) applying the proposed protocol: a) UNM raters and b) NMSU raters

Raveling and weathering. The severity rating of raveling and weathering did not change much from the current to the proposed protocols. The rating criteria were revised so that the severity of this distress could be rated more consistently (i.e., with greater agreement) and a new provision was included to indicate whether no raveling and weathering was present. (The current protocol states that all sections, regardless of age, condition or appearance, should be rated as a minimum with severity 1 and extent 3. Because of the application of this new rating criteria, variability in the severity aspect was reduced among raters, as shown in Figure 19.

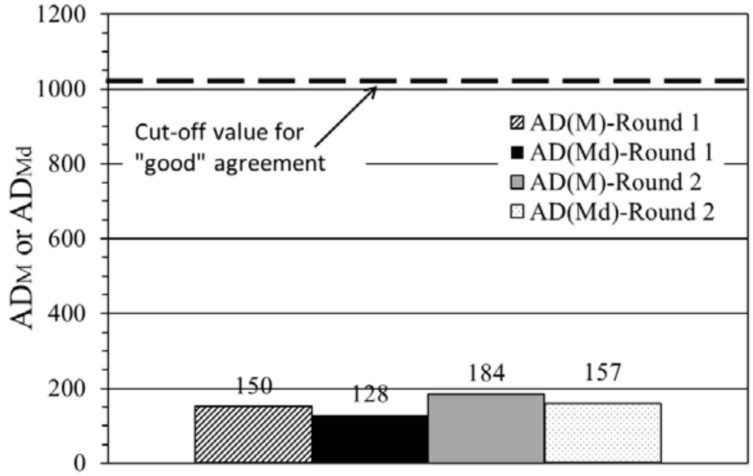


FIGURE 17 Results of AD_M and AD_{Md} for aggregated (all severities) transverse cracking (c = 1,020) applying the proposed protocol for UNM raters' data

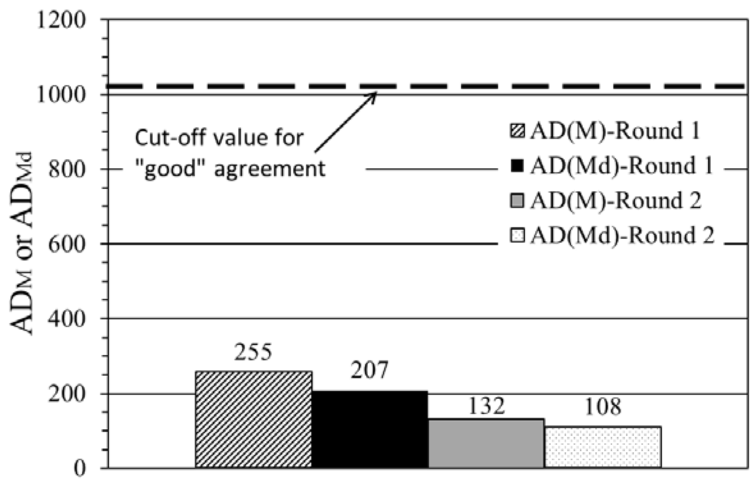
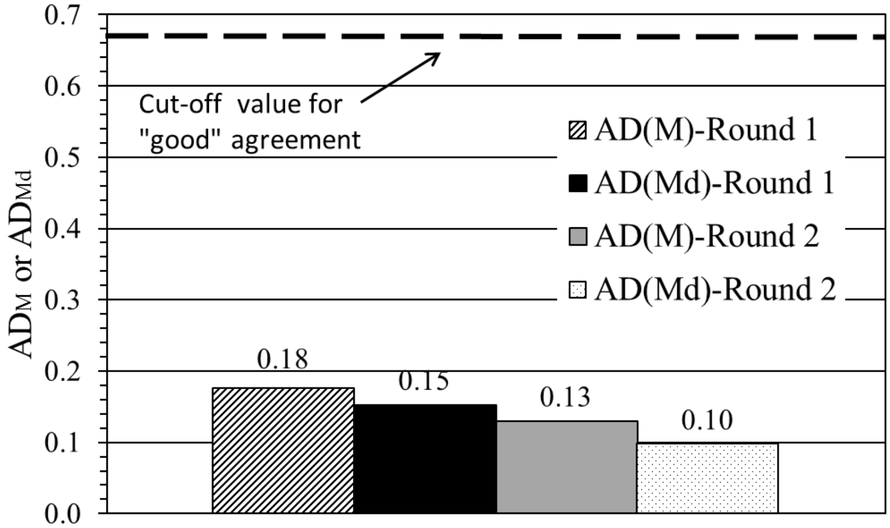
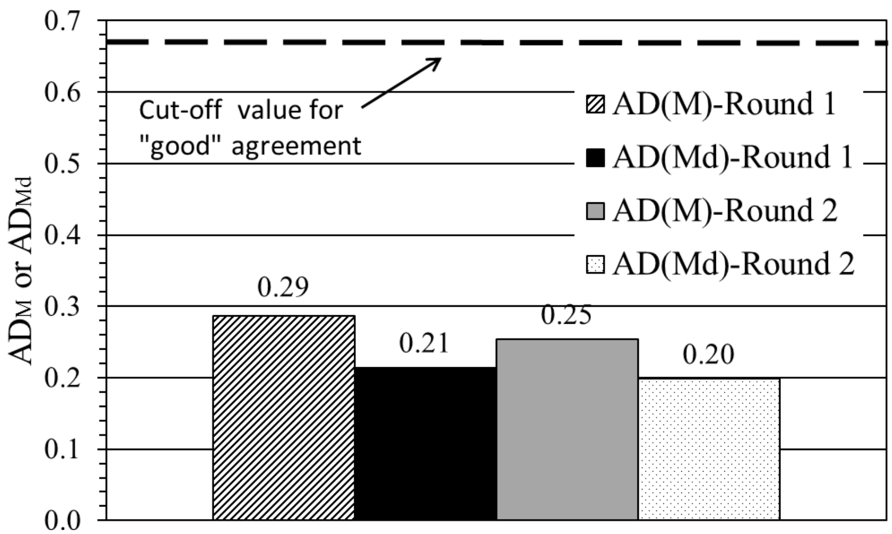


FIGURE 18 Results of AD_M and AD_{Md} for aggregated (all severities) transverse cracking (c = 1,020) applying the proposed protocol for NMSU raters' data

Bleeding. The distress of bleeding is still the hardest distress to identify and quantify due to the nature of the defect. In the proposed protocol, raters are to identify all severities that they encounter across the test section. This can be especially difficult. One rater may perceive a discoloration or tire marks on the pavement surface as a spill, while another rater may perceive it as a severity 3 (which is defined as "no aggregate shows through"). An evaluator may miss a small occurrence entirely, while one rater may catch them all. Even more complexity is added when raters are asked to note all three severities rather than the most severe. However, the variability of severity ratings for bleeding that was observed when applying the current protocol has been reduced because of revised rating criteria in the proposed protocol. Figure 20 shows the most recent analysis of interrater variability (severity) for bleeding applying the proposed protocol.



(a)

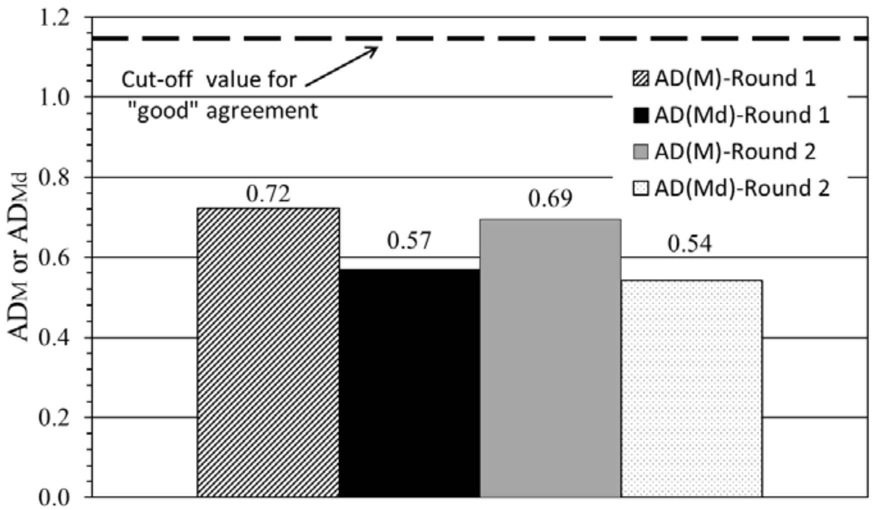


(b)

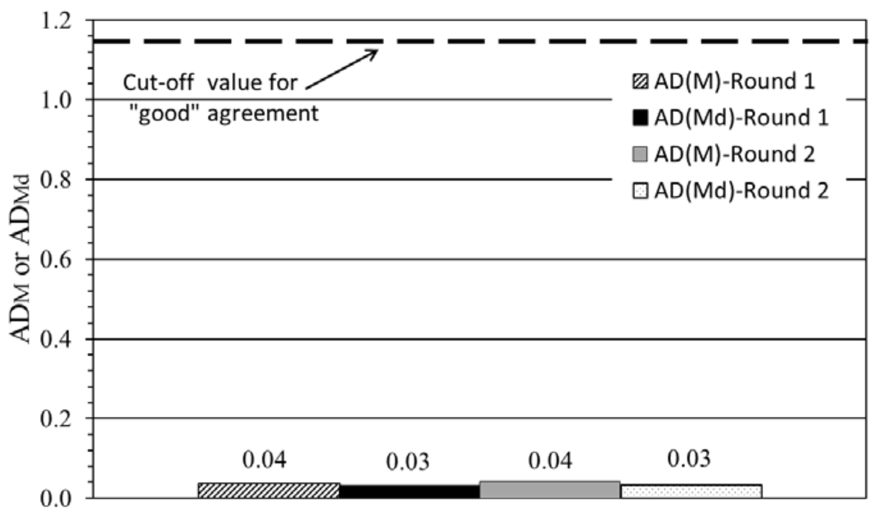
FIGURE 19 Results of AD_M and AD_{Md} for raveling and weathering (c = 0.67) applying the proposed protocol: a) UNM raters and b) NMSU raters

Longitudinal cracking. The rating procedure for longitudinal cracking did not change, except that now this distress is to include edge cracking and exclude longitudinal cracks along (or within) the wheel paths. Edge cracking is longitudinal cracking that occurs within one foot on either side of the pavement's edge or edge stripe. Because the proposed protocol requires that each severity for longitudinal cracking be rated, the variability of this distress was expected to increase. The rater no longer can focus solely on rating the extent of the highest severity present, but should keep track of the extent of all severity levels found on the sample section. In addition, the difficulty in determining the exact location of the wheel paths to avoid including longitudinal cracks in the wheel paths (which are now part of alligator cracking) may contribute to increased disagreement among raters' data. This issue is shown by the results shown in Figure 21a for a group of raters. It can be seen that the agreement among raters increased significantly and dropped below cut-off value (c = 3.17) in round 2. This is likely due to the experience and familiarity about the criteria and procedures gained by that group of raters with time and training.

Finally, the level of interrater agreement obtained with the current and proposed protocols were compared and the results are shown in Figure 22. It was found that the proposed protocol produced greater levels of interrater agreement for all distresses considered.

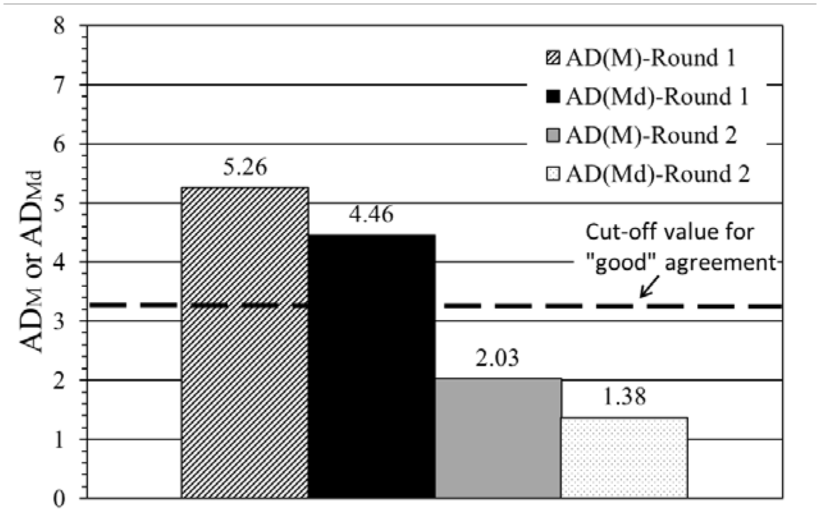


(a)

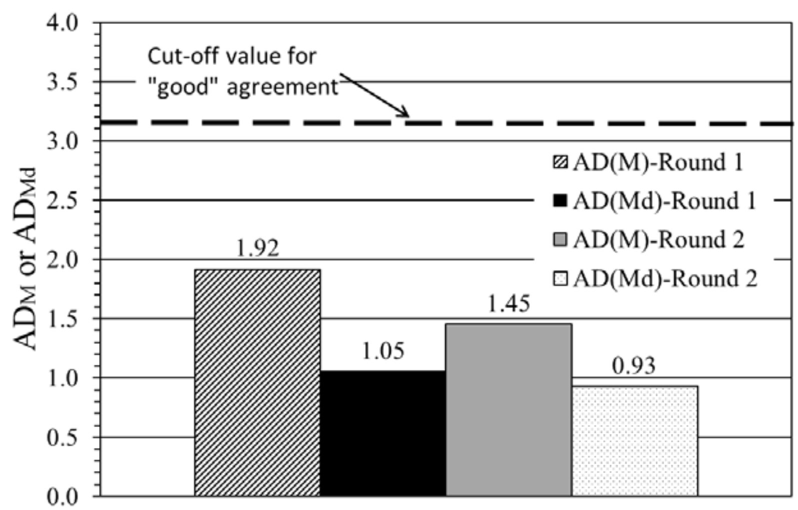


(b)

FIGURE 20 Results of AD_M and AD_{Md} for bleeding (c = 1.17) applying the proposed protocol: a) UNM raters and b) NMSU raters



(a)



(b)

FIGURE 21 Results of AD_M and AD_{Md} for longitudinal cracking (c = 3.17) applying the proposed protocol: a) UNM raters and b) NMSU raters

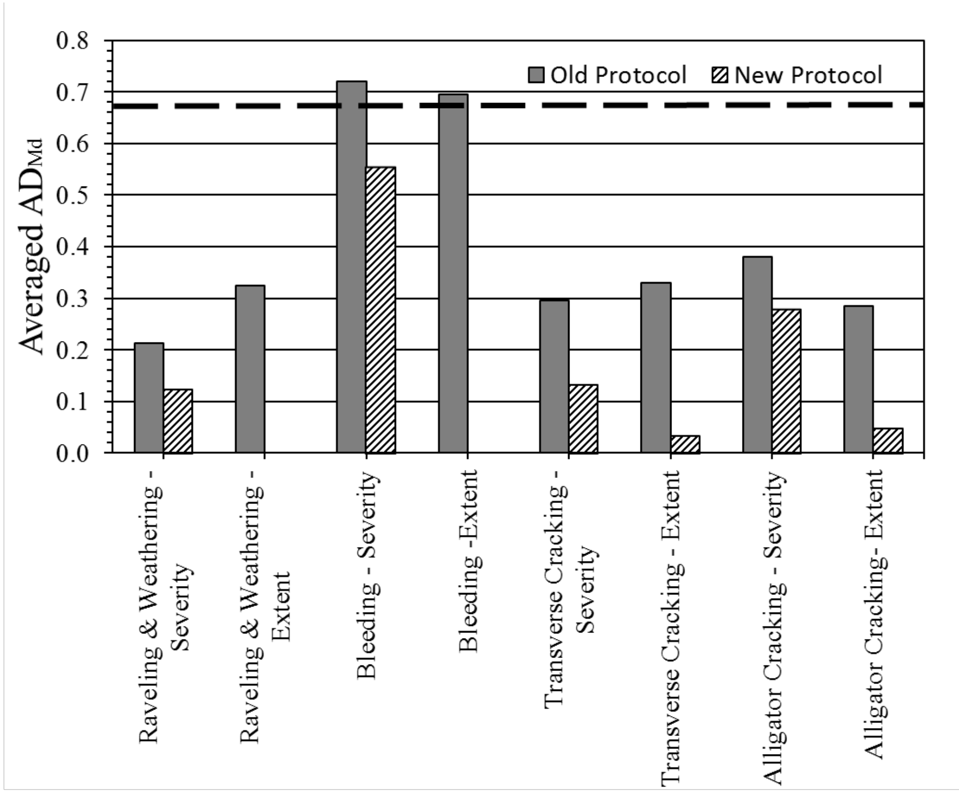


FIGURE 22 Results of averaged AD_{Md} (rounds 1 and 2) for four distress types for the current and proposed protocols

Survey Time

Flexible Pavements

The proposed protocol for flexible pavements evaluates five distress types. For the distress of raveling and weathering, raters report the highest severity rating only. The extent of the distress of raveling and weathering is assumed to be 3 (High). For the distress of bleeding, the proposed protocol rates all severity levels present and assumes that the extent of each severity found is 1 (Low). For these two first distresses, the time required to report the information is about the same as in the current protocol.

For the transverse, longitudinal and alligator cracking, the proposed protocol requires that the raters report all severity levels and the corresponding extent data, given in either paces (or pace counts) or extent rating for each severity level present in the section. The raters will have to keep track of pace and percentage of section for several distress types and severity levels. For sample sections having all or most distress types considered by the proposed protocol and in fair or poor condition, the time required for the survey may be longer compared to the current protocol. The required survey time per section also may vary with the level of experience of the raters on applying the protocol. However, in the trial runs, the time required to evaluate a given section was in average comparable for both protocols.

Rigid Pavements

If the recommendation of maintaining the same protocol and criteria for severity and extent of rigid pavements but reporting the ratings for all severity levels is adopted, the survey time for rigid sections will increase, possibly about 50% of the current time per section. However, the number of concrete sections in New Mexico is considerably small, so the effect on the overall state-wide pavement evaluation program would not be significant. Nevertheless, it will be important to take this change into consideration for planning and scheduling purposes.

Analysis and Comparison of PSI Values

One of the goals of this study was to revise the factors (Table 1) in the current PSI and DR equations to minimize the difference (or error) between the PSI calculated with data from the current protocol and the PSI calculated with data from the proposed protocol for a given sample section. The focus will be in the formulation for flexible pavements. The statistical analysis of PSI values (current and proposed protocols) determined new values of the weight factors for the five distress types in the proposed protocol for flexible pavements. The number of sample sections in the field test was 66, which is the number of observed or predicted values (= ND).

The new weight factors that produced the best fit of the available data (and minimized the square error) are shown in Table 5. The optimization was constrained so that the weight factors were equal to or greater than 1.0. Note that the weight factor and extent factors for the distress of rutting and shoving were not changed and are the factors currently used in the PSI formulation. For the other five distress types, the extent factors were eliminated because all severity levels present on a sample section are reported, along with their corresponding extent levels, in the proposed protocol. The PSI equation was calculated with equations 1 through 3. The Distress Rate (DR) was calculated with the revised equation described in the Implementation Plan (Appendix G).

Figure 23 compared the PSI values calculated using distress data obtained with the current protocol and PSI values calculated with the factors in Table 5 and raters' data obtained with the proposed protocol for visual distress surveys. In this figure, the best-fit straight line, its equation and coefficient of determination are shown.

Of the 66 sample sections considered in this analysis, 9 sections (13.6%) would be rated, based on their PSI value, in a pavement condition level that was either higher or lower than the one in which they were ranked applying the current protocol and PSI equation and factors. Of these, 2 sections (3%) fell in a higher (better) condition level, whereas 7 sections (10.6%) fell in a lower (worse). The rest of the sections (55 or 86.4%) were rated in the same condition level (i.e., they fell in the same pavement condition level based on PSI) regardless of the type of distress data used. As a reference, the NMDOT's pavement condition ranking criteria for interstates and non-interstates are given in Table 2.

TABLE 5 Proposed Weight Factors for Flexible Pavements

Distress Type	Weight Factor	Extent Level	Extent Rating	Extent Factor
Raveling and Weathering	1.0	(Do not apply)		
Bleeding	5.8			
Rutting and Shoving	14.0	Low	1	0.5
		Medium	2	0.8
		High	3	1.0
Longitudinal Cracking	4.5	(Do not apply)		
Transverse Cracking	1.8			
Alligator Cracking	8.1			

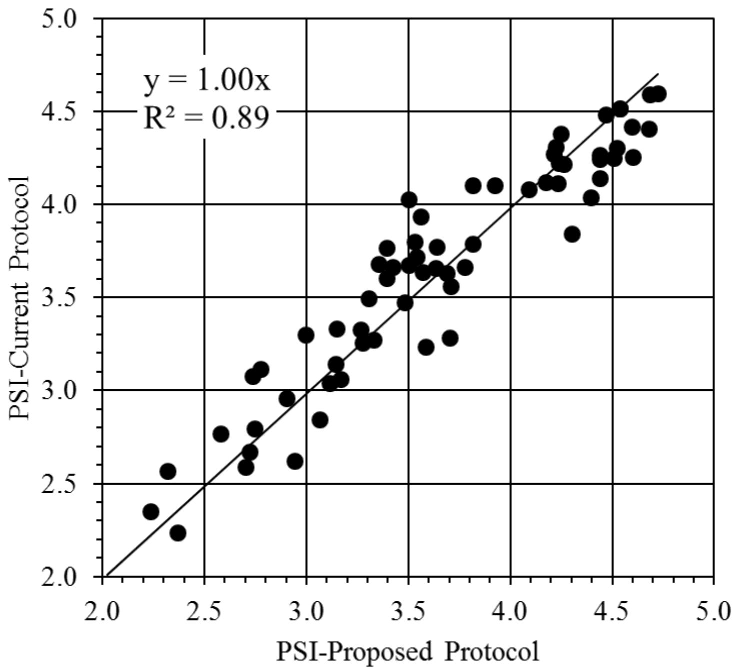


FIGURE 23 Comparison of PSI values calculated with raters' data from current and proposed protocols of visual distress surveys

ESTIMATE OF HPMS DATA AND PMS PARAMETERS FROM VISUAL DISTRESS SURVEY DATA

Starting in 2009, the FHWA Office of Highway Policy Information requires that all state DOTs collect and report certain pavement condition data on approximately 1,000 highway sections for the Highway Performance Monitoring System (HPMS). One of the objectives of this project was to determine an adequate method for estimating HPMS's pavement distress data to be reported annually to FHWA from the PMS distress data and/or distress ratings that NMDOT will collect regularly as part of NMDOT's Annual Pavement Evaluation Program. The implementation of the proposed procedures will provide the means for NMDOT to comply with the reporting requirements of the FHWA Office of Highway Policy Information's HPMS regarding pavement distresses.

The FHWA Office of Highway Policy Information has indicated to NMDOT that the HPMS data to be reported, particularly pavement distress data, can be composed of approximations of the field conditions and that high level of sophistication or accuracy in the data estimation methods or measurements is not necessary for the purpose of this reporting (NMDOT, *Invitation to Propose* for Project NM10MNT-01, May 2009). The NMDOT does not plan to carry out any additional pavement condition data collection activities to obtain data exclusively for HPMS requirements. Therefore, the required HPMS information should be extracted from NMDOT's pavement distress data collection regularly obtained for PMS purposes.

In addition, NMDOT has reduced the number of sample sections to be evaluated in visual distress surveys each year, starting in 2012. The sections are divided into National Highway System (NHS) routes and non-NHS routes. The NMDOT Pavement Distress Data Collection Program will include evaluation of distresses on all NHS routes annually and on non-NHS routes every other year. In the NMDOT program, half of non-NHS routes will be evaluated one year and the other half will be evaluated the next year. This will maintain constant the number of sample sections to be surveyed per year. This number is approximately 10,500 sample sections throughout New Mexico.

HPMS PAVEMENT SECTIONS AND DISTRESS REQUIREMENTS

The HPMS sample is a stratified random sample of physical roadway sections selected by the State DOT for the purpose of reporting to the FHWA Office of Highway Policy Information. Additions and deletions of sections can be made to the HPMS sample throughout the years. It can include flexible and rigid pavements. Because over 98% of the pavements in New Mexico are flexible, it is anticipated that the HPMS sample in this state will be composed mainly of flexible pavements with very few rigid sections.

The length of the sections for HPMS reporting varies depending on the classification as urban or rural roads and other factors, from 0.805 km (0.5 mile) to 8.05 km (5 miles). The HPMS sections may start and end at odd locations that do not necessarily coincide with established mileposts, sample sections of the NMDOT's distress evaluation program, or existing pavement sections of the NMDOT's PMS database.

Specifically for pavement distresses, the state DOTs will be required to report the following information, among other data, for each HPMS-selected section:

Flexible (AC) pavement sections:

- percent area of fatigue cracking (also referred in this report as alligator cracking), to the nearest 5%, and
- total length of transverse cracks, given in feet (ft) per mile.

Rigid (PCC) pavement sections:

- percent cracked slabs to the nearest 5%, and
- faulting, given by the average difference in elevation, in inches, across adjacent jointed concrete panels or slabs for the section (in the travel direction only), reported to the nearest 0.1 inch.

The percent area of fatigue cracking in a flexible pavement section is an aggregated percent area of this distress type including all severity levels present in the HPMS section. Similarly, the length of transverse cracks in a flexible pavement section is the aggregated length for all severity levels in the HPMS section. For rigid pavements, the total percentage of slabs with cracking is also an aggregate percentage for all severity levels present in the HPMS sections.

METHODOLOGY TO ESTIMATE HPMS DISTRESS DATA

Flexible Pavements

The goal was to determine a practical method to estimate distress data for HPMS from the distress data regularly collected as part of the NMDOT's Pavement Distress Evaluation Program. For flexible pavements, the approach was to find correlations through statistical analysis between raters' data of fatigue cracking and transverse cracking and detailed field measurements of extent of these two distress types on the same pavement sections. For these tests, traffic control and warning signs were provided by NMDOT District 1 Maintenance Crew based in Las Cruces, NM (Figure 24) to ensure safety of the raters, research assistants and traveling public during the detailed field measurements. No traffic was allowed in the test section during the work.

Fifteen test sections of flexible pavement were selected to include interstate highways (high traffic volume, heavy traffic), U.S. highways (medium/high traffic volume) and New Mexico highways (thin AC layer, low traffic volume). In selecting the test sections, important factors were considered, including their proximity to NMSU main campus, pavement surface condition (distress types, severity and extent), absence of potential road hazards for the student technicians, and possibility of minimizing disruption of traffic and access to adjacent roads and private property during the fieldwork. Table 6 lists the 15 test sections selected for this work and their location. For the purpose of these measurements, a test section was 161 m (0.1 mile = 528 ft) long and had the width of the driving lane. These are the same characteristics of the sample sections evaluated in the NMDOT's Pavement Distress Data Collection Program.

Before the field distress measurements were made, three experienced student technicians (raters) performed independent evaluations of the test sections according to the proposed (new) protocol. Once the independent ratings were completed in a given route, the raters, research assistant and PI identified and determined by consensus the severity of each transverse crack (all lengths) and fatigue cracking (all severities). The latter included longitudinal cracks along or mostly within the wheel path(s) and alligator cracking (anywhere in the section). The crack length was measured with measuring wheels; the alligator cracking area was estimated using 0.9 m × 0.9 m (3 ft × 3 ft) grids, made of thin laths stapled at 90 degree angles.

The student technicians and research assistants followed these steps to carry out the measurement of areas of alligator cracking and length of transverse and longitudinal cracks in each test section:

1. Using white chalk and a measuring wheel, mark the beginning and end of the test section. Also, mark 50 ft (15.24 m) long subsections starting from the beginning of the test section. (The last subsection will be shorter, being just 28 ft or 8.5 m long.) Next to each chalk mark, write the cumulative distance from the start of the section to that

point; for example, 0 ft, 50 ft, 100 ft, 150 ft, and so on (Figure 25). Make these marks on the pavement surface near the edge stripe.

FIGURE 24 The NMDOT District 1 Maintenance Crew of Las Cruces provides traffic control and warning signs during field measurements

TABLE 6 Test Sections for Field Measurements of Fatigue Cracking and Transverse Cracking

Route	Milepost		Direction	General Location
	Begin	End		
I-25	15.0	15.1	Positive (Northbound)	About 7 miles north of city limits, Las Cruces, NM
	15.1	15.2		
	15.2	15.3		
I-10	129.0	129.1	Positive (Eastbound)	About 3 miles west of Las Cruces Airport Interchange
	129.1	129.2		
	129.2	129.3		
	129.3	129.4		
US 70	144.9	144.8	Minus (Westbound)	Picacho Hills area, Las Cruces, NM
	145.0	144.9		
NM 28	17.0	17.1	Positive (Northbound)	About 11 miles south of junction with NM 101 (University Ave.), Las Cruces, NM
	17.1	17.2		
	17.2	17.3		
NM 478	19.0	19.1	Positive (Northbound)	About 2 miles south of junction with NM 373 (Union Ave.), Las Cruces, NM
	19.1	19.2		
	19.2	19.3		

FIGURE 25 A rater marks the start and end of the test section before the field measurements in NM 28

In each 50-ft long subsection:

2. Identify the areas of alligator cracking, transverse cracks and longitudinal cracks. Using chalk, write "A," "T" or "L" on or near the distress. ("A" stands for alligator cracking, "T" stands for transverse cracking, and "L" stands for longitudinal cracking.) Write the corresponding severity rating (1, 2, or 3) next to the letter. For example, "A2" means alligator cracking of severity 2. Use a ruler to measure the crack width if needed to determine severity level. For transverse and longitudinal cracks, draw a chalk mark across the defect indicating the start and end of each crack to facilitate the length measurements (Figure 26).
3. Using the measuring wheel, determine the ***length*** of each transverse crack and each longitudinal crack, regardless of their length or severity (Figure 27). Record the type, severity and lengths of each crack. Take into account the following:
    - Differentiate between longitudinal cracks along the wheel path(s) and longitudinal cracks outside the wheel path(s).
    - Include edge cracks and longitudinal cracks located ***within one foot on either side*** of the edge stripe or mid-lane stripe as part of the "longitudinal cracks outside the wheel path."
    - Do not include or measure the part(s) of a crack that lie(s) outside the test section or beyond one foot of the mid-lane stripe or edge stripe.
    - Do not count or measure longitudinal cracks along the wheel path that are already part of alligator cracking (do not double count these distresses).

- You will measure two types of length for each crack. First, measure the "*actual crack length*" following the crack's wavy or sinuous profile (Represented by the continuous line in Figure 28). Record this length, reset the counter of the measuring wheel, and measure the "*length*" as if the crack were composed entirely of a straight segment. For the 2-point length, follow an imaginary straight line between *two points* located at the ends of the crack (Represented by the segmented line in Figure 28). Record this length and reset the counter. Record the corresponding crack type and severity.
- After each measurement and using chalk, draw a line across the crack indicating that it has been already measured and recorded.

FIGURE 26 Markings on the pavement surface for transverse cracks and alligator cracking in preparation for length and area measurements of these distresses

FIGURE 27 A student technician measures the length of transverse cracks while his partner records the data

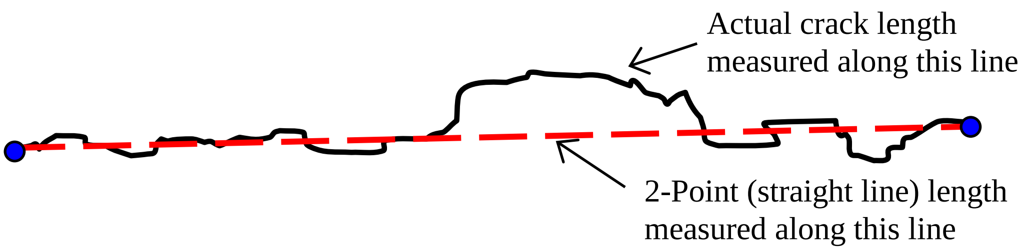


FIGURE 28 Two measurements of length of longitudinal and transverse cracks

4. Using chalk, draw an outline around each alligator cracking area. The outline should fully contain the alligator cracking area within the test section (Figure 29). This line should approximately follow the perimeter of the alligator cracking area, about 6 inches (0.15 m) beyond the outer cracks. (Alligator cracking must contain at least three connected cells; otherwise, disregard it.)
5. Place the reference grid on the pavement surface over the outlined alligator cracking. Mark the location of the grid's corners with chalk as shown in Figure 30b. Count the number of whole and partial "squares" of the grid that lie on the outlined alligator cracking area. Record this number with the corresponding severity.
6. If the grid is smaller than the outlined area, move the grid and count the remaining "squares" until the complete distress area has been covered. Using chalk, mark the alligator crack indicating that it has been already measured. Compute the surface area as the sum of the number of whole and partial squares times the pre-determined area of each square.
7. If the alligator area is approximately rectangular, you can use a measuring tape to determine the dimensions and calculate the area.
8. Compute the following for each 50-ft subsection and for each severity:
    - Cumulative area of alligator cracking,
    - Cumulative "actual length" of transverse cracks,
    - Cumulative "2-point length" of transverse cracks,
    - Cumulative "actual length" of longitudinal cracks,
    - Cumulative "2-point length" of longitudinal cracks.

In the field test, three experienced raters were used. Their averaged data were considered instead of their individual data.

Rigid Pavements

The percentage of rigid sections in New Mexico is less than 2% and is not expected to significantly increase in the future. Thus, it is anticipated that the percentage of sections selected by FHWA for HPMS reporting in New Mexico each year will be close to or smaller than 2%. Therefore, it is recommended that the HPMS distress parameters to be reported for rigid pavements be obtained during the visual surveys, mostly from the data already collected or as an addition to the current protocol for rigid pavements. Let us recall that for HPMS's rigid sections, the following data should be reported:

(a) (b)

FIGURE 29 Measurement of alligator cracking area: (a) outline of the area, and (b) estimation of area using a grid

- total percentage of slabs with fatigue cracking (FC%), and
- average vertical displacement (D) (difference in elevation or faulting), given in inches, between adjacent jointed concrete panels or slabs in the direction of the travel only.

A rater will report the count of concrete slabs with fatigue cracking ($N_{fatigue}$) and the total number of slabs (T_{slab}) in the section. The percentage of slabs with fatigue cracking will be calculated as

$$FC\% = \frac{N_{fatigue}}{T_{slab}} 100\% \qquad (8)$$

The concrete slabs with "fatigue cracking" include all the slabs with any cracking (any severity), such as corner breaks, longitudinal cracks, and transverse and diagonal cracks as defined in the current *NMDOT's Distress Evaluation Criteria for Rigid Pavements* (Appendix B).

The average displacement between adjacent slabs (D) will be estimated from the extent rating of "Faulting of Transverse Joints and Cracks" reported by the raters for each severity present. The severity rating criteria for "Faulting of Transverse Joints and Cracks" are:

- Severity rating 0: There is no noticeable elevation difference across transverse joints or cracks.
- Severity rating 1 (Low): Faulted joints or cracks average 1/16 inch (4.2 mm) or less.
- Severity rating 2 (Medium): Faulted joints or cracks average more than 1/16 inch (4.2 mm) but less than 1/4 inch (6.4 mm).
- Severity rating 3 (High): Faulted joints or cracks average 1/4 inch (6.4 mm) or more.

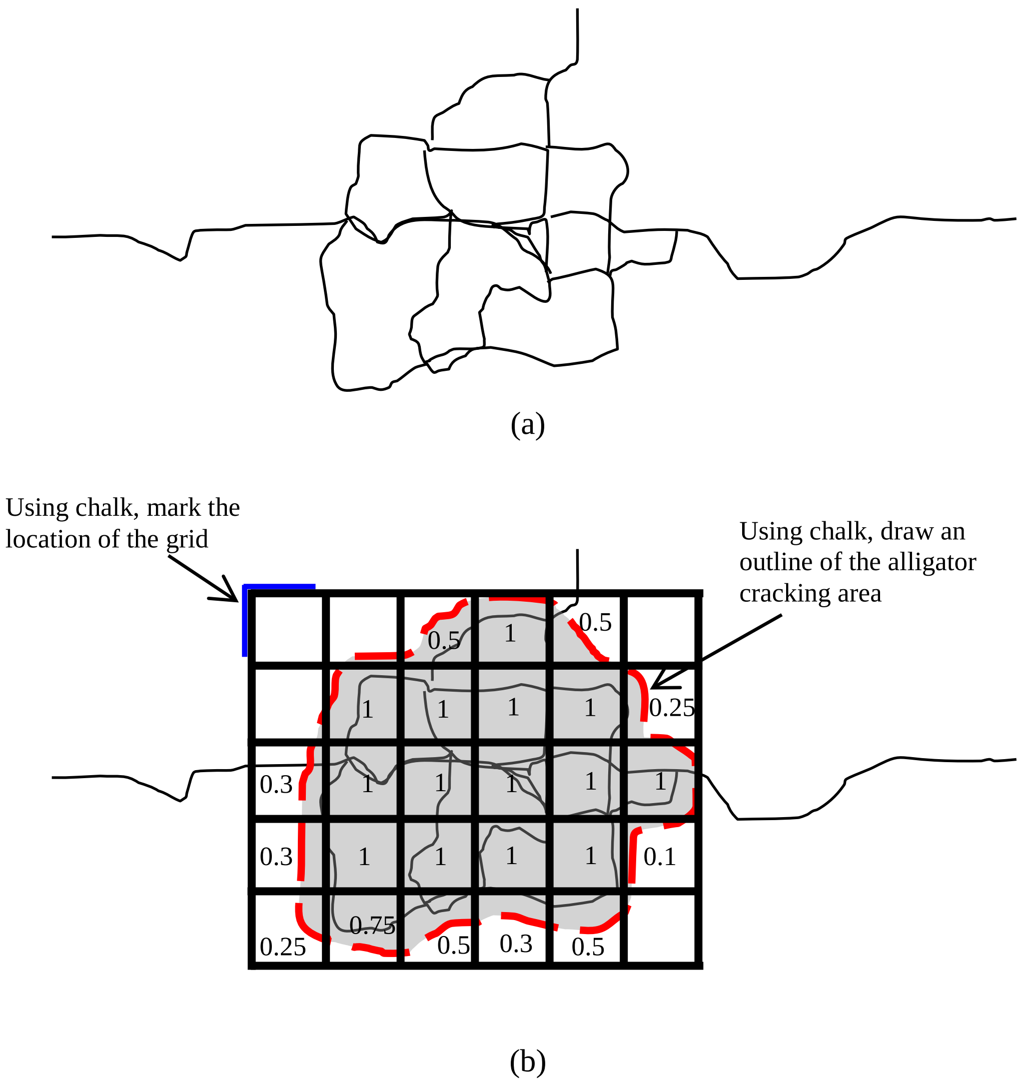


FIGURE 30 (a) Plan view of alligator cracking and longitudinal cracks along the wheel path, and (b) reference grid for area measurement

The extent rating criteria for "Faulting of Transverse Joints and Cracks" are:

- Extent rating 0: Rater reports severity 0.
- Extent rating 1 (Low): from 1% to 30% of the sample section.
- Extent rating 2 (Medium): more than 30% of the sample section but no more than 60% of the sample section.
- Extent rating 3 (High): more than 60% of the sample section.

Finally, the average displacement (D) throughout the section can be estimated as a weighted average of the severity levels:

$$D = \frac{(0.0625\ A1\%)(0.25\ A2\%)(0.5\ A3\%)}{100\%} \quad (9)$$

where D is given in inches, and A1%, A2% and A3% are the estimated percentage of the area of the sample section with severity levels 1, 2 and 3, respectively, of “Faulting of Transverse Joints and Cracks.” These values are 0%, 30%, 60% or 100% if the extent rating is 0, 1, 2 or 3, respectively. The sum of A1%, A2% and A3% should not be greater than 100%.

CHARACTERISTICS OF FLEXIBLE PAVEMENT DISTRESS DATA - PROPOSED PROTOCOL

According to the proposed (new) protocol for visual distress surveys, all severities and their corresponding extents are rated for each distress type. The distress data obtained during the visual surveys for flexible pavements include the following:

1. Alligator cracking (also referred to as fatigue cracking): For each severity, the area (A) of alligator cracking is assessed from the rater’s pace count, for one or two wheel paths, along the parts of the section that exhibit this distress. Note that pace counts for longitudinal cracks along the wheel path(s) are included in the area of alligator cracking of severity 1 (Low). The rater reports the pace count, not an extent rating, for each severity level. The rater’s pace count can be converted into extent rating.
2. Transverse cracking: For each severity, the rater’s count of transverse cracks (equal to or longer than 6 ft or 1.8 m) is recorded and not the extent rating. The rater’s crack count can be converted into extent rating.

DATA ANALYSIS AND RESULTS – FLEXIBLE PAVEMENT SECTIONS

In this section, the relationships between the field distress measurements and the raters’ data obtained according to the proposed (new) protocol of visual surveys for flexible pavements were studied. The effect or importance of considering the actual length of cracks along their “wavy” or irregular geometry compared to the crack length measured along a straight line (called here 2-point length) was also assessed. Simple procedures to estimate distress data for HPMS reporting and PMS use from raters’ data were proposed in this section.

Estimate HPMS Distress Data from Raters’ Distress Data

Length of Transverse Cracking

According to the proposed protocol of visual distress surveys, the raters report their count of transverse cracks that are “at least 6 ft long” for each severity. Transverse cracks shorter than 6 ft or 1.8 m are not counted or reported by raters. For each severity, an estimated length of transverse cracking was calculated by multiplying the rater’s count of transverse cracks times the assumed lane width, resulting in total length (given in linear feet) of transverse cracking. These data were labeled as Column 2 in Table 7. In this analysis, the width of the sections (i.e., width of driving lane) was assumed to be 12 ft.

On the other hand, the field tests provided the length of the transverse cracks as measured on the pavement surface. The transverse cracks were divided into two groups: cracks that were less than 6 ft long, and cracks that were 6 ft or longer. The cumulative length of each group was calculated for each section. The data are shown in Table 7. In this table, Column 3 provides the cumulative length ("actual length") of transverse cracks that were at least 6 ft in length. Column 4 provides the cumulative length ("actual length") for all cracks (all lengths). Column 5 shows the difference in length of crack between the two methods considered: estimate from raters' counts and measured length. For the sections studied, most of the cracks corresponded to severities 1 and 2.

Figure 31 shows the correlation between the measured total length (Field Tests) and the estimated total length from raters' crack count for all transverse cracks. The coefficient of determination (R^2) was 0.87. The total length estimated from the visual surveys showed a tendency to underestimate the actual length of the transverse cracks, by about 25%. This was due to the fact that the visual distress surveys rated transverse cracks that were "6 ft or longer" only. When the estimated total length from raters' count was compared to the cumulative length of the cracks that were "6 ft or longer" only (Column 3 in Table 7), the data scattering decreased considerably (Figure 32) and the correlation improved significantly ($R^2 = 0.97$). This is because the measurements in the later comparison corresponded to the same parameter (i.e., cracks that were "6 ft or longer").

The average difference (cumulative for a section) between the estimate from raters' count and from measurements was 2 ft and the standard deviation was 20.3 ft. Finally, the length of transverse cracking for HPMS reporting can be estimated from the cumulative length estimated from raters' data using a multiplication factor of 1.25 (equation shown in Figure 31).

Effect of Crack Geometry on Cumulative Crack Length

One of the purposes of the field tests was to determine the effect of the crack's "wavy" or irregular geometry or pattern on the cumulative crack length in a section. Of particular interest was to determine whether it was necessary to apply a correction factor to the length estimated from the raters' data (visual surveys). Throughout this section, the proposed methods to estimate HPMS and PMS parameters were based on measurements of actual length of cracks; therefore, a correction factor is not necessary.

Figure 33 compares the cumulative length of transverse cracks, of each test section and severity level, corresponding to actual length and 2-point length measurements. In this figure, the segmented line represents the equality (both parameters are equal, $y = x$) and the continuous line is the best-fit line (equation shown). The R^2 value is 1.00 indicating that the best-fit equation can predict very well the relationship between actual and 2-point length measurements for transverse cracks. Similar observations were made for longitudinal crack measurements.

Table 8 contains the data used to prepare Figure 33 (Columns 3 and 4). Columns 5 and 6 of Table 8 show the differences in linear feet and percentage, respectively, between the cumulative actual and 2-point lengths. The mean and standard deviation of the length difference were 6 ft and 8.8 ft, respectively. The mean and standard deviation of the percent difference were 3% and 3.7%, respectively. Considering that the HPMS and PMS parameters are estimated from raters' data and that the purposes of the visual surveys and both HPMS and PMS data are to evaluate pavement condition at the network level, the difference found between actual and 2-point length is not significant in practice and should not be a concern in regard to the quality of the information estimated from visual distress surveys.

TABLE 7 Length of Transverse Cracks from Rater's Data and from Field Measurements (1 ft = 0.305 m)

		Column 1	Column 2	Column 3	Column 4	Column 5
Route	Test Section and Direction	Severity Rating	Length by Raters, Proposed Protocol	Transverse Cracks, at least 6 ft Long, Actual Length	Transverse Cracks, all Lengths, Actual Length	Difference of Methods (Column 3 Minus Column 2)
			ft	ft	ft	ft
NM 28	17.0 P	1	192	229.6	305.1	38
NM 28	17.1 P	1	412	374.8	491.2	-37
NM 28	17.2 P	1	356	384.9	466.9	29
I 25	15.0 P	1	80	109.5	134.4	30
I 25	15.1 P	1	100	73.3	146.1	-27
I 25	15.2 P	1	48	37.8	67.0	-10
I 10	129.0 P	1	88	70.7	92.8	-17
I 10	129.1 P	1	24	25.1	60.8	1
I 10	129.2 P	1	48	32.1	67.5	-16
I 10	129.3 P	1	44	22.9	54.0	-21
US 70	144.8 M	1	32	16.5	164.8	-16
US 70	144.9 M	1	64	44.9	346.7	-19
NM 478	19.0 P	1	276	293.8	305.8	18
NM 478	19.1 P	1	342	339.0	375.7	-3
NM 478	19.2 P	1	360	375.3	408.0	15
NM 28	17.0 P	2	28	39.8	65.8	12
NM 28	17.1 P	2	60	119.0	143.8	59
NM 28	17.2 P	2	8	6.0	6.0	-2
I 25	15.0 P	2	0	0.0	0.0	0
I 25	15.1 P	2	0	0.0	0.0	0
I 25	15.2 P	2	0	0.0	0.0	0
I 10	129.0 P	2	0	0.0	0.0	0
I 10	129.1 P	2	8	0.0	0.0	-8
I 10	129.2 P	2	0	0.0	0.0	0
I 10	129.3 P	2	0	0.0	0.0	0
US 70	144.8 M	2	40	36.3	55.7	-4
US 70	144.9 M	2	84	95.5	126.3	12
NM 478	19.0 P	2	54	133.5	133.5	80
NM 478	19.1 P	2	24	30.8	39.3	7
NM 478	19.2 P	2	0	0.0	0.0	0

TABLE 7 Length of Transverse Cracks from Rater's Data and from Field Measurements (1 ft = 0.305 m) (Continuation)

		Column 1	Column 2	Column 3	Column 4	Column 5
Route	Test Section and Direction	Severity Rating	Length by Raters, Proposed Protocol	Transverse Cracks, at least 6 ft Long, Actual Length	Transverse Cracks, all Lengths, Actual Length	Difference of Methods (Column 3 Minus Column 2)
			ft	ft	ft	ft
NM 28	17.0 P	3	0	0.0	0.0	0
NM 28	17.1 P	3	0	0.0	0.0	0
NM 28	17.2 P	3	0	0.0	0.0	0
I 25	15.0 P	3	0	0.0	0.0	0
I 25	15.1 P	3	0	0.0	0.0	0
I 25	15.2 P	3	0	0.0	0.0	0
I 10	129.0 P	3	0	0.0	0.0	0
I 10	129.1 P	3	0	0.0	0.0	0
I 10	129.2 P	3	0	0.0	0.0	0
I 10	129.3 P	3	0	0.0	0.0	0
US 70	144.8 M	3	16	0.0	5.7	-16
US 70	144.9 M	3	28	9.4	9.4	-19
NM 478	19.0 P	3	0	0.0	0.0	0
NM 478	19.1 P	3	0	0.0	0.0	0
NM 478	19.2 P	3	0	0.0	0.0	0

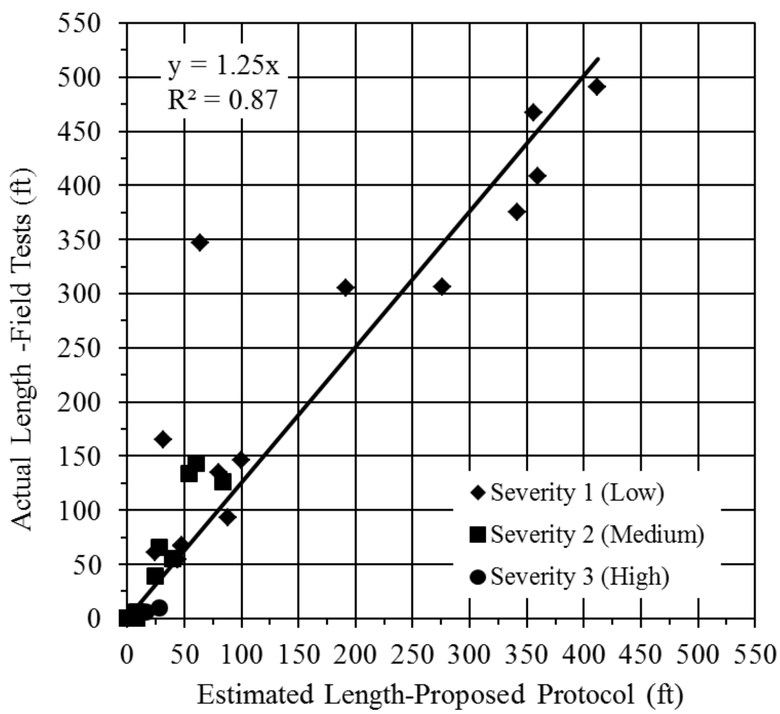


FIGURE 31 Comparison of estimated length from raters' data and measured length of transverse cracks, all lengths and severity levels (1 ft = 0.305 m)

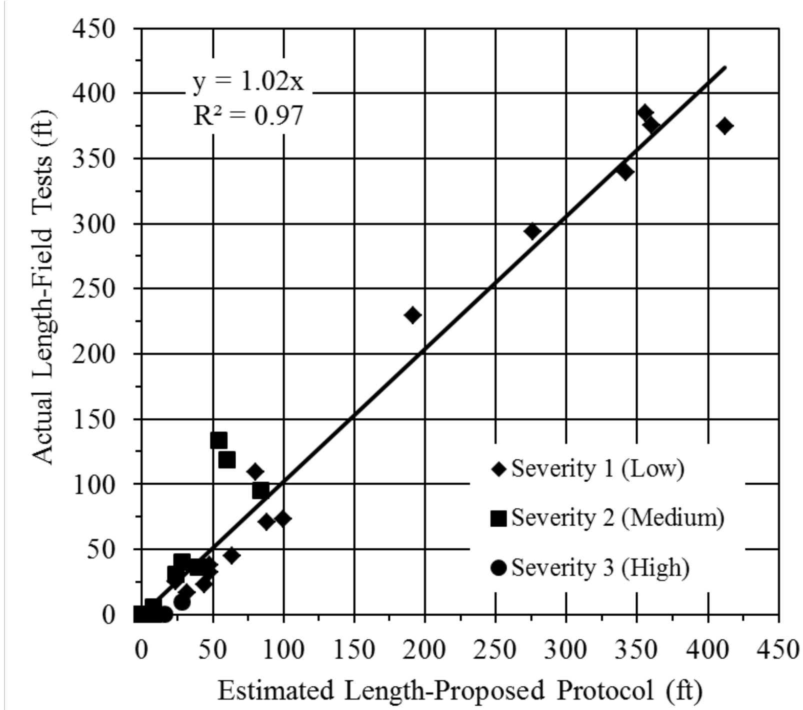


FIGURE 32 Comparison of estimated length from raters' data and measured length of transverse cracks that were 6 ft or longer only (1 ft = 0.305 m)

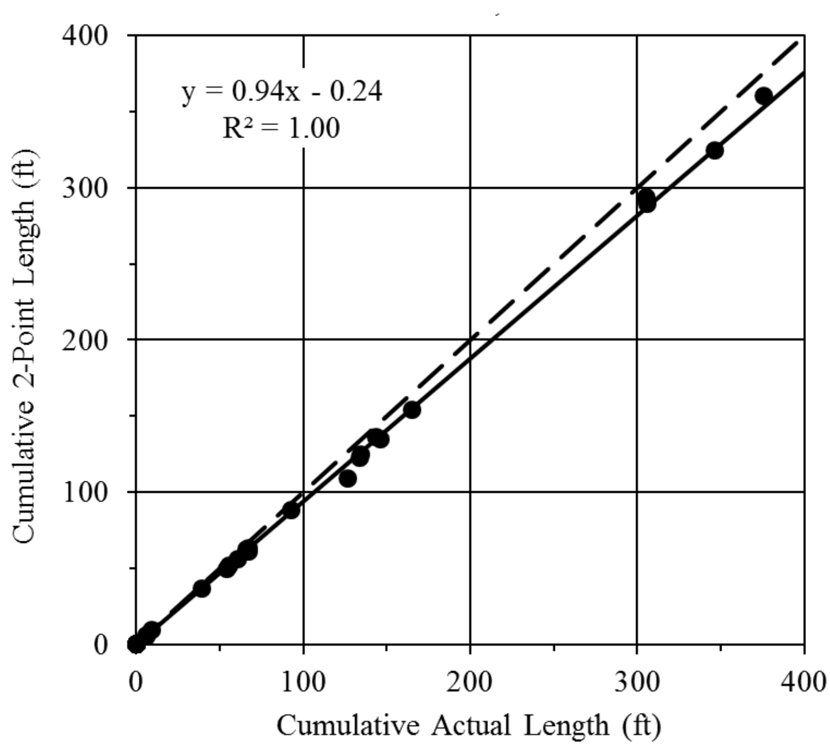


FIGURE 33 Comparison of cumulative 2-point length and actual length of transverse cracks (all lengths and severities) (1 ft = 0.305 m)

TABLE 8 Data from Field Measurements of Transverse Cracks: Actual Length and 2-Point Length (1 ft = 0.305 m)

		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Route	Test Section and Direction	Severity Rating	Length by Raters, Proposed Protocol	Transverse Cracks, all Lengths, Actual Length	Transverse Cracks, all Lengths, 2-Point Length	Difference (Column 3 Minus Column 4)	Percent Difference (Column 3 Minus Column 4)
			ft	ft	ft	ft	%
NM 28	17.0 P	1	192	305.1	293.9	11	4
NM 28	17.1 P	1	412	491.2	462.2	29	6
NM 28	17.2 P	1	356	466.9	433.4	34	7
I 25	15.0 P	1	80	134.4	124.6	10	7
I 25	15.1 P	1	100	146.1	134.7	11	8
I 25	15.2 P	1	48	67.0	60.9	6	9
I 10	129.0 P	1	88	92.8	88.7	4	4
I 10	129.1 P	1	24	60.8	56.3	5	7
I 10	129.2 P	1	48	67.5	63.6	4	6
I 10	129.3 P	1	44	54.0	49.4	5	8
US 70	144.8 M	1	32	164.8	153.9	11	7
US 70	144.9 M	1	64	346.7	324.6	22	6
NM 478	19.0 P	1	276	305.8	289.1	17	5
NM 478	19.1 P	1	342	375.7	360.0	16	4
NM 478	19.2 P	1	360	408.0	378.7	29	7
NM 28	17.0 P	2	28	65.8	62.9	3	4
NM 28	17.1 P	2	60	143.8	136.6	7	5
NM 28	17.2 P	2	8	6.0	5.9	0	1
I 25	15.0 P	2	0	0.0	0.0	0	0
I 25	15.1 P	2	0	0.0	0.0	0	0
I 25	15.2 P	2	0	0.0	0.0	0	0
I 10	129.0 P	2	0	0.0	0.0	0	0
I 10	129.1 P	2	8	0.0	0.0	0	0
I 10	129.2 P	2	0	0.0	0.0	0	0
I 10	129.3 P	2	0	0.0	0.0	0	0
US 70	144.8 M	2	40	55.7	51.5	4	7
US 70	144.9 M	2	84	126.3	109.2	17	14
NM 478	19.0 P	2	54	133.5	122.7	11	8
NM 478	19.1 P	2	24	39.3	36.9	2	6
NM 478	19.2 P	2	0	0.0	0.0	0	0

TABLE 8 Data from Field Measurements of Transverse Cracks: Actual Length and 2-Point Length (1 ft = 0.305 m) (Continuation)

		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Route	Test Section and Direction	Severity Rating	Length by Raters, Proposed Protocol	Transverse Cracks, all Lengths, Actual Length	Transverse Cracks, all Lengths, 2-Point Length	Difference (Column 3 Minus Column 4)	Percent Difference (Column 3 Minus Column 4)
			ft	ft	ft	ft	%
NM 28	17.0 P	3	0	0.0	0.0	0	0
NM 28	17.1 P	3	0	0.0	0.0	0	0
NM 28	17.2 P	3	0	0.0	0.0	0	0
I 25	15.0 P	3	0	0.0	0.0	0	0
I 25	15.1 P	3	0	0.0	0.0	0	0
I 25	15.2 P	3	0	0.0	0.0	0	0
I 10	129.0 P	3	0	0.0	0.0	0	0
I 10	129.1 P	3	0	0.0	0.0	0	0
I 10	129.2 P	3	0	0.0	0.0	0	0
I 10	129.3 P	3	0	0.0	0.0	0	0
US 70	144.8 M	3	16	5.7	5.3	0	6
US 70	144.9 M	3	28	9.4	9.4	0	0
NM 478	19.0 P	3	0	0.0	0.0	0	0
NM 478	19.1 P	3	0	0.0	0.0	0	0
NM 478	19.2 P	3	0	0.0	0.0	0	0

Area of Fatigue Cracking

In the proposed protocol of visual distress surveys, the raters report the pace count along the pavement section with alligator (or fatigue) cracking, and indicate if the pace count corresponds to one or two wheel paths. Note that pace count for longitudinal cracks along the wheel path(s) are included in the area of alligator cracking of severity 1 (Low), as part of fatigue cracking.

For each severity, the area of alligator or fatigue cracking is deduced by multiplying first the rater's pace count, for one or two wheel paths, by the rater's individual pace, resulting in length (ft). This length is then multiplied by the assumed width of 0.61 m (2 feet) of each wheel path, to obtain the area of alligator cracking (A) in ft^2.

On the other hand, the field test provided the severities and measured areas of alligator cracking plus the length of longitudinal cracks along the wheel path but outside the alligator cracking area (to avoid double counting). The latter was multiplied by 2 feet, which is the assumed width of the wheel path. The test sections considered did not have alligator (fatigue) cracking of severity 3.

Table 9 contains the area deduced from the raters' data using the proposed protocol and the areas measured in the field tests. A discrepancy in the raters' data was found for section I 25 MP 15.0 P, particularly in the evaluation of the alligator cracking and, therefore, these data were not used in this analysis. The three raters reported longitudinal cracks along the wheel path of severity 1 only. In a second look and by consensus, some of these cracks were upgraded to severity 2 when measured and recorded in the field tests. The sum of the alligator cracking area of severities 1 and 2 from field tests was 515.7 ft^2, which is very close to the average area of alligator cracking from the three raters (534.1 ft^2). These two data points of this section are labeled as 'Discrepancy' in Figure 34.

It was also noted that in sections with alligator cracking of severity 2 or higher, the width of the cracking area was generally wider than 2 ft, as illustrated by the examples in Figure 35. As a result, the area deduced from the raters' data underestimated the area of alligator cracking compared to the measured area from the field tests. This difference is not caused by the raters but by the way in which the area is estimated from the raters' data. However, in a heuristic search, changing the assumed wheel-path width to values greater and smaller than 2 ft did not improve the linear correlation. In Figure 34, the segmented line represents the equality of the two areas (y = x) and the continuous line is the best fit to the data (the best-fit equation is shown in the figure). For example, sections in US 70 presented well developed alligator cracking throughout the surface. The underestimating effect of assuming a narrow (2 ft wide) area of alligator cracking along the wheel path is clearly seen from the data of US 70 (Table 9).

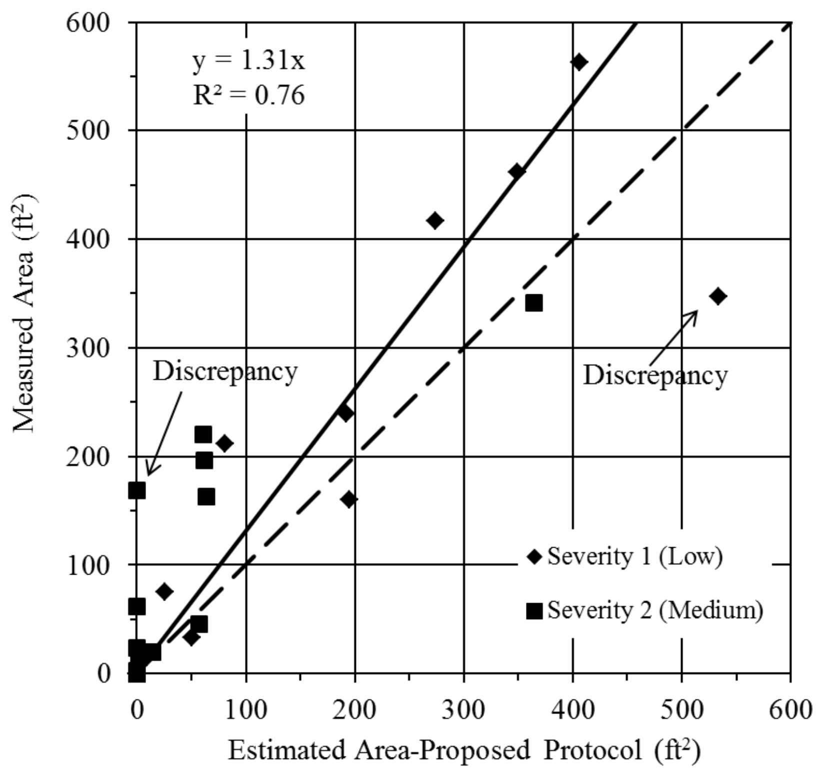


FIGURE 34 Comparison of estimated area from raters' data and measured area of alligator (fatigue) cracking for all severities (1 ft = 0.305 m)

TABLE 9 Area of Alligator (Fatigue) Cracking from Rater's Data and from Field Measurements (1 ft = 0.305 m)

Route	Test Section and Direction	Severity Rating	Area by Raters, Proposed Protocol	Measured Area	Comments
			ft^2	ft^2	
NM 28	17.0 P	1	25.5	75.3	
NM 28	17.1 P	1	195.5	160.2	
NM 28	17.2 P	1	81.2	211.8	
I 25	15.0 P	1	534.1	347.5	Discrepancy. Data not used
I 25	15.1 P	1	951.3	1033.3	
I 25	15.2 P	1	349.5	461.8	
I 10	129.0 P	1	50.3	33.5	
I 10	129.1 P	1	0.0	0.0	
I 10	129.2 P	1	0.0	0.0	
I 10	129.3 P	1	0.0	0.0	
US 70	144.8 M	1	488.8	739.5	Area much wider than 2 ft
US 70	144.9 M	1	255.0	981.7	Area much wider than 2 ft
NM 478	19.0 P	1	192.3	239.5	
NM 478	19.1 P	1	406.5	562.7	
NM 478	19.2 P	1	274.4	416.5	
NM 28	17.0 P	2	1.8	14.7	
NM 28	17.1 P	2	64.3	162.5	
NM 28	17.2 P	2	364.7	341.4	
I 25	15.0 P	2	0.0	168.2	Discrepancy. Data not used
I 25	15.1 P	2	0.0	61.5	
I 25	15.2 P	2	14.4	19.9	
I 10	129.0 P	2	57.3	45.9	
I 10	129.1 P	2	0.0	0.0	
I 10	129.2 P	2	0.0	0.0	
I 10	129.3 P	2	0.0	0.0	
US 70	144.8 M	2	62.4	196.1	Area much wider than 2 ft
US 70	144.9 M	2	61.0	219.8	Area much wider than 2 ft
NM 478	19.0 P	2	0.0	23.5	
NM 478	19.1 P	2	0.0	2.3	
NM 478	19.2 P	2	0.0	0.0	

FIGURE 35 Examples of alligator cracking area that is wider than 2 ft and lies outside the limits of the wheel paths. Areas are outlined on the pavement surface

METHODOLOGY TO ESTIMATE PMS PARAMETERS

This section describes how the raters' distress data are converted into extent ratings of transverse cracking and alligator cracking to be used in PMS's calculations of distress rate (DR) and PSI values.

Extent Rating of Transverse Cracking

In the proposed (new) protocol of visual distress surveys, the raters report their count of transverse cracks that are "6 ft or longer" for each severity (transverse cracks that appear to be shorter than 6 ft (1.8 m) are not counted or reported by raters). Even though transverse cracks are very narrow, their area of influence can extend significantly on both sides. The literature did not provide data or recommendations on what influence area could be assigned to a transverse crack. Therefore, the raters' data from the current and proposed protocols were used to determine threshold values of extent ratings to be used in the proposed protocol.

For each severity, the extent rating of transverse cracks was deduced from the averaged raters' count of transverse cracks (equal to or longer than 6 ft or 1.8 m) according to the following criteria:

- Extent rating 0: Raters report no transverse cracks of "at least 6 ft" in length for the given severity.
- Extent rating 1 (Low): from 1 to 8 transverse cracks reported.
- Extent rating 2 (Medium): from 9 to 16 transverse cracks reported.
- Extent rating 3 (High): 17 or more transverse cracks reported.

These threshold values for transverse cracks were determined from the data of visual surveys: severity and extent ratings based on the current protocol, and severity and crack counts from the proposed (new) protocol. The data of 6 raters obtained in round 2 of the distress surveys (NMSU and UNM raters) were used in this part of the analysis. For each section, the mean value of the crack count (proposed protocol) with highest severity present was compared to the extent rating (current protocol). For the data available, the mean values of crack count were 6.5, 14.0 and 19.0 for extent ratings of 1, 2 and 3 respectively. The standard deviations were 1.7, 2.4 and 1.7 for extent ratings of 1, 2 and 3 respectively. For severity 1, the mean plus standard deviation was 8.2 cracks (approximated to 8), and the mean minus standard deviation for severity 3 was 17.3 (approximated to 17 cracks).

Extent Rating of Alligator Cracking

In the proposed protocol of visual distress surveys, the raters report the pace count along the parts of pavement section that show alligator (or fatigue) cracking, and indicate if the pace count corresponds to one or two wheel paths. Note that pace count for longitudinal cracks in the wheel path(s) is included in the area of alligator cracking of severity 1 (Low), as part of fatigue cracking.

Recall that for each severity level, the area of alligator (or fatigue cracking) is deduced by first multiplying the rater's pace count by one or two wheel paths and by the rater's individual pace, resulting in length (ft). This length is multiplied by the assumed width of 0.61 m (2 ft) of each wheel path to obtain the area of alligator cracking (A) in ft^2 in the sample section.

The total surface area (A_t) of a test section is the full length of the section times the assumed lane width: $A_t = 528 \text{ ft} \times 12 \text{ ft} = 6{,}336 \text{ ft}^2$ (= 588.6 m^2). For each severity level, the percentage of area (A%) of alligator cracking is obtained dividing the area A by the section area A_t, and multiplying this ratio by 100%. Finally, the extent rating for each severity level is deduced according to the following criteria:

- Extent rating 0: No alligator cracking present (A% = 0) (Rater reports zero pace count for the given severity).
- Extent rating 1 (Low): A% up to 11%.
- Extent rating 2 (Medium): A% greater than 11% and up to 22%.
- Extent rating 3 (High): A% greater than 22% (up to 33%).

In this approach, the maximum percent area (A%) of alligator cracking that can occur in a section is 33% of the whole section area.

Results and Observations

In the previous section, it was mentioned that the rater's pace count tends to underestimate the actual area of alligator cracking mainly because of the assumed width (2 ft = 0.61 m) of the wheel paths. To further consider this issue, the data from the field tests were analyzed. The percent area of the section with alligator cracking was calculated for each severity level from the areas measured in the field tests. The measured areas of alligator cracking are in Column 5 of Table 10, and the corresponding percent area of the section with alligator cracking is given in

Column 7 of Table 10. Column 6 of this table indicates the number of 50 ft subsections with this distress.

In the field tests, the occurrence of alligator cracking was not limited to the assumed width (2 ft) of a wheel path. Therefore, in these measurements, the theoretical maximum area of alligator cracking could be 100% of the sample section. Extent ratings were deduced using the threshold values of extent of alligator cracking in the current protocol. These values are presented in Column 8 of Table 10. It was found that the extent rating deduced from the raters' data was in general agreement with the extent rating from the field tests.

SURVEY OF STATE OF PRACTICE OF HPMS DATA COLLECTION AND USE

METHODOLOGY

A survey of state Departments of Transportation (DOTs) was performed in 2010. The purpose of this survey was to summarize the current state of practice of Highway Performance Monitoring System (HPMS) data collection, specifically related to pavement distress items in flexible pavements. These items refer to HPMS Items #50 through 53 in the 2010 Edition of the *Highway Performance Monitoring System Field Manual* (13). Questions were asked regarding the status of data reporting, the version in which data were reported, data collection methods, and any data manipulation that must be performed in order to report items correctly. State DOTs were contacted via telephone and email, of which 37 responded to the survey. Five agencies could not be contacted due to changed telephone numbers, vacant positions, or relocation of personnel, and the remaining eight agencies did not respond as of the date of this report.

SURVEY RESULTS

This section summarizes the responses of the agencies who replied. The vertical axes in these figures represent the number of agencies that responded. Detailed responses by state are included in Appendix F. For each question, responses were grouped according to answers, followed by explanations of the question, responses, and comments on the responses.

TABLE 10 Extent Rating of Alligator Cracking from Visual Surveys and Field Measurements (1 ft = 0.305 m)

		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
Route	Test Section and Direction	Severity Rating	Area by Raters, Proposed Protocol	Estimated Percent of Section, Proposed Protocol	Estimated Extent Rating, Proposed Protocol	Measured Area, Field Tests	Number of Subsections Affected by Alligator Cracking	Percent of Section, Field Tests	Estimated Extent Rating, Field Tests
			ft^2	%		ft^2		%	
NM 28	17.0 P	1	25.5	0.40	1	75.3	3	1.19	1
NM 28	17.1 P	1	195.5	3.09	1	160.2	8	2.53	1
NM 28	17.2 P	1	81.2	1.28	1	211.8	8	3.34	1
I 25	15.0 P [a]	1	534.1	8.43	1	347.5	9	5.48	1
I 25	15.1 P	1	951.3	15.01	2	1033.3	11	16.31	1
I 25	15.2 P	1	349.5	5.52	1	461.8	6	7.29	1
I 10	129.0 P	1	50.3	0.79	1	33.5	2	0.53	1
I 10	129.1 P	1	0.0	0.00	0	0.0	0	0.00	0
I 10	129.2 P	1	0.0	0.00	0	0.0	0	0.00	0
I 10	129.3 P	1	0.0	0.00	0	0.0	0	0.00	0
US 70	144.8 M	1	488.8	7.71	1	739.5	11	11.67	1
US 70	144.9 M	1	255.0	4.02	1	981.7	11	15.49	1
NM 478	19.0 P	1	192.3	3.04	1	239.5	6	3.78	1
NM 478	19.1 P	1	406.5	6.42	1	562.7	8	8.88	1
NM 478	19.2 P	1	274.4	4.33	1	416.5	9	6.57	1
NM 28	17.0 P	2	1.8	0.03	1	14.7	2	0.23	1
NM 28	17.1 P	2	64.3	1.01	1	162.5	7	2.56	1
NM 28	17.2 P	2	364.7	5.76	1	341.4	9	5.39	1
I 25	15.0 P [a]	2	0.0	0.00	0	168.2	2	2.65	1
I 25	15.1 P	2	0.0	0.00	0	61.5	1	0.97	1
I 25	15.2 P	2	14.4	0.23	1	19.9	2	0.31	1
I 10	129.0 P	2	57.3	0.90	1	45.9	2	0.72	1
I 10	129.1 P	2	0.0	0.00	0	0.0	0	0.00	0
I 10	129.2 P	2	0.0	0.00	0	0.0	0	0.00	0
I 10	129.3 P	2	0.0	0.00	0	0.0	0	0.00	0
US 70	144.8 M	2	62.4	0.98	1	196.1	6	3.09	1
US 70	144.9 M	2	61.0	0.96	1	219.8	7	3.47	1
NM 478	19.0 P	2	0.0	0.00	0	23.5	1	0.37	1
NM 478	19.1 P	2	0.0	0.00	0	2.3	1	0.04	1
NM 478	19.2 P	2	0.0	0.00	0	0.0	0	0.00	0

Note: [a] Values were not used in statistical analysis due to discrepancy in these data

Question 1: Is your agency currently providing data for HPMS?

Of the 37 agencies surveyed, only one was not reporting data to HPMS in 2010 (Figure 36). The primary reason was that this agency was in the process of preparing for next year's submission according to the new HPMS version.

Question 2: Which HPMS version is your agency reporting in this year (2010)?

In summer of 2010, state DOTs had the option to report data either in the HPMS version used until 2010 (referred in this section as the "old" version) or the version required starting in 2011 (refereed here as the "new" version). Of the agencies questioned, 11 chose the "new" version, and 21 chose the "old" version (Figure 37). There are 5 agencies who did not submit a response to this item because at the time of questioning the interviewer was unaware that there was a choice until later in the interviewing process.

Many agencies chose to report data in the "old" HPMS version for varying reasons. The majority of the comments include:

- At the time of the survey, the FHWA had not released enough information on the "new" (2011) version for accurate and complete data reporting. The information most needed by reporting agencies included items such as database format. Many had not received the new software at the time of interviewing, which made it virtually impossible for the agencies to predict the way in which items had to be reported. Several agencies expressed wanting to see their completed data reports after submission to assess what needed to be changed in the future.
- Many agencies were not prepared for the scope that the "new" (2011) version required. New sample sections would be added, and the agencies did not have the time and/or resources to evaluate those additional sections before reporting was due in 2010.
- New data conversion systems had to be completed before agencies could feel comfortable submitting data in the "new" (2011) format. Most of these were still in progress at the time of the survey.

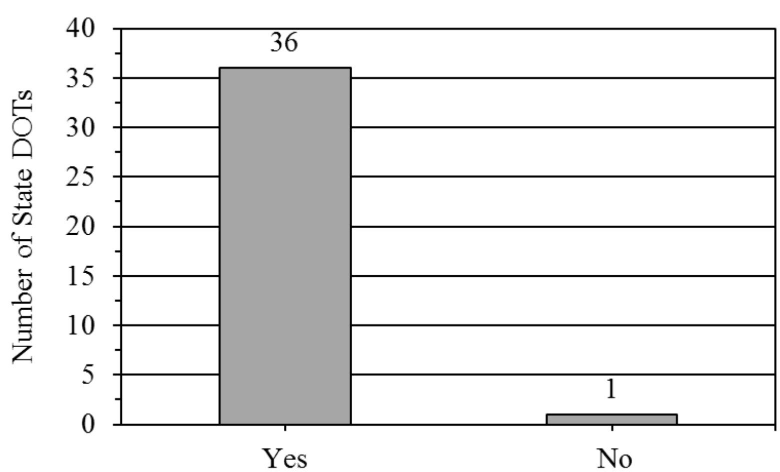


FIGURE 36 Number of state DOTs that reported HPMS data in 2010

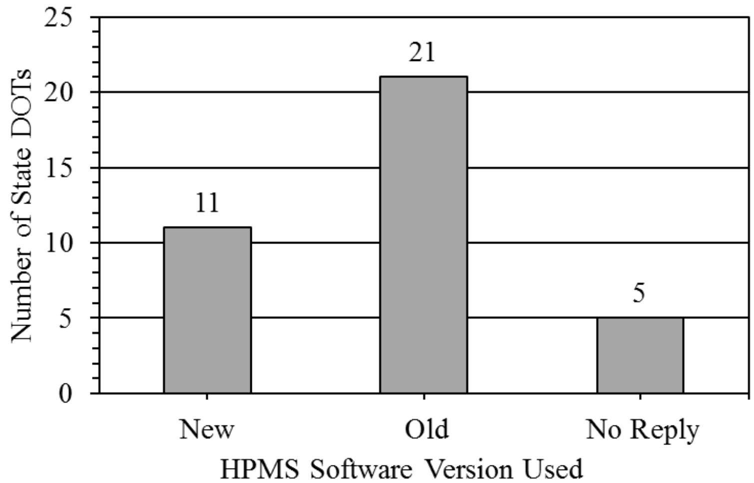


FIGURE 37 Number of state DOTs that reported HPMS data in the "new" and "old" software versions in 2010

<u>Question 3</u>: Does your agency collect data specifically for and according to HPMS guidelines?

The HPMS data collection guidelines are based on a series of AASHTO protocols, primarily R36-04, PP37-99, PP38-00, and PP44-01, which deal with faulting, roughness, rutting, and cracking, respectively. Of the 37 responding state DOTs, 14 reported collecting data in a manner consistent with these standards (Figure 38). This group also included the agencies that used automated means of data collection, in which the software used by the contracted companies provided data item values that were in the format required by HPMS. Nine agencies reported that they did not collect data according to these standards. Instead, they collected data for their respective states' PMS and performed minor adjustments in order to "fit" their data into the required HPMS format. Eleven state DOTs fell into the "Certain Items" group because they regularly obtained data for their states' PMS and sent out additional crews to specifically collect the required data for HPMS reporting. The remaining three agencies that fell into the "Attempt" category were mainly the agencies that were attempting to report their data in the new HPMS version and were following the guidelines to the best of their ability.

A few common comments on this question, specifically referring to the HPMS "new" reporting version, were:

- We are honestly not aware of how well our collection methods will match what HPMS wants until we can either get more feedback or see the data after we report it.
- Our data collection methods will have to change for next year's submission, either going fully automated or revising field techniques to better match what HPMS wants.

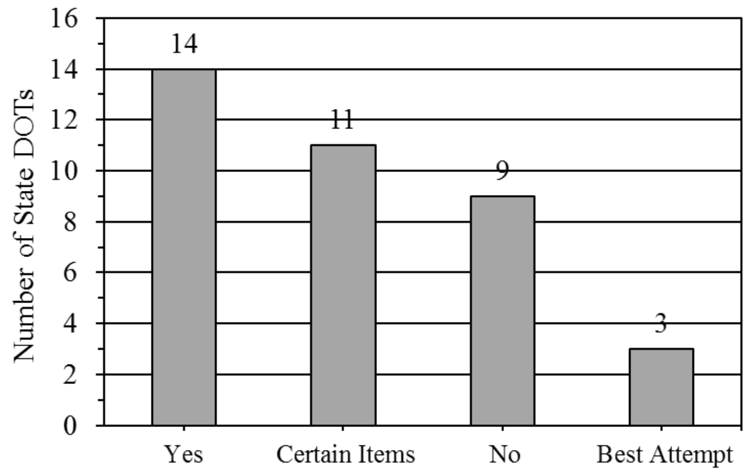


FIGURE 38 Number of state DOTs that reported collecting pavement condition data according to HPMS requirements in 2010

Question 4: How is your (HPMS's pavement condition) data collected?

This question was directed at the method in which pavement distress or pavement condition data were obtained for use in HPMS reporting. Five agencies reported that they used manual data collection, in which a crew was sent out and followed detailed field guides to obtain the desired item. Most agencies, 15, used automated means of data collection (Figure 39). Examples of these automated means included laser profiling vans, in which road geometry data are analyzed, and digital imaging vehicles, in which snapshots are taken at specific intervals while the vehicles are in motion. The primary companies/vendors used were Fugro Roadware Inc. and Pathways Services Inc. The agencies that reported "Automated" data collection relied on the vendor's software to produce values to be reported directly to HPMS. The 6 state DOTs that fell into the "Semi-Automated" category used automated means of surveying their road systems, but had a designated person or department that manually reviewed the images obtained by the vehicles and assigned the required values, particularly for cracking length and percentage. Eight agencies used a combination of these methods depending on the desired item, and 3 agencies did not respond, primarily because the contact was not aware of the method used and the person in charge of the data collection could not be reached at the time of this report.

The five agencies that reported using manual data collection techniques did so in house or hired college students during the summer to perform pavement evaluations. Of the 29 agencies that reported using some type of automated collection method, 22 contracted out their pavement condition data collection and 7 used agency-owned equipment and internal personnel.

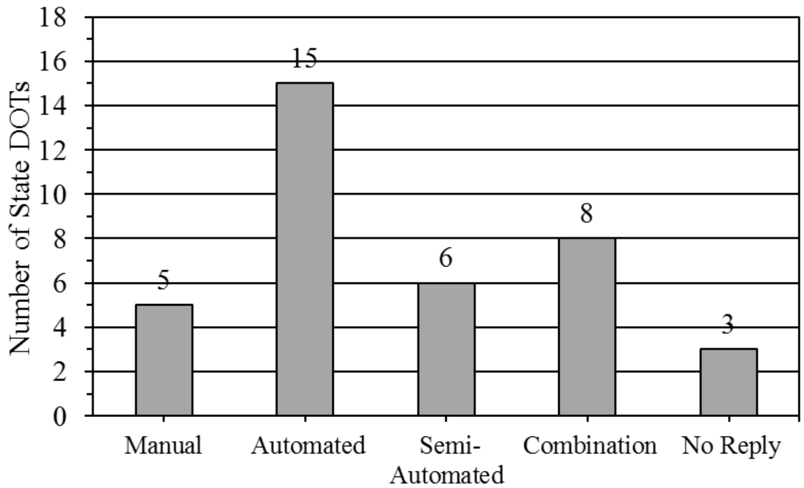


FIGURE 39 Number of state DOTs that indicated the collection method of HPMS's pavement distress or pavement condition data used or applied in 2010

Question 5: Does your agency already collect similar data in a compatible format to the one required for HPMS (reporting)?

This question was geared toward determining whether or not state DOTs had been collecting data in a format similar to the HPMS data requirements for use in their respective PMS or other agency uses. Of the 13 who replied Yes, the data that they had been collecting for their own uses was very similar to the HPMS requirements (Figure 40). Seven agencies were collecting data that did not fit at all into HPMS reporting. Thirteen agencies had collected data that, with minor adjustments and conversions, could be used for HPMS reporting. These minor adjustments dealt with changing codes, for example, pavement types did not match between state and federal systems, section lengths had to be adjusted, and database locations and formats had to be altered. The two agencies that fit into the "Combination" category had some items that fit and some that did not, and the "No Reply" category contained two agencies because the responders were not aware of the data collection methods and the persons in charge could not be reached at the time of this report.

Prevalent comments on this question include:

- Certain items that had the correct data had to be ran through queries to find the relevant data items and database formats converted from one type to another, such as Access to SQL.
- Several agencies had begun to adapt their own data collection years ago anticipating the new HPMS requirements.
- A few had reported having "No use for HPMS," their PMS was working efficiently for them and saw no need to collect data in HPMS format.

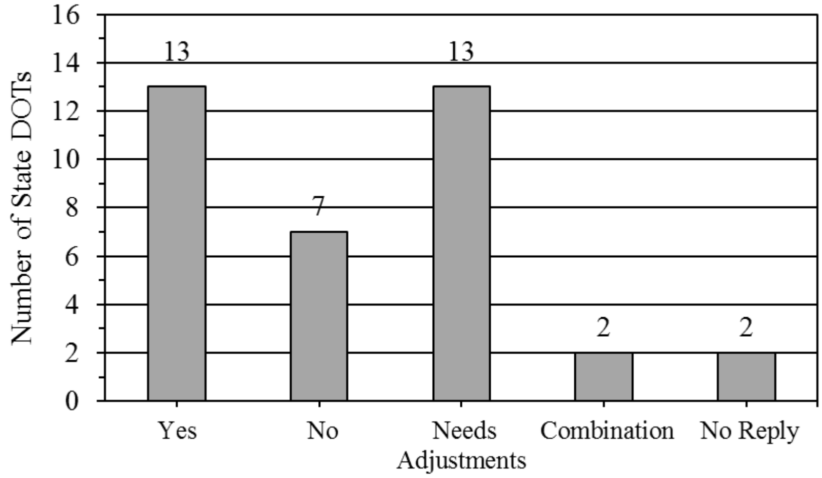


FIGURE 40 Number of state DOTs that indicated already collection data (in 2010) in a format comparable to the one required for HPMS reporting

Question 6: How does your agency share these data with HPMS?

The purpose of this question was to find out how agencies reported pavement condition data to HPMS in the event that the data they collected did not match HPMS requirements. Six agencies said that their data were forwarded on to another department that handled data reporting and had no information on what that department did to get the data to match (Figure 41). Sixteen agencies reported using HPMS software, which enabled database transfer between agencies (state DOT and HPMS). The four in the "Waiting" category were agencies that were reporting data in the new HPMS version and had not received the new software package from FHWA at the time of the interview (2010). The large "No Reply" section was due to the number of agencies that had no issues with reporting data in either version.

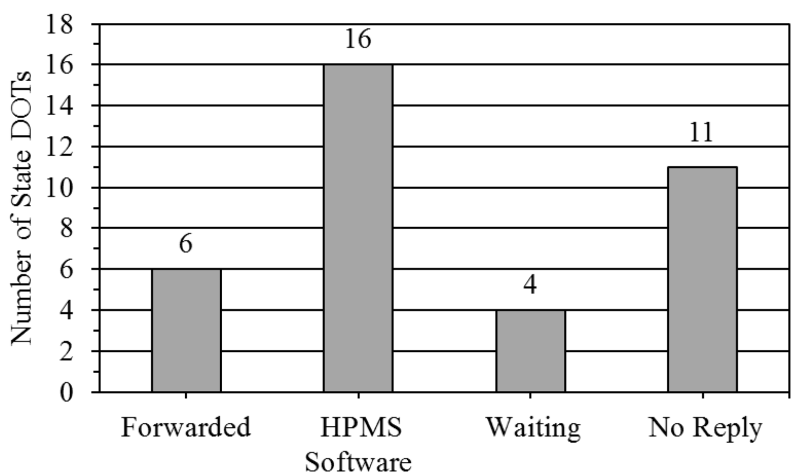


FIGURE 41 Number of state DOTs that expressed having some issues with HPMS reporting in 2010 and indicated the method used for HPMS reporting

Question 7: How do you (your agency) convert your data to the HPMS format? (e.g., have you developed a conversion system, algorithms, formulas, etc.? Do you have any documentation relating to this that you can send me?

This question refers to any method that was used in order to get agency data to match HPMS formatting requirements. Due to the timing of this survey, many agencies are finding that certain data items would need to be adjusted to meet HPMS requirements for the next reporting year (2011). Eighteen agencies were developing conversion systems (Figure 42). It was still to be determined whether these conversions included scripting or batch formatting of existing data or mathematical conversions, depending on the feedback received from FHWA when the "new" version would be used. Nine agencies needed only simple formulas or algorithms to fit data into HPMS items. Most of these were due to the ways that agencies collected data –some needed to convert linear feet to area, hence multiplying by lane width. The "Codes/ Batch Formatting" category referred to agencies whose data matched, but were not located in the same spatial reference as the HPMS databases, and line-by-line changing of data codes. Three agencies reported that their data collection method was perfect as-is and required no changes. The one "No Reply" was recorded due to a contact that was unaware of what happened to the data after it was forwarded to another department, and that person could not be reached at the time of this report.

Two agencies sent copies of documentation used to get data formats to match. Three other agencies were very close to completing their documentation but copies were not available at the time of the survey.

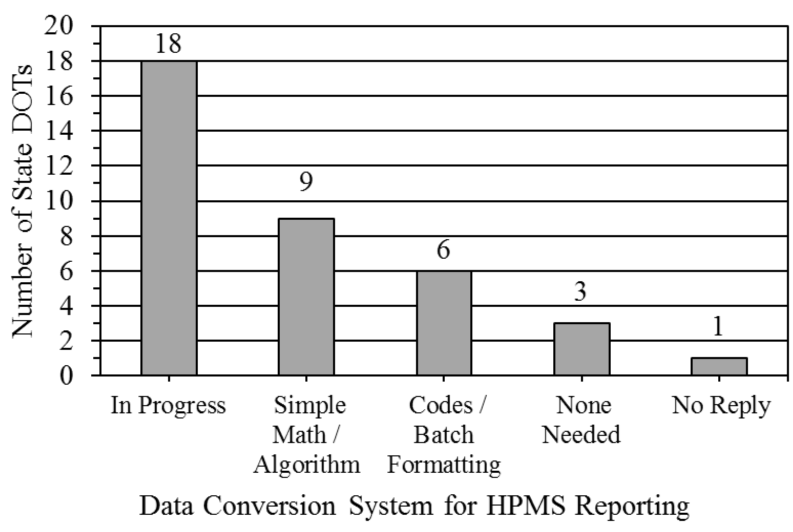


FIGURE 42 Number of state DOTs that indicated method or means of pavement data conversion to HPMS format in 2010

POTENTIAL USE OF DISTRESS DATA FOR MEPDG

As most state DOTs calibrate prediction models and develop their methodology according to the *Mechanistic-Empirical Pavement Design Guide* (MEPDG) (21), there may be an opportunity to use distress data from the PMS for MEPDG model calibration. Use of PMS distress data for MEPDG calibration was assessed through an interview with Dr. Rafiqul Tarefder from the University of New Mexico, who is working with NMDOT on the design guide.

The common distress parameters between the proposed NMDOT's PMS and MEPDG methodology include rutting, longitudinal cracking, alligator cracking, and transverse cracking. The units required for the MEPDG distress model calibration are comparable to the data that would be collected using the recommended revised protocol for alligator cracking and transverse cracking. The data for rutting and longitudinal cracking may require that data be converted from PMS data for MEPDG calibration. The PMS data are only collected on a 161-m (0.1-mile) long section at each milepost, which results in approximately 10% of the pavement being directly assessed. This data could be used for initial calibration purposes for the MEPDG in New Mexico, but detailed distress evaluations along a continuous (longer) section, e.g. 2 to 3 miles long (3.2 to 4.8 km long) would eventually be required for MEPDG model calibrations.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1) The proposed protocol for visual distress surveys addresses the needs of NMDOT in terms of HPMS distress data reporting and PMS parameters needed to assess the condition of the highway pavement network. It also addresses the recommendations of the 2010 FHWA review of NMDOT Pavement Condition Data Collection Program.

2) The main changes introduced to the distress rating protocol are the reduction of distress types from eight to five for flexible pavements, the rating and reporting of all severity levels and their corresponding extents, and the type of data collected (for example, count of transverse cracks, length of sections with alligator cracking). Modifications were incorporated to the evaluation criteria as well as to the surveys in the field.

3) The data from field tests, including application of the current and proposed protocols in 66 sample sections and detailed surface measurements of distresses in 15 sample sections, were used to obtain the statistical correlations to estimate HPMS distress data and PMS parameters with relatively simple procedures. The data was also used to determine new weight factors to be used in the distress rate equation to calculate the PSI. For the later analysis, the goal was to minimize the difference (or error) between the PSI calculated with data from the current protocol and the PSI calculated with data from the proposed protocol for a given sample section.

4) Using results from the field test and applying the averaged deviation index method, it was found that there is very good interrater agreement when applying the new protocol. Some issues associated with rating bleeding and other distress types are decreased with the new protocol.

5) The visual surveys are meant to collect distress data and information at the network level. The PSI and distress data deduced in this manner could be used for initial calibration purposes of models for MEPDG. However, longer (continuous) sections than those adopted in the annual pavement distress data collection would be needed for more detailed model calibration for local conditions.

RECOMMENDATIONS

1) It is recommended that the proposed protocol for visual distress surveys be implemented in the 2012 data collection cycle. The NMDOT's QA/QC plan for distress surveys may need to be revised to take into account the changes in the protocol and format of the data collected by the raters in the field, among other factors. This revision to QA/QC requirements should be completed before the summer of 2012, when the next distress data collection cycle is expected to take place.

2) If the proposed protocol is adopted, the PSI formulation, particularly the distress rate, should be modified in the appropriate systems and software and tested, so that the data processing and PSI reporting by NMDOT will be possible in the fall of 2012. In addition, modifications to the codes to calculate HPMS data and/or PMS parameters from raters' data should be incorporated and tested.

3) Rut depth information will be collected by NMDOT (in-house) solely using automated method starting in 2012. The NMDOT's visual distress surveys will not include rutting and shoving ratings. However, it is recommended to incorporate spot checks of rut depth measurements in selected sections as part of the program of visual distress surveys. This valuable information can be used for Quality Assurance/Quality Control (QA/QC) of rut depth measurements performed with automated measurements. Inconsistencies and potential problems of equipment and calibration could be identified and corrected.

4) It is recommended to provide presentations or workshops to District Maintenance Engineers and other staff to inform them about the NMDOT's Pavement Distress Evaluation Program, procedures, QA/QC procedures, data format and potential use of the available data in the context of the district needs.

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10. Bogus, S. M., Migliaccio, G. C., and Cordova, A. A. Assessment of Data Quality for Evaluations of Manual Pavement Distress. *In Transportation Research Record: Journal of the Transportation Research Board, No. 2170*, TRB, National Research Council, Washington, D.C., 2010, pp 1–8.

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12. Federal Highway Administration (FHWA). *Highway Performance Monitoring System*. http://www.fhwa.dot.gov/policy/ohpi/hpms/hpmsprimer.cfm. Accessed October 28, 2010.

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19. Burke, M. J., Finkelstein, L. M., and Dusig, M. S. On Average Deviation Indices for Estimating Interrater Agreement. *Organizational Research Methods*, 2(1), 1999, pp 49–68.

20. Cordova Alvidrez, A. A. *A Framework for Assessing and Improving Quality of Data from Visual Evaluation of Asset Conditions*. Master Thesis, Civil Engineering Department, University of New Mexico, 2010.

21. National Cooperative Highway Research Program (NCHRP) (2004). *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*. *Final Report NCHRP Project 1-37A.*

APPENDICES

APPENDIX A

Annotated Bibliography

1. American Association of State Highway and Transportation Officials (AASHTO). *Standard Practice for Quantifying Cracks in Asphalt Pavement Surface*, AASHTO Designation PP 44-01(2003). June 2004 AASHTO Provisional Standards. Washington D.C., 2004, PP44-1 to PP44-5.

This practice covers the procedures for quantifying cracking in asphalt pavement surfaces both in wheel path and non-wheel path areas. The standardization of this practice will produce consistent pavement condition estimates for network-level pavement management. It is also used to quantify the difference between fatigue and environmental pavement cracking. The cracks to be reported may be longitudinal, transverse, or interconnected, and are to be rated using a severity index that is based on the crack widths. The standard includes which data items are to be reported, and contains a quality assurance plan.

2. American Association of State Highway and Transportation Officials (AASHTO). *Standard Practice for Determining Maximum Rut Depth an Asphalt Pavements*, AASHTO Designation PP 38-04. June 2004 AASHTO Provisional Standards. Washington D.C., 2004, PP38-1 to PP38-4.

This practice describes a five-point method for estimating rut depth in asphalt pavement surfaces. While five points are the minimum according to this standard, more may be used, which would provide greater accuracy. This practice should be used to obtain consistent results that can be used for network-level pavement management. Measurements are made longitudinally at 10-m intervals, with measurements taken along a transverse profile at each of five points. The standard includes which data items are to be reported, and contains a quality assurance plan.

3. American Association of State Highway and Transportation Officials (AASHTO). *Evaluating Faulting of Concrete Pavements*, AASHTO Designation R36-04. Standard Specifications for Transportation Materials and Methods of Sampling and Testing, 24th ed. Washington D.C., 2004, R36-1 to R36-4.

This designation describes the procedure used to evaluate faulting in jointed concrete pavement surfaces. A standard practice is essential to provide consistent estimates of faulting for network-level pavement management. Faulting is reported to the nearest 1mm by taking the difference in elevations measured on either side of a transverse joint or crack. Data is to be measured at 0.1-km intervals. The data items to be reported are also listed in the standard, as well as a quality assurance plan.

4. American Association of State Highway and Transportation Officials (AASHTO). *Standard Practice for Determination of International Roughness Index (IRI) to Quantify Roughness of Pavements*, AASHTO Designation PP 37-04. June 2004 AASHTO Provisional Standards. Washington D.C., 2004, PP37-1 to PP37-4.

This practice describes a method for estimating roughness for pavement sections that can be repeated and produce consistent estimations of IRI for pavement management networks. The IRI is computed from longitudinal profile measurements, averaged between both wheel paths. This designation includes data collection methods, data items to be collected, and a quality assurance plan.

5. Amirkhanian, Serji N., Juang, C. Hsein, Koduru, Hari Krishan, and Xiao, Feipeng. Using Fuzzy Logic and Expert System Approaches in Evaluating Flexible Pavement Distress: Case Study. *Journal of Transportation Engineering*, Vol. 136, No. 2, February 2010, pp 149-157

Fuzzy logic and expert system techniques are effective in evaluating the flexible pavement distress. Distress classification has usually been performed by visual inspection of the surface of the pavement or from the data gathered by automated distress measuring equipment. Consistency in this process can be increased and subjectivity is minimized by using an expert system. A methodology has been developed that uses fuzzy logic for the categorization of distresses. An expert system was developed in C language using fuzzy logic for reasoning. The objective of the developed methodology was to use automated techniques for quick, efficient, and consistent classification for flexible pavement distresses using data from the automated distress measuring system. The developed expert system has been designed to be used as a module within a pavement management system. This will help to completely automate pavement condition evaluation and strategy development for maintenance and rehabilitation of pavements, thus eliminating subjectivity and inconsistency in the process. According to the experts, mostly highway officials, the differences between the actual measured data and results from fuzzy logic expert system approaches were well within acceptable ranges.

6. Bandini, Paola, Bianchini, Alessandra, and Smith, David W. Interrater Reliability of Manual Pavement Distress Evaluations. *Journal of Transportation Engineering*, Vol. 136, No. 2, February 2010, pp. 165-172.

Many government agencies are faced with the challenge of pavement evaluation and maintenance as part of their pavement management systems. These agencies perform or contract manual or automated distress surveys over the pavement network to monitor the structure performance and obtain the necessary data to calculate pavement condition indexes. Although manual distress ratings are done according to well-defined criteria, a certain amount of subjectivity and the experience of the raters have an undoubted influence on the ratings. This study proposes a new approach to estimate the interrater or intercrew reliability for manual or semiautomated distress data collection. The proposed analysis acknowledges that a certain degree of variability in the visual distress ratings is likely to occur and, thus, minimum acceptable values of complete and partial agreements of the crews or raters are suggested. The statistical approach to validate the level of agreement between the ratings of two raters or crews is based on the use of the chi-square distribution to test hypotheses about multinomial experiments.

7. Bugao Xu and Yaxiong Huang. Center for Transportation Research at the University of Texas at Austin. Project Summary Report 7-4975-S: *Automated Pavement Cracking Rating System*, October 2003. Retrieved from: http://www.utexas.edu/research/ctr/pdf_reports/7_4975_S.pdf

Pavement cracking is one of the most important distress types. To characterize pavement cracks quantitatively, three parameters of cracking are often used: type, extent, and severity. For flexible pavements, cracks are often classified into three types: network (alligator or map), longitudinal, and transverse. For rigid pavements, cracking is often evaluated in the AASHTO protocol, i.e., by the crack density in five separate passes of the pavement. Traditionally, pavement cracks are rated with the standardized visual inspection method, which is subjective, tedious, and unsafe to the human graders. To improve the objectivity and efficiency of the pavement distress rating, various automated systems have been developed worldwide since the 1970s. But, most of the systems developed still have shortcomings, such as offline processing, partial coverage, and low speed alternatives, which hinder their widespread applications. The overall goal of this project is to design a system that can acquire and analyze pavement images at real-time and highway speed, and to create effective image-processing algorithms that can reliably detect pavement cracks on both flexible and rigid pavements. After completing the research, several recommendations are made in order to improve the automated data collection process.

8. Bogus, Susan M., Lenke, Lary R., Song, Jongchul, and Waggerman, Raymond. Rank Correlation Method for Evaluating Manual Pavement Distress Data Variability. *Journal of Infrastructure Systems*, Vol. 16, No. 1, March 2010, pp. 66-72.

Evaluations of surface distresses in pavements, such as cracking, bleeding, and raveling, are often used as one component of overall pavement condition indexes. Both manual and automated survey methods are available for pavement distress evaluation; however, all distress evaluations experience a certain level of variability in their results. How this level of variability is determined depends on the type of data collected during the pavement distress evaluations. When distress data are collected as ordinal values, the variability may be determined by comparison of pairs of ranked values. This paper presents one rank correlation method, Kendall's correlation coefficient, and illustrates how it can be used to assess variability in ordinal distress data collected through manual surveys. Using Kendall's correlation coefficient, variability between different raters and variability between multiple evaluations by one rater were determined for each individual distress type. As a result, the ratings for certain distresses such as bleeding were found to have a high level of variability. This information can be useful when used to develop training programs to reduce data variability.

9. Chua, Koon Meng and Xu, Ling. Simple Procedure for Identifying Pavement Distresses from Video Images. *Journal of Transportation Engineering*, Vol. 120, No. 3, May/June 1994, pp 412-431.

Pavement distress information is important to highway engineers in managing pavement networks. At the present time, there are several research groups working to develop a more efficient and unbiased method of obtaining pavement distress data. The general approach desired is to capture pavement images using video cameras mounted on a moving vehicle and then use a computer to recognize and quantify the pavement distresses from the video images. An automated pavement distress survey system developed at the University of New Mexico is described in the paper. This prototype system uses an 8-mm camcorder, an inexpensive image-digitizing board, and a 486 personal microcomputer. The algorithm is capable of automatically identifying longitudinal, transverse, diagonal, alligator, and map cracking. The distresses are then reported appropriately as lengths or areas according to the type of distress. The program has an accuracy in prediction of over 85% in asphalt concrete pavements and over 90% in portland cement concrete pavements. The described automated survey system is capable of accurately analyzing images captured at a vehicle speed of 24 km/h (15 mph) and below.

10. Clevenson, Lawrence, Lukanen, Erland, and Stubstad, Richard. *Study of Long-Term Pavement Performance (LTPP): Pavement Deflections, Final Report*, April 2001 – September 2001. Federal Highway Administration, LTPP Division, HNR–40, Turner-Fairbank Highway Research Center, 6300 Georgetown Pike, McLean, VA 22101-2296. Retrieved from: http://www.fhwa.dot.gov/pavement/ltpp/pubs/03093/03093.pdf

This report presents the results of a study of pavement deflections. The study covered all level E falling weight deflectometer (FWD) deflections and associated data in LTPP's database from Data Release 9.0, November 23, 1998. Although the limited amount of data from unbound material testing was also provided, these data were not screened due to the large variations in the recorded deflections in comparison with bound layer tests. The report covers the screening techniques developed and used to identify data errors and anomalies in the FWD load deflection database, along with a description of each category of data errors identified. Contrary to prior expectations, the vast majority of these data errors were related to manually input data elements, not the deflections themselves. Approximately 8 percent of the 4.4 million lines, or records, in the pre-autumn 1998 load-deflection database were affected by manual input data errors alone, while less than 0.2 percent appear to be affected by actual load-deflection data anomalies generated by the FWD. Out of the approximately 8 percent of manual input data errors found, around 7 percent were associated with nonprotocol and unreported placement of the deflection sensors along the FWD's raise-lower bar. Other types of manual data entry errors, each occurring at a rate of less than 1 percent, included incorrect lane designation, station number, date- or timestamp, test site, drop height, and configuration of the sensors for joint testing on Portland cement concrete (PCC) pavements. Deflection reading data errors included deflection basin anomalies and sensor malfunctioning errors. A universally applicable deflection basin screening tool called SLIC was also developed for use on select FWD data file formats. The overall quality of the pre-autumn 1998 FWD database can be characterized as good to excellent.

11. Dantas Nets, Silvrano, Oliveira de Sousa, Ricardo, and Muniz de Farias, Marcio. *Statistical Analysis between Roughness Indices and Roughness Prediction Model Using Neural Networks*. University of Brasilia, Brasilia, Distrito Federal Brazil, 2006 Retrieved from: http://wwwcf.fhwa.dot.gov/pavement/ltpp/pubs/06109/06109.pdf

This paper presents an analysis between the International Roughness Index (IRI) and the standard deviation of longitudinal roughness (σ), as well as a neural network study developed to predict the critical level of roughness. Measured longitudinal profiles available in the Long-Term Pavement Performance (LTPP) program database were used. A total of 207 pavement sections in 42 States of the United States were used to do this analysis. Using a suitable software, the International Roughness Index (IRI) and the standard deviation of longitudinal roughness (σ) values were computed for every longitudinal pavement profile measured. Afterwards, these values were used in regression analysis and a high correlation was found between them (R2=0.93). Neural network analysis correlated the IRI-computed values with the type of subgrade soil, pavement structure (layer thickness), climate, and traffic data of 157 pavement sections. The neural network could forecast the IRI with an extremely high correlation factor

(R^2=0.99). Besides, the neural network provided a sensitivity analysis indicating the relative contribution of factors related to the structural number (49 percent), climate (31 percent), and traffic (20 percent). Multivariate linear and nonlinear statistic regressions were also performed to predict IRI, but no correlation was found.

12. Federal Highway Administration. *PAVEMENT DISTRESS IDENTIFICATION MANUAL for the NPS ROAD INVENTORY PROGRAM, Cycle 4, 2006-2009*. Retrieved from: http://mrutc.org/outreach/mqa/library/docs/National/Distress%20ID%20Manual.pdf

The Federal Highway Administration (FHWA), Road Inventory Program (RIP) for the National Park Service (NPS), collects roadway condition data on paved asphalt surfaces including roads, parkways, and parking areas in national parks nationwide. The road surface condition data is collected using an automated data collection vehicle called ARAN (Automated Road ANalyzer). The FHWA RIP is implemented based on the premise that an accurate pavement surface condition assessment can be accomplished using automated crack detection technology as applied to digital images. Longitudinal and transverse cracking, alligator cracking, and rutting are all rated by the review of digital pictures taken from an automated vehicle mounted survey. Longitudinal and transverse cracking are measured in linear feet, converted to number of cracks per .02 mile, and also assigned a severity level based n crack widths. Alligator cracking is measured in square feet, converted to percent of lane per .02 mile, and also assigned a severity level based on crack width and pattern of cracking. Data for rutting is obtained by an FHWA data collection vehicle. Rutting is measured in inches, converted to an average depth per .02 mile, and assigned a severity based on the depth of the depression in the wheel path.

13. Gong, Weiguo and Wang, Kelvin C. P. Real-Time Automated Survey System of Pavement Cracking in Parallel Environment. *Journal of Infrastructure Systems*, Vol. 11, No. 3, September 2005, pp 154-164.

As a part of the digital highway data vehicle (DHDV), the automated survey system developed at the University of Arkansas is the implementation of a real-time system for pavement surface cracking survey. The researchers faced tremendous tasks in optimizing imaging algorithms to speed up the processing at the same time without sacrificing accuracy in identifying and classifying cracks. This paper introduces the automated real-time system and summarizes the experiences in developing parallel algorithms in imaging processing used in the real-time system. The hardware system for processing images is based on the ubiquitous multiple Central Processing Unit (CPU) 86 platform that has the capability of two levels of parallel processing at multiple CPU level and within each CPU level. The former is commonly called Symmetrical Processing (SMP) and the latter is called Single Instruction Multiple Data (SIMD). The paper also presents results of a network level survey with the DHDV and the distress analyzer on a network of about 161 km (100 mil) of pavements. In addition, a manual survey was conducted on the same network of pavements. World Bank’s universal cracking indicator (CI) is used in this study. Because the distress analyzer is fully automated and results of the analysis are provided in synch with image collection, the potential cost savings when compared with manual survey methods and other semi-automated survey technologies are tremendous.

14. Hudson, W. Ronald, Sun, Lu, and Zhang, Zhanming. Empirical-Mechanistic Method-Based Stochastic Modeling of Fatigue Damage to Predict Flexible Pavement Cracking for Transportation Infrastructure Management. *Journal of Transportation Engineering*, Vol. 129, No. 2, March/April 2003, pp 109-117.

In the purely theoretical approach of pavement design, percentage fatigue cracking is related to damage in a probabilistic manner according to the Miner's law. Two methods that are currently widely in use are based on assumptions of damage distribution. One method assumes fatigue damage being normally distributed, while the other one assumes fatigue damage being lognormally distributed. Since mechanistic-empirical pavement design and pavement management require precise forecasting of pavement fatigue cracking, much effort should be taken to characterize and predict fatigue cracking in terms of damage distribution. In this paper, we formulate the probability density distribution of fatigue damage of flexible pavements according to the underlying structure of fatigue cracking equations so that pavement fatigue-cracking damage can be interpreted in a more meaningful way. Numerical computation is conducted for a case study. It is found that damage is neither normally nor lognormally distributed. It is therefore recommended that methodology and damage distribution model established in this paper be used in practice to predict damage distribution and percentage cracking so that a better estimation of fatigue cracking can be made.

15. Iowa State University. *Proceedings of the 2003 Mid-Continent Transportation Research Symposium*, Ames, Iowa, August 2003. Adaptability of AASHTO Provisional Standards for Condition Surveys for Roughness and Faulting in Kansas. Retrieved from: http://www.intrans.iastate.edu/pubs/midcon2003/VedulaStandards.pdf

The Kansas Department of Transportation (KDOT) currently uses a comprehensive, network-level pavement management system known as Network Optimization System (NOS). Annual condition surveys for roughness and faulting generate important inputs for NOS. Recently, AASHTO has published provisional standards for condition surveys in order to harmonize data collection efforts among the states. To study the effects of these provisional standards on KDOT NOS, profile data was collected on about 346 km (215 miles) of Kansas highways following these standards. The comparison data came from KDOT's annual condition survey using KDOT standards. The roughness values, in terms of International Roughness Index, IRI, were computed and aggregated for 20 test sections and the faulting values were computed and compared for four test sections. Various statistical analyses compared the results from the algorithms following KDOT NOS and the AASHTO provisional standards. The roughness measurements and subsequent analysis using AASHTO provisional standard PP-37-00 and current KDOT methodology tend to produce statistically similar results. This may indicate this standard (PP 37-00) can be adopted for NOS without any major changes in current practice. However, significant differences were found in calculated fault values computed from the two methods even after some modification to PP 38-00 following current practices in Kansas.

16. Kaul, Vivek, Mersereau, Russell M., and Tsai, Yi-Chang. Critical Assessment of Pavement Distress Segmentation Methods. *Journal of Transportation Engineering*, Vol. 136, No. 1, January 2010, pp 11-19.

Image segmentation is the crucial step in automatic image distress detection and classification (e.g., types and severities) and has important applications for automatic crack sealing. Although many researchers have developed pavement distress detection and recognition algorithms, full automation has remained a challenge. This is the first paper that uses a scoring measure to quantitatively and objectively evaluate the performance of six different segmentation algorithms. Up-to-date research on pavement distress detection and segmentation is comprehensively reviewed to identify the research need. Six segmentation methods are then tested using a diverse set of actual pavement images taken on interstate highway I-75/I-85 near Atlanta and provided by the Georgia Department of Transportation with varying lighting conditions, shadows, and crack positions to differentiate their performance. The dynamic optimization-based method, which was previously used for segmenting low signal-to-noise ratio (SNR) digital radiography images, outperforms the other five methods based on our scoring measure. It is robust to image variations in our data set but the computation time required is high. By critically assessing the strengths and limitations of the existing algorithms, the paper provides valuable insight and guideline for future algorithm development that are important in automating image distress detection and classification.

17. Kohn, Starr D. Soil and Materials Engineers, Inc. *LTPP Data Analysis: Factors Affecting Pavement Smoothness.* National Cooperative Highway Research Program RESEARCH RESULTS DIGEST, February 2002—Number 264. The report is available as NCHRP Web Document 40 on the NCHRP website at http://www4.nationalacademies.org/trb/crp.nsf; copies are available for loan on request to the National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, DC 20418.

An analysis was made of the data available in the LTPP IMS database classified as "Level E" for four Specific Pavement Studies (SPS) experiments and seven General Pavement Studies (GPS) experiments. This analysis took into account the time-sequence nature of the data at the test sections and used the IRI as the measure of pavement smoothness. Through this analysis, the factors related to pavement structure and features, rehabilitation techniques, climatic conditions, traffic levels, layer materials and properties, and pavement distress variables that contribute to changes in pavement smoothness were identified for each type of pavement structure.

18. McQueen, Jason M., and Timm, David H. Statistical Analysis of Automated Versus Manual Pavement Condition Surveys. *Transportation Research record: Journal of the Transportation Research Board,* 1940, 2005, pp 55-62.

The Alabama Department of Transportation (ALDOT) has used a vendor to perform automated pavement condition surveys for the Alabama pavement network since 1997. In 2002, ALDOT established a quality assurance (QA) program to check the accuracy of the automated pavement condition data. The QA program revealed significant discrepancies between manual and automatically collected data. ALDOT uses a composite pavement condition index called pavement condition rating (PCR) in its pavement management system. The equation for PCR was developed in 1985 for use with manual pavement condition surveys; however, ALDOT continues to use it with data from automated condition surveys. Since the PCR equation was developed for manual surveys, the discrepancies between the manual and automated data led ALDOT to question the continuity between its manual and automated pavement condition survey programs. A regression analysis was completed to look for any systematic error or general trends in the error between automated and manual data. Also, Monte Carlo simulation was used to determine which distress parameters most influence the PCR and whether they require more accuracy. The regression analysis showed the following general trends: automated data overreport outside wheelpath rut depth, underreport alligator severity Level 1 cracking, and overreport alligator severity Level 3 cracking. Through Monte Carlo simulation, it was determined that all severity levels of transverse cracking, block cracking, and alligator cracking data require greater accuracy.

19. Miller, Rick, Reigle, Jennifer, and Vedula, Kamesh. *Comparison of 3-point and 5-point Rut Depth Data Analysis*. Kansas Department of Transportation Bureau of Materials & Research, 2002. Retrieved from: http://pms.nevadadot.com/2002presentations/41.pdf

The Kansas Department of Transportation (KDOT) currently utilizes a comprehensive, network-level pavement management system (PMS) known as Network Optimization System (NOS). For input into NOS, KDOT collects three-sensor rut depth data on its network annually, using two South Dakota-type road profilers. Recently, AASHTO has published provisional standards by modifying FHWA protocols for pavement condition data collection. The primary purpose of these data collection standards is to standardize Highway Performance Monitoring System (HPMS) reporting with the eventual goal of using them in all states' PMS. AASHTO provisional standard PP 38-00 is a protocol for quantifying maximum rut depth. Under AASHTO PP38-00, maximum rut depth is quantified using a five-sensor calculation. In order to study the effect of AASHTO PP 38-00 on KDOT NOS, profile data was collected on about 241.4 kilometers (150 miles) of bituminous and composite pavements in Kansas, using an ICC profiler equipped with a five-sensor rut bar and a KDOT South Dakota-type profiler with a three-sensor rut bar. The rut depth values were computed and aggregated for the KDOT PMS segments within 11 bituminous and two composite pavement sections. Various statistical analyses were then conducted to compare the results from the KDOT NOS and PP 38-00 algorithms for rut depth computation. The results obtained thus far show that the four-level stratification for rut depth severity suggested by AASHTO PP 38-00 compares reasonably well with the current NOS practice. Both algorithms compared well for the composite pavement test sections. On six out of 11 bituminous sections, the KDOT and the ASSHTO algorithms produced statistically similar mean rut depths. On these sections, the effects of 0.16-km (0.1-mile) and 0.1-km aggregations are insignificant. The dissimilarities on other sections may result from lateral wander of the survey vehicle as well as due to the outer sensors. The outer sensors may not have measured the profile elevations in the cross slope plane (off the edge of the road or over the centerline crown).

20. Olga Selezneva, Jane Jiang, and Shiraz D. Tayabji. *PRELIMINARY EVALUATION AND ANALYSIS OF LTPP FAULTING DATA – Final Report*. ERES Consultants, Inc., June 2000. Retrieved from: http://www.pavementpreservation.org/library/getfile.php?journal_id=601

A major goal of the Long-Term Pavement Performance (LTPP) study is the development of recommendations for improving the design and construction of new and rehabilitated pavements to provide longer lasting pavements. As part of the condition monitoring of the LTPP test sections, joint and crack faulting data are being collected on a regular basis at each jointed concrete pavement test site.

The LTPP faulting data are collected using the Georgia Faultmeter. Data are collected at joints and cracks along the wheelpath and along the outside pavement edge. As part of the study reported here, the quality of the faulting data was evaluated, and missing and questionable data were identified. The data were then used to develop faulting data indices (average joint faulting for each visit) and related statistical parameters.

Also, data analysis was carried out to determine the usefulness of joint faulting and related data in identifying factors that affect joint faulting. The analysis indicated that doweled joints exhibit very little faulting even after many years of service and that the effect of design features such as drainage, tied-concrete shoulder use, and joint spacing is not as significant when doweled joints are used. For non-doweled jointed plain concrete (JPC) pavements, the following design features were found to significantly reduce faulting: use of widened lanes, effective drainage system, stabilized base/subbase, and shorter joint spacing. Effect of faulting on ride quality was also investigated using jointed plain concrete pavements (JPCP) sections with three or more faulting and International Roughness Index (IRI) surveys. A strong correlation was found between rate of change in faulting values versus rate of change in IRI values for JPCP sections. The results indicate that faulting is a major component of increased roughness of JPC pavements.

21. Ozbay, Kaan and Laub, Ryan. *Models for Pavement Deterioration Using LTPP*, 2001. Dept. of Civil & Environmental Engineering, Rutgers, The State University, Piscataway, NJ 08854. Retrieved from : http://cait.rutgers.edu/files/FHWA-NJ-1999-030.pdf

The significant contribution of this research lies in the fact that it utilizes the most comprehensive database of pavement conditions (LTTP) that is readily available and promises to provide the sought data in future years. The Long Term Pavement Project (LTTP) Database was chosen to provide the required data of related parameters or the model development. The first part of this report reviews the existing literature covering related topics including pavement roughness, the Long Term Pavement Project LTPP background, artificial neural networks, regression analysis, and the existing pavement deterioration models developed by Federal Highway Agency or reported by Transportation Research Record as well as the default model that is utilized by the Pavement Management System. The second part discusses the work done in data analysis and data manipulation in addition to the development of the training of the neural network model. The third part deals with various aspects of the model development using neural networks and regression analysis. The next part concludes the research with summarizing the results of model development and then by presenting a comparison between the models developed in this research and some existing models by applying these models to similar data sets and performing statistical analysis of the results. Lastly, the report presents some recommendations for future research in this area.

22. Tighe, Susan L. *Assignments with Purpose: Using LTPP for Educating Tomorrow's Engineer*. University of Waterloo, Ontario, Canada, 2006. Retrieved from: http://wwwcf.fhwa.dot.gov/pavement/ltpp/pubs/06109/06109.pdf

The overall scope of this paper involves a university perspective on how the Long-Term Pavement Performance (LTPP) program can be used to educate and train skilled engineers in the pavement sector.

Building on a presentation at the 2003 Transportation Research Board Annual Meeting, this paper first presents a context for using the LTPP data. In formulating and addressing the use of the data, the following main points are discussed: education and training using LTPP, development of assignments with purpose, discussion of using LTPP to develop pavement research themes, and conclusions. The paper is directed primarily at academics. However, it does have relevance to the public and private sectors, as it directs assignments that will result in highly qualified people and potential leaders in the field of pavement engineering. It also recognizes the competing demands that face academics, so the assignments are intended to be straightforward and are designed for academics with limited preparation time. Overall there is a need to produce intelligent engineers with good problem-solving skills. Thus, the primary focus is to encourage independence and creativity through inquiry-based learning.

In summary, the basic premise of this paper is that good design, construction, and maintenance of long-life pavements can be realized most effectively in education and training through inquiry-based learning with LTPP.

23. Transportation Research Board and National Cooperative Highway Research Program. NCHRP Synthesis 334 – *Automated Pavement Distress Collection Techniques, A Synthesis of Highway Practice*, 2004. Retrieved from:
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_334.pdf

This document is a synthesis of the information collected in 2003 on highway community practice and research and development efforts in the automated collection and processing of pavement condition data typically used in network-level pavement management. The scope of the effort covered all phases of automated pavement condition data collection and processing for pavement surface distress, pavement ride quality, rut-depth measurements, and joint-faulting measurements. Included in the scope were the technologies employed, contracting issues, quality assurance (QA) issues, costs and benefits of automated techniques, monitoring frequencies and sampling protocols in use, degree of adoption of national standards for data collection, and contrast between the state of the art and the state of the practice in automated data collection and processing. Although emphasis was on network-level pavement management, project-level or research-level work, such as the Long-Term Pavement Performance Program, was included where it was helpful in contributing to the knowledge base on the subject matter.

24. U.S. Department of Transportation, Federal Highway Admiration. *Long-Term Pavement Performance Program Manual for Profile Measurements and Processing*. Research, Development, and Technology, Turner-Fairbank Highway Research Center, 6300 Georgetown Pike, McLean, VA 22101. November 2008. Retrieved from: http://ntl.bts.gov/lib/30000/30800/30895/FHWA-HRT-08-056.pdf

The Long-Term Pavement Performance (LTPP) program is a study of pavement performance at nearly 2,500 in-service pavement sections in the United States and Canada. LTPP's goal is to improve pavement performance and cost-effectiveness.
Toward accomplishing these objectives, LTPP is collecting data on in-service pavement sections over a 20-year period. The data collected at the test sections are stored in the LTPP Pavement Performance Database (PPDB). These data are being used and will continue to be used to achieve the goal and objectives of the LTPP program.
This manual describes operational procedures to be followed when measuring longitudinal pavement profiles for the LTPP program using the International Cybernetics Corporation (ICC) road profiler, Face Company Dipstick®, and the rod and level. This manual also describes procedures to be followed in the office when processing profile data that were collected in the field as well as guidelines for performing interregional comparison tests among the four LTPP profilers.

25. U.S. Department of Transportation, Federal Highway Administration. *Distress Data Consolidation Final Report*. October 2003. Retrieved from:
http://www.tfhrc.gov/pavement/ltpp/reports/01143/01143.pdf

Pavement distress is an important indicator of pavement performance. The Long-Term Pavement Performance (LTPP) program has been collecting distress information on more than 2,000 test sections located across North America since 1989. However, these surveys were performed using three different methodologies—two photographic and one manual. Additionally, over the years, distress definitions and measurement techniques were revised in an attempt to improve consistency in data collection. The primary objective of the research reported here was to produce a comprehensive consolidated distress data set to reconcile differences between data collected using these different methodologies.
After thorough review, two-thirds of the LTPP distress data were considered to be in "good shape" and could be included in the consolidated data set with no further effort. The other one-third of the data will require additional review by the agencies that performed the data collection. Overall, the discrepancies found between surveys were independent of distress methodology. The data sets from these different data collection methods could be combined without concern about a consistent bias existing in the data. Of the discrepancies that were observed, 17 percent could be attributed to human error, 6 percent to data collection methodology, 36 percent to the strategies used in this review, and 41 percent were unidentifiable.

26. Venkatesa Prasanna Kumar Ganesan. *Use of LTPP Data to Verify the Acceptance Limits Developed for PennDot Pavement Distress Data*. Pennsylvania State University, 2006. Retrieved from : http://wwwcf.fhwa.dot.gov/pavement/ltpp/pubs/06109/06109.pdf

State transportation agencies use various methods of pavement data collection. The major methods are manual, film-based, semi-automated, and automated collection. The Federal Highway Administration (FHWA) Long-Term Pavement Performance (LTPP) program has used both the manual method and the Pavement Distress Analysis System (PADIAS) film-based survey for its pavement data collection.(1) The Pennsylvania Department of Transportation (PennDOT) replaced its former manual method with a semi-automated method. The project team at the Pennsylvania Transportation Institute developed a quality assurance plan for PennDOT for pavement data collection and rating. Initial acceptance limits were developed by the project team with the assistance of PennDOT. The manual distress data are compared with the PADIAS 4.2 distress data. This paper also summarizes the PennDOT quality assurance plan. The sources of variability affecting surface distress are also discussed. In this paper, the LTPP distress data are used to verify the PennDOT acceptance limits. The findings indicate that the proposed limits may require modification. Two types of modifications are attempted with the LTPP data, providing input to PennDOT's future decisions.

State Transportation Agency Documents

27. Kentucky Transportation Cabinet. *KYTC Pavement Distress Identification Manual*, 2009. Retrieved from:
http://transportation.ky.gov/Maintenance/PM%20Reports/PM%20Field%20Manual09.pdf

This manual provides information on how to perform this state's yearly evaluation of pavement. The evaluations are used to document roadway deterioration, recommend pavement rehabilitation treatments, and prioritize projects. Fatigue cracking is assessed and given an Extent and Severity rating, based on the percent area and crack widths, respectively. Longitudinal cracking is given a severity based on crack width. Rutting is rated by measuring several sections of roadway with a 4 foot or longer ruler, and averaging the depth of the ruts. Faulting is reported by assigning an extent based on the number of panels with elevation differences and a severity assigned by the depth of these differences.

28. Nevada Department of Transportation. *Flexible Pavement Distress Identification Manual*. State of Nevada Department of Transportation Materials Division. Carson City, NV., 2002.

This document describes types and causes of flexible pavement distress and how to identify them. Severity is defined as the average crack width of this type of cracking throughout the rating area. The crack widths are measured using a "crack width gauge." A minimum of six crack width measurements are taken and averaged, and given a rating based on the gauge marks. Type A fatigue cracking is known as longitudinal cracking. Extent is defined as the total linear feet of this type of cracking in the wheel path area. Type B fatigue cracking is known as alligator cracking. Measuring of this value is similar to Type A cracking, but extent is reported as total square feet in the wheel path area. Transverse cracking is also measured according to the same guidelines, and the reported extent value is given in total linear feet in the wheel path area.

29. The Ohio Department of Transportation Office of Pavement Engineering. *Pavement Condition Rating System*, 2006. Retrieved from:
http://www.dot.state.oh.us/Divisions/TransSysDev/Innovation/InfrastructureManagement/PCRManual/Documents/2006PCRManual.pdf

Rutting is reported based on the rut depth and frequency of occurrence, as a percentage of section length. Severity is based upon both crack width and multiplicity of the cracking. Fatigue cracking and longitudinal cracking, also called wheel track cracking, is recorded using a severity and an extent level. The severity rating is based on crack width and the extent level is assigned based on upon percentage of the wheel track length within the section which exhibits cracking. Transverse cracks are rated based on the distance between the cracks for severity and a percentage of section length covered for extent level. Longitudinal cracking outside the wheel path is assigned a severity based on the sum of all cracks if more than one is present at the location of measurement. The extent level is based upon the average linear feet of longitudinal cracking per station of 100 feet length (30 m). Faulting is reported based on the difference in elevation of the slabs, where severity levels are concerned, and the extent level is based on the percentage of occurrences along the joints.

30. Oregon Department of Transportation Research Unit. *Automated Data Collection Equipment for Monitoring Highway Condition, Final Report*, 2005. Retrieved from:
http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/AutomatedDataCollection.pdf?ga=t

This study was conducted to evaluate automated vehicle mounted equipment to collect data on the needs of Oregon's highway inventory. Four vendors accepted invitations to evaluate their equipment. Although ODOT had conducted a similar evaluation in 1997, vendors claimed that improved technology had solved past problems. The evaluation included an assessment of the machines' performance in a survey of pavement condition, road roughness and the ODOT video log program. Because the video log and the road roughness inventories had been already automated (although not combined), the main focus of the evaluation was on the pavement condition rating. Several test sections on the state highway system were selected, including both asphalt and concrete pavements in various stages of wear. A standard value for the condition of these sections was established by a conventional "walk and look" survey by experienced ODOT pavement unit staff members. Also a survey was made by three rating crews, typically used by ODOT in assessing pavement condition. A comparison was made between the crews' ratings, those of the automated equipment, and the "ground truth" established by ODOT staff. The analysis of ratings showed that those of the rating crews were closer to the ground truth than the automated equipment ratings were.

31. Texas Department of Transportation (TxDOT). *Pavement Management Information System Rater's Manual Fiscal Year 2010*. Retrieved from: ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/raters_manual.pdf

"The information in this manual defines the methods for conducting a visual pavement evaluation, as part of the Fiscal Year (FY) 2010 Pavement Management Information System (PMIS) survey. The purpose of the visual survey is to provide data concerning the condition of pavements which can be used by itself or in combination with ride quality, structural adequacy, skid resistance, climate, and traffic data to assist in describing the overall condition of the State-maintained highway system.” Rutting is measured throughout the PMIS section using an approved method of measurement (a minimum of a 6-foot (2-meters) straight edge or string and a measuring device).Rutting is rated by area and severity. Area of rutting is measured as a percent of the section's total wheel path area that is rutted. Severity of rutting is described in terms of rut depth. Alligator cracking is rated by percentage area that contains such cracking. Longitudinal cracking is measured in terms of linear feet per station (i.e. average feet of cracking in each 100 feet (31 meters) of surface). Transverse cracking is measured in terms of number per station (i.e. average number of cracks in each 100 feet (31 meters) of surface). All of these items are reported using values from a lookup table on page 108 of the document that assists raters in assigning areas and lengths.

32. Washington State Department of Transportation. *Pavement Surface Condition Field Rating Manual for Asphalt Pavements*, 1999. Retrieved from:
http://www.wsdot.wa.gov/publications/manuals/fulltext/m0000/AsphaltPavements.pdf

This manual provides inspection procedures that “offer a method of determining pavement condition through observing and recording the presence of specific types and severities of defects or distresses in the pavement surface.” The document as a whole concentrates on flexible pavement distresses, including rutting, alligator cracking, and longitudinal and transverse cracking. Rutting is calculated by measuring the depth of the rut at several locations and using an average depth and given a severity of low, medium, or high depending on that depth. Alligator cracking is reported in a percentage of wheel path length. The lengths of cracking in each severity are added, in both wheel paths, divided by twice the length of the segment, multiplied by 100 to get percent, and rounded to a whole number. The extent of longitudinal cracking is recorded as a percent of the length of the surveyed segment. The lengths of the cracks are measured, in each severity, divided by the length of the segment, multiplied by 100 to get percent, and rounded to a whole number.

APPENDIX B

NMDOT's Distress Evaluation Chart for Flexible and Rigid Pavements (Current)

NMDOT's Distress Evaluation Chart for Flexible Pavements

DISTRESS	SEVERITY
Raveling & Weathering: The wearing away of the pavement surface, due to dislodged aggregate particles and loss of asphalt binder. Normally the extent will be throughout the test section.	Low: (1) Aggregate or binder has starte pavement surface. Some dislo the shoulder. Med: (2) Aggregate or binder has worn rough and pitted. High: (3) Aggregate and/or binder has w texture is severely rough and p
Bleeding: A film of bituminous material on the pavement surface.	Low: (1) Film is evident, but aggregate Med: (2) Film is clearly seen, covers m a little sticky. High: (3) Film is predominant, very stic enough to shove.
Rutting and Shoving: Longitudinal surface depressions in wheel path. (Check with a 4-foot rut bar.)	Low: (1) ¼-inch to ½-inch in depth. Med: (2) ½-inch to 1-inch in depth. High: (3) More than 1-inch in depth.
Cracks: **Longitudinal Cracks:** Wheel Track Mid-Lane Center Line	Low: (1) Sealed or non-sealed with a m ¼-inch. May have very mino Med: (2) A. Sealed or non-sealed, and width. B. Sealed, but sealant separat C. Non-sealed cracks that are wide.

NMDOT's Distress Evaluation Chart for Rigid Pavements

DISTRESS	SEVERITY
Corner Break: Crack intersects joints at a distance less than 6 feet on either side, measured from the corner. Crack extends vertically through the entire slab thickness.	Low: Crac (1) No f Med: Crac (2) break inch. High: Cracl (3) into 2
Faulting of Transverse Joints and Cracks: Elevation difference across a transverse joint or crack.	Low: Fault (1) Med: Fault (2) but l High: Faul (3)
Joint Seal Damage: Any condition which allows incompressible materials or water to infiltrate the joint from the surface. Types of joint seal damage: (1. Joint sealant stripping. 2. Joint sealant extrusion. 3. Weed growth. 4. Hardening of filler. 5. Loss of bond to slab edges. 6. Joint sealant absence.)	Low: Seal (1) dama the j Med: Seal (2) of da some High: Seal (3) of da inco

APPENDIX C

Proposed Distress Evaluation Reference Chart for Flexible Pavements:
Criteria Set and Rater's Field Version

Flexible Pavement: Pavement Evaluation Reference Chart – NMDOT

DISTRESS	SEVERITY	EXTENT
Raveling & Weathering: The wearing away of the pavement surface, due to dislodged aggregate particles and loss of asphalt binder. Only highest severity level is reported. Normally the extent will be throughout the sample section.	(1) Low: Aggregate or binder has started to wear away on pavement surface. Some dislodged aggregate can be found on the shoulder. (2) Medium: Aggregate or binder has worn away. Surface texture is rough and pitted. (3) High: Aggregate and/or binder has worn away, and surface texture is severely rough and pitted.	(3) High: The highest severity present is assumed to occur throughout the section.
Bleeding: A film of bituminous material on the pavement surface.	(1) Low: Film is evident, but aggregate can still be seen. Spotty. (2) Medium: Film is clearly seen, covers most of the aggregate and is a little sticky. (3) High: Film is predominant, very sticky, and material is thick enough to shove.	(1) Low: 1% to 30% of sample section. (2) Medium: 31% to 60% of sample section. (3) High: 61% or more of sample section.
Transverse Cracks: Half width to full width transverse cracks (6ft or longer cracks).	(1) Low: Unsealed, mean width of less than ¼-inch. OR sealed with sealant in good condition, any width. May have very minor spalls. (2) Medium: Any crack with mean width greater than ¼-inch and less than ¾ inch. May have adjacent Low severity random cracks, some spalling. (3) High: Any crack wider than ¾ inch, may have adjacent moderate to high random cracking.	(1) Low: 1% to 30% of sample section. (2) Medium: 31% to 60% of sample section. (3) High: 61% or more of sample section.
Alligator Cracking (Fatigue Cracking): Pattern of interconnected cracks resembling chicken wire or alligator skin. Longitudinal cracks in the wheel path are rated as Low severity alligator cracking.	(1) Low: Hairline, disconnected cracks. 1/8-inch wide or less. No spalls. AND/OR a single longitudinal crack, any severity, in the wheel path. (2) Medium: Fully developed cracks wider than 1/8-inch, lightly spalled. (3) High: Severely spalled, cells rock, and may pump.	(1) Low: 1% to 30% of sample section. (2) Medium: 31% to 60% of sample section. (3) High: 61% or more of sample section.
Longitudinal Cracks: Any longitudinal crack outside the wheel path, including 1 ft width on either side of the edge stripe.	(1) Low: Unsealed, average width of less than ¼-inch. OR sealed with sealant in good condition, any width. May have very minor spalls. (2) Medium: Any crack with average width greater than ¼-inch and less than ¾ inch. May have adjacent Low severity random cracks and some spalling. (3) High: Any crack wider than ¾ inch, may have adjacent moderate to high random cracking and spalling.	(1) Low: 1% to 30% of sample section. (2) Medium: 31% to 60% of sample section. (3) High: 61% or more of sample section.

Flexible Pavement: Pavement Evaluation Reference Chart – Rater Version

DISTRESS	SEVERITY	NOTES
Raveling & Weathering: The wearing away of the pavement surface, due to dislodged aggregate particles and loss of asphalt binder. Rate the HIGHEST severity level only. Normally the extent will be throughout the sample section.	(1) Low: Aggregate or binder has started to wear away on pavement surface. Some dislodged aggregate can be found on the shoulder. (2) Medium: Aggregate or binder has worn away. Surface texture is rough and pitted. (3) High: Aggregate and/or binder has worn away, and surface texture is severely rough and pitted.	Mark HIGHEST severity present
Bleeding: A film of bituminous material on the pavement surface, from the asphalt concrete mix and not from the vehicles or external sources. The extent will usually be Low (1).	(1) Low: Film is evident, but aggregate can still be seen. Spotty. (2) Medium: Film is clearly seen, covers most of the aggregate and is a little sticky. (3) High: Film is predominant, very sticky, and material is thick enough to shove.	Mark EACH severity present.
Transverse Cracks: Half-width lane to full-width lane transverse cracks (6ft or longer cracks). Disregard cracks shorter than 6 ft.	(1) Low: Unsealed, mean width of less than ¼-inch. OR sealed with sealant in good condition, any width. May have very minor spalls. (2) Medium: Any crack with mean width greater ¼-inch and less than ¾ inch. May have adjacent Low severity random cracks, some spalling. (3) High: Any crack wider than ¾ inch, may have adjacent moderate to high random cracking.	COUNT the number of cracks of EACH severity within sample section. Include half-width lane and longer cracks. Record the totals of each severity on field form.
Alligator Cracks: Pattern of interconnected cracks resembling chicken wire or alligator skin. Longitudinal cracks in the wheel path are rated as Low severity alligator cracking. Severities 2 and 3 must have at least 3 cells.	(1) Low: Hairline, disconnected cracks, 1/8-inch wide or less, less than 3 cells. No spalls. AND/OR a longitudinal crack, any severity, in the wheel path. (2) Medium: Fully developed cracks greater than 1/8-inch wide. Three or more cells. Lightly spalled. (3) High: Severely spalled, cells rock, and may pump. Three or more cells.	PACE OFF the cumulative lengths of EACH severity present. Do not double count long. cracks in wheel path and alligator cracking. Record lengths (in paces). Mark location of occurrence in field form: 1 or 2 wheel paths.
Longitudinal Cracks ANY longitudinal crack NOT in the wheel path, including 1 ft width on either side of the edge stripe.	(1) Low: Unsealed, mean width of less than ¼-inch. OR sealed with sealant in good condition, any width. May have very minor spalls. (2) Medium: Any crack with average width greater than ¼-inch and less than ¾ inch. May have adjacent Low severity random cracks and some spalling. (3) High: Any crack wider than ¾ inch, may have adjacent moderate to high random cracking and spalling.	(1) Low: 1% to 30% of sample section. (2) Medium: 31% to 60% of sample section. (3) High: 61% or more of sample section.

<u>10% Rule</u>: If 10% or more of the crack shows a higher severity, use this higher severity to rate the crack.

APPENDIX D

Field Forms for Flexible and Rigid Pavements

Field Form for Flexible Pavements

New Mexico Department of Transportation		**Rater's Pace (ft):**			
Distress Rating of Flexible Pavements - Field Form		**Route:**			
Sample Section Milepost:		**Direction:**		P	M
Raveling & Weathering Circle h**ighest** severity present		0	1	2	3
Bleeding Circle a**ll** severity levels present		0	1	2	3
Alligator Cracking	**Severity**	**Paces (1 or 2) [Example: 43 (2)]**			
Single crack in wheel path is severity 1. Mark severity 0 if section has no alligator cracking	0				
Crack length is in number of paces. Indicate if 1 or 2 wheel paths in parenthesis.	1				
	2				
	3				
Transverse Cracking	**Severity**	**Crack Counts**			**Total Counts**
(Crack **6 ft or longer** is counted)	0				
Count all cracks present. Mark severity 0 if section has no transverse cracks.	1				
	2				
	3				
Longitudinal Cracking	**Severity**	**Extent**			
(Cracks outside the wheel path are counted)	0	0			
Estimate % area affected for EACH severity	1	0	1	2	3
and circle the extent rating. Mark severity and	2	0	1	2	3
extent 0 if section has no longitudinal cracks.	3	0	1	2	3

Remarks:____

Date: ________________ Rater's name:________________

Field Form for Flexible Pavements

New Mexico Department of Transportation
Distress Rating of Rigid Pavements - Field Form

Route:			
Sample Section Milepost:	Direction:	P	M
	Severity	Extent	
Corner Break	0		
	1		
	2		
	3		
Faulting of Transverse Joints and Cracks	0		
	1		
	2		
	3		
Joint Seal Damage	0		
	1		
	2		
	3		
Lane/Shoulder Drop-Off or Heave	0		
	1		
	2		
	3		
Longitudinal Cracks	0		
	1		
	2		
	3		
Patch Deterioration	0		
	1		
	2		
	3		
Spalling of Transverse and Longitudinal Joints	0		
	1		
	2		
	3		
Transverse and Diagonal Cracks	0		
	1		
	2		
	3		
Cracking %	# Slabs	Cracked	%
(Pecent cracked slabs)			

Remarks:____

Date: __________________ Rater's name:__________________

APPENDIX E

NMDOT District Survey and Responses

NMDOT DISTRICT SURVEY INSTRUMENT AND RESPONSES

QUESTIONNAIRE - INTRODUCTION

An NMSU and UNM research team has been tasked with revising and improving the NMDOT's Annual Distress Evaluation protocol and distress rating criteria for NMDOT. As part of this work, the research team is interested in learning how the distress ratings collected by NMDOT at the network level are used or could be used by the Districts for their annual maintenance planning and decision making process. This questionnaire will focus on distresses in flexible pavements in your District and your maintenance practices.

If you have questions about this questionnaire or the use of the answers provided, please contact the principal investigators:

Dr. Paola Bandini, Associate Professor, NMSU, paola@nmsu.edu, 575-646-2471
Dr. Susan Bogus Halter, Associate Professor, UNM, sbogus@unm.edu, 505-277-1395

QUESTIONNAIRE

1) How familiar are you with the distress evaluation procedures and criteria for distress ratings (severity and extent) of NMDOT? (Check one)

( ) I am very familiar with the procedures and criteria
( ) I am somewhat familiar with the procedures and criteria
( ) I am NOT familiar with the procedures and criteria

2) Do you have access to (or do you receive) the distress ratings (severity and extent) and PSI collected annually in your District? (PSI is the NMDOT's Pavement Serviceability Index, given by a number between 0 to 5)

( ) Yes I have received the data in the past, but it has been quite some time since I received updated info.
( ) No

If the answer is YES, go to question 4.

3) Are you (or your District) interested in having access to this information in the future for use in your maintenance planning?

( ) Yes
( ) No

4) Do you use the distress ratings (severity and extent) and PSI data in any way in your District?

( ) Yes
( ) No

If YES, please explain in detail how you (or your District) use network-level PSI and distress ratings.
If NOT, please explain why you (or your District) do not use the PSI and distress ratings.

5) Regardless of whether you use the data or not, rate these distress types (for flexible pavements) depending on how well they serve as indicators of the pavement condition and serviceability.

(Pavement Condition/Serviceability as used here refers to the structural capacity of the pavement to carry traffic load)

Rating = 1: Distress type is an excellent indicator of the pavement condition/serviceability
Rating = 2: Distress type is a good indicator of the pavement condition/serviceability
Rating = 3: Distress type has some relationship with the pavement condition/serviceability
Rating = 4: Distress type is NOT a good indicator of the pavement condition/serviceability

Note: Descriptions of the distresses are provided at the end of the questionnaire.

( ) Raveling and Weathering
( ) Bleeding
( ) Rutting and Shoving
( ) Alligator Cracking (or Fatigue Cracking)
( ) Transverse Cracking
( ) Edge Cracking

6) For your District's maintenance planning and budgeting (project level), which pavement condition data do you use? Cracking, rutting and shoving, alligator cracking, raveling and weathering.

7) Do your District personnel collect pavement condition data for your maintenance planning/decisions?

( ) Yes
( ) No

If YES, please provide details about type of data, frequency of collection, locations, etc.

8) List the criteria you use to determine which routes or projects require maintenance (Most important = 1)

( ) ____
( ) ____
( ) ____
( ) ____

9) How do you obtain the information/data used to determine the routes or projects that require/will receive maintenance? (Check all those that apply):

( ) Weekly/monthly reports of my maintenance crews.
( ) My own observations when I travel throughout the District.
( ) I send my personnel to inspect sections/projects and they report the condition to me.
( ) Distress ratings and PSI data collected annually by NMDOT.
( ) Roughness (IRI) data collected annually by NMDOT.
( ) Other (write in): ________________________________
( ) Other (write in): ________________________________

10) How do you deal with the maintenance of pavements that show signs of "Bleeding" in your District? (Check all those that apply):

( ) We do not schedule treatment based on bleeding alone.
( ) We give priority to bleeding and schedule a treatment on the whole project.
( ) We give priority to bleeding and schedule a treatment only on the spots that show bleeding.
( ) We look at the severity of bleeding and decide if treatment is a priority.
( ) We look at the percentage of the mile or section with bleeding and decide if treatment is a priority.
( ) We schedule treatment only if bleeding affects most of the section.
( ) We schedule treatment only if bleeding affects several miles of the route.
( ) Other (write in): ________________________________
( ) Other (write in): ________________________________

11) What information would be useful to you and your maintenance crews regarding sections in your District that show signs of "Raveling and Weathering"? (Check all those that apply):

( ) Percent of each sample section (1/10 mile long) that shows the highest severity level.
( ) Percent of each sample section (1/10 mile long) that show high, medium and low severity levels.
( ) Percent of each sample section (1/10 mile long) that show high and medium severity levels.
( ) Where the high severity "raveling and weathering" spots are located so we can repair them.
( ) Data is only useful if available for the complete mile, not just at 1/10 mile intervals.
( ) Information about raveling and weathering is not really useful to us. We don't need it.
( ) Other (write in): ________________________________
( ) Other (write in): ________________________________

12) Do you recommend us to discuss these questions with another person in your District? (Provide contact information and position)

13) Is there anything else you would like to add?

Please provide your contact information below:
Name of person interviewed or responding:
Position:
District:

Address:
Email:
Phone:
Date:

If you have questions about this questionnaire or the use of the answers provided, please contact the principal investigators:

Dr. Paola Bandini, Associate Professor, NMSU, paola@nmsu.edu, 575-646-2471
Dr. Susan Bogus Halter, Associate Professor, UNM, sbogus@unm.edu, 505-277-1395

Distress definitions:

Raveling and Weathering: The wearing away of the pavement surface due to dislodged aggregate particles and loss of asphalt binder.

Bleeding: A film of bituminous material or asphalt binder on the pavement surface. It usually creates a shiny, glass-like reflecting surface.

Rutting and Shoving: Longitudinal surface depressions along wheel paths (Checked with a 4-foot rut bar or determined using a profiler).

Alligator Cracking (or Fatigue Cracking): Pattern of interconnected cracks resembling chicken wire or alligator skin. Longitudinal cracks (parallel to the pavement’s centerline) frequently appear in the onset of fatigue cracking.

Transverse Cracking (Thermal Cracking): Cracks perpendicular to the pavement's centerline.

Edge Cracking: Cracks that run along the pavement edge, within about 1 ft on both side of the edge stripe.

DISTRICT RESPONSES

Response from District 1

1) How familiar are you with the distress evaluation procedures and criteria for distress ratings (severity and extent) of NMDOT? (Check one)

(X) I am very familiar with the procedures and criteria
( ) I am somewhat familiar with the procedures and criteria
( ) I am NOT familiar with the procedures and criteria

2) Do you have access to (or do you receive) the distress ratings (severity and extent) and PSI collected annually in your District? (PSI is the NMDOT's Pavement Serviceability Index, given by a number between 0 to 5)

(X) Yes
( ) No
If the answer is YES, go to question 4.

3) Are you (or your District) interested in having access to this information in the future for use in your maintenance planning?

(X) Yes
( ) No

4) Do you use the distress ratings (severity and extent) and PSI data in any way in your District?
(X) Yes
( ) No

If YES, please explain in detail how you (or your District) use network-level PSI and distress ratings.
I will physically review all roadways with an inadequate PSI

If NOT, please explain why you (or your District) do not use the PSI and distress ratings.

5) Regardless of whether you use the data or not, rate these distress types (for flexible pavements) depending on how well they serve as indicators of the pavement condition and serviceability. (Pavement Condition/Serviceability as used here refers to the structural capacity of the pavement to carry traffic load)

(1) Raveling and Weathering
(1) Bleeding
(1) Rutting and Shoving
(1) Alligator Cracking (or Fatigue Cracking)
(4) Transverse Cracking
(4) Edge Cracking

6) For your District's maintenance planning and budgeting (project level), which pavement condition data do you use?

Raveling and Weathering
Rutting and Shoving
Alligator Cracking (or Fatigue Cracking)

7) Do your District personnel collect pavement condition data for your maintenance planning/decisions?

(X) Yes
( ) No
If YES, please provide details about type of data, frequency of collection, locations, etc.
Age of the Pavement and the distresses.

8) List the criteria you use to determine which routes or projects require maintenance (Most important = 1)

( ) _Route Priority____
( ) _Age____
( ) _Distress____
( ) ____

9) How do you obtain the information/data used to determine the routes or projects that require/will receive maintenance? (Check all those that apply):

( ) Weekly/monthly reports of my maintenance crews.
(X) My own observations when I travel throughout the District.
( ) I send my personnel to inspect sections/projects and they report the condition to me.
( ) Distress ratings and PSI data collected annually by NMDOT.
( ) Roughness (IRI) data collected annually by NMDOT.
(X) Other (write in): _*Budget*____________________________
( ) Other (write in): ______________________________

10) How do you deal with the maintenance of pavements that show signs of "Bleeding" in your District (Check all those that apply):

(X) We do not schedule treatment based on bleeding alone.
( ) We give priority to bleeding and schedule a treatment on the whole project.
( ) We give priority to bleeding and schedule a treatment only on the spots that show bleeding.
( ) We look at the severity of bleeding and decide if treatment is a priority.
( ) We look at the percentage of the mile or section with bleeding and decide if treatment is a priority.
( ) We schedule treatment only if bleeding affects most of the section.
( ) We schedule treatment only if bleeding affects several miles of the route.
( ) Other (write in): ______________________________
( ) Other (write in): ______________________________

11) What information would be useful to you and your maintenance crews regarding sections in your District that show signs of “Raveling and Weathering” (Check all those that apply):

(   ) Percent of each sample section (1/10 mile long) that shows the highest severity level.
(   ) Percent of each sample section (1/10 mile long) that show high, medium and low severity levels.
(   ) Percent of each sample section (1/10 mile long) that show high and medium severity levels.
(   ) Where the high severity “raveling and weathering” spots are located so we can repair them.
(   ) Data is only useful if available for the complete mile, not just at 1/10 mile intervals.
(   ) Information about raveling and weathering is not really useful to us. We don’t need it.
(   ) Other (write in): _*don’t understand this*_______________________________
(   ) Other (write in): ________________________________

12) Do you recommend us to discuss these questions with another person in your District? (Provide contact information and position)
No

13) Is there anything else you would like to add?
A lot of the roads in NM have out lived their pavement design life and continue to get rehabbed in order to extend the life.

Please provide your contact information below:
Name of person interviewed or responding:
Position: Maintenance Engineer
District: 2
Address: 4505 W. Second Roswell, NM
Email: Ralph.meeks@state.nm.us
Phone: 575-737-7231
Date: 12/20/2010

Response from District 3

1) How familiar are you with the distress evaluation procedures and criteria for distress ratings (severity and extent) of NMDOT? (Check one)

(X) I am somewhat familiar with the procedures and criteria
(   ) I am NOT familiar with the procedures and criteria

2) Do you have access to (or do you receive) the distress ratings (severity and extent) and PSI collected annually in your District? (PSI is the NMDOT’s Pavement Serviceability Index, given by a number between 0 to 5)

(   ) Yes
(X) No

If the answer is YES, go to question 4.

3) Are you (or your District) interested in having access to this information in the future for use in your maintenance planning?

(X) Yes
(   ) No

4) Do you use the distress ratings (severity and extent) and PSI data in any way in your District?

(   ) Yes
(X) No

If YES, please explain in detail how you (or your District) use network-level PSI and distress ratings.
If NOT, please explain why you (or your District) do not use the PSI and distress ratings.

The District conducts its own field evaluations on the conditions of its roadways and the extent of the distresses. In the past we have noticed that our evaluations differ from the evaluations that were conducted by the University. There are also question on the formula that is being used to calculate the PSI.

5) Regardless of whether you use the data or not, rate these distress types (for flexible pavements) depending on how well they serve as indicators of the pavement condition and serviceability. (Pavement Condition/Serviceability as used here refers to the structural capacity of the pavement to carry traffic load)

(4) Raveling and Weathering
(3) Bleeding
(1) Rutting and Shoving
(1) Alligator Cracking (or Fatigue Cracking)
(4) Transverse Cracking
(3) Edge Cracking

6) For your District's maintenance planning and budgeting (project level), which pavement condition data do you use?

Data collected by the district which includes evaluates of pavements and their distresses; whether they are load related or environment related. Also historical information like age of pavement and last pavement preservation process that was done.

7) Do your District personnel collect pavement condition data for your maintenance planning/decisions?

(X) Yes
(   ) No

If YES, please provide details about type of data, frequency of collection, locations, etc.

Pavement evaluations are done on a yearly basis and data is stored on the districts data base. Information that is collected includes pavement distresses including environmental cracking, raveling, rutting, bleeding, pumping and fatigue cracking. Drainage issues are also looked at.

8) List the criteria you use to determine which routes or projects require maintenance (Most important = 1)

(1) _*Condition of the roadway determines which pavement preservation process is needed.*

(2) __*Priority and use of the roadway.* ________________

(3) _*Available funding.*_____________________________

(   ) __*Request and complaints from the public and or others*__

9) How do you obtain the information/data used to determine the routes or projects that require/will receive maintenance? (Check all those that apply):

(X) Weekly/monthly reports of my maintenance crews.
(X) My own observations when I travel throughout the District.
(X) I send my personnel to inspect sections/projects and they report the condition to me.
(   ) Distress ratings and PSI data collected annually by NMDOT.
(   ) Roughness (IRI) data collected annually by NMDOT.
(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

10) How do you deal with the maintenance of pavements that show signs of "Bleeding" in your District (Check all those that apply):

(   ) We do not schedule treatment based on bleeding alone.
(   ) We give priority to bleeding and schedule a treatment on the whole project
(   ) We give priority to bleeding and schedule a treatment only on the spots that show bleeding
(X) We look at the severity of bleeding and decide if treatment is a priority
(X) We look at the percentage of the mile or section with bleeding and decide if treatment is a priority
(   ) We schedule treatment only if bleeding affects most of the section
(   ) We schedule treatment only if bleeding affects several miles of the route
(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

11) What information would be useful to you and your maintenance crews regarding sections in your District that show signs of "Raveling and Weathering" (Check all those that apply):

(   ) Percent of each sample section (1/10 mile long) that shows the highest severity level.
(X) Percent of each sample section (1/10 mile long) that show high, medium and low severity levels.
(   ) Percent of each sample section (1/10 mile long) that show high and medium severity levels.
(X) Where the high severity "raveling and weathering" spots are located so we can repair them.
(   ) Data is only useful if available for the complete mile, not just at 1/10 mile intervals.
(   ) Information about raveling and weathering is not really useful to us. We don't need it.
(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

12) Do you recommend us to discuss these questions with another person in your District? (Provide contact information and position)

13) Is there anything else you would like to add?

Please provide your contact information below:
Name of person interviewed or responding:
Position: Maintenance Technical Engineer
District: D3
Address: 7500 Pan American Freeway N.E. Albuquerque NM, 87199
Email: Mike.Vigil@state.nm.us
Phone: (505) 553-2882
Date: 12/20/2010

Response from District 4

With two responses that we have identified them as 4A and 4B.

Response 4A:

1) How familiar are you with the distress evaluation procedures and criteria for distress ratings (severity and extent) of NMDOT? (Check one)

(X) I am very familiar with the procedures and criteria
(   ) I am somewhat familiar with the procedures and criteria
(   ) I am NOT familiar with the procedures and criteria

2) Do you have access to (or do you receive) the distress ratings (severity and extent) and PSI collected annually in your District? (PSI is the NMDOT's Pavement Serviceability Index, given by a number between 0 to 5)

(X) Yes
(   ) No
If the answer is YES, skip question 3.

3) Are you (or your District) interested in having access to this information in the future for use in your maintenance planning?

(   ) Yes
(   ) No

4) Do you use the distress ratings (severity and extent) and PSI data in any way in your District?

(X) Yes
(   ) No

If YES, please explain in detail how you (or your District) use network-level PSI and distress ratings.

To identify and prioritize future projects

If NOT, please explain why you (or your District) do not use the PSI and distress ratings.

5) Regardless of whether you use the data or not, rate these distress types (for flexible pavements) depending on how well they serve as indicators of the pavement condition and serviceability. (Pavement Condition/Serviceability as used here refers to the structural capacity of the pavement to carry traffic loads)

(3) Raveling and Weathering
(4) Bleeding
(3) Rutting and Shoving
(2) Alligator Cracking (or Fatigue Cracking)
(2) Transverse Cracking
(3) Edge Cracking

6) For your District's maintenance planning and budgeting (project level), which pavement condition data do you use? All of them

7) Do your District personnel collect pavement condition data for your maintenance planning/decisions?

(X) Yes
(   ) No

If YES, please provide details about type of data, frequency of collection, locations, etc.

Types of cracking, annually if possible, and only on US and Interstate routes

8) Rank the criteria you use to determine which routes or projects require maintenance (Most important = 1)

(1) __*route type (interstate, US routes, etc)*____________________
(2) ___*history of last work performed on roadway*____________
(3) ____*severity of distress*_______________________

(4) ____*type of distress*____________________________

9) How do you obtain the information/data used to determine the routes or projects that require/will receive maintenance? (Check all those that apply):

(X) Weekly/monthly reports of my maintenance crews.
(X) My own observations when I travel throughout the District.
(X) I send my personnel to inspect sections/projects and they report the condition to me.
(X) Distress ratings and PSI data collected annually by NMDOT.
(X) Roughness (IRI) data collected annually by NMDOT.
(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

10) How do you deal with the maintenance of pavements that show signs of "Bleeding" in your District (Check all those that apply):

(   ) We do not schedule treatment based on bleeding alone.
(   ) We give priority to bleeding and schedule a treatment on the whole project.
(   ) We give priority to bleeding and schedule a treatment only on the spots that show bleeding.
(X) We look at the severity of bleeding and decide if treatment is a priority.
(   ) We look at the percentage of the mile or section with bleeding and decide if treatment is a priority.
(   ) We schedule treatment only if bleeding affects most of the section.
(   ) We schedule treatment only if bleeding affects several miles of the route.
(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

11) What information would be useful to you and your maintenance crews regarding sections in your District that show signs of "Raveling and Weathering" (Check all those that apply):

(   ) Percent of each sample section (1/10 mile long) that shows the highest severity level.
(   ) Percent of each sample section (1/10 mile long) that show high, medium and low severity levels.
(   ) Percent of each sample section (1/10 mile long) that show high and medium severity levels.
(   ) Where the high severity "raveling and weathering" spots are located so we can repair them.
(X) Data is only useful if available for the complete mile, not just at 1/10 mile intervals.
(   ) Information about raveling and weathering is not really useful to us. We don't need it.
(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

12) Do you recommend us to discuss these questions with another person in your District? (Provide contact information and position)

13) Is there anything else you would like to add?

Please provide your contact information below:
Name of person interviewed or responding:
Position: Assistant District Engineer

District: four
Address: PO Box 10, Las Vegas, NM 87701
Email: abel.esquibel@state.nm.us
Phone: 505-454-3610
Date: February 10, 2011

Response 4B:

1) How familiar are you with the distress evaluation procedures and criteria for distress ratings (severity and extent) of NMDOT? (Check one)

( ) I am very familiar with the procedures and criteria
(X) I am somewhat familiar with the procedures and criteria
( ) I am NOT familiar with the procedures and criteria

2) Do you have access to (or do you receive) the distress ratings (severity and extent) and PSI collected annually in your District? (PSI is the NMDOT's Pavement Serviceability Index, given by a number between 0 to 5)

(X) Yes I have received the data in the past, but it has been quite some time since I received updated info.
( ) No
If the answer is YES, go to question 4.

3) Are you (or your District) interested in having access to this information in the future for use in your maintenance planning?

( ) Yes
( ) No

4) Do you use the distress ratings (severity and extent) and PSI data in any way in your District?

(X) Yes
( ) No

If YES, please explain in detail how you (or your District) use network-level PSI and distress ratings.

Information is used to help determine project locations, determine proposed project scope of work; and prioritize projects.

If NOT, please explain why you (or your District) do not use the PSI and distress ratings.

5) Regardless of whether you use the data or not, rate these distress types (for flexible pavements) depending on how well they serve as indicators of the pavement condition and

serviceability. (Pavement Condition/Serviceability as used here refers to the structural capacity of the pavement to carry traffic load)

(2) Raveling and Weathering
(3) Bleeding
(1) Rutting and Shoving
(1) Alligator Cracking (or Fatigue Cracking)
(2) Transverse Cracking
(3) Edge Cracking

6) For your District's maintenance planning and budgeting (project level), which pavement condition data do you use? Cracking, rutting/shoving, alligator cracking, raveling

Raveling, cracking, alligator cracking, rutting and shoving

7) Do your District personnel collect pavement condition data for your maintenance planning/decisions?

( ) Yes
(X) No Other than visual inspection, no data is collected.

If YES, please provide details about type of data, frequency of collection, locations, etc.

8) List the criteria you use to determine which routes or projects require maintenance (Most important = 1)

(1) _*Roadway/Pavement Condition*___________
(3) __*Traffic Volume & % Heavy Commercial* ____
(3) __*Roadway Function/Classification*________
(2) __*Past Knowledge and Performance of Roadway and how quickly the roadway is deteriorating*

9) How do you obtain the information/data used to determine the routes or projects that require/will receive maintenance? (Check all those that apply):

(X) Weekly/monthly reports of my maintenance crews.
(X) My own observations when I travel throughout the District.
(X) I send my personnel to inspect sections/projects and they report the condition to me.
(X) Distress ratings and PSI data collected annually by NMDOT.
(X) Roughness (IRI) data collected annually by NMDOT.
(X) Other (write in): _*Past Knowledge/performance of roadway*_____
( ) Other (write in): ________________________________

10) How do you deal with the maintenance of pavements that show signs of "Bleeding" in your District (Check all those that apply):

( ) We do not schedule treatment based on bleeding alone.
( ) We give priority to bleeding and schedule a treatment on the whole project
( ) We give priority to bleeding and schedule a treatment only on the spots that show bleeding
(X) We look at the severity of bleeding and decide if treatment is a priority
( ) We look at the percentage of the mile or section with bleeding and decide if treatment is a priority
( ) We schedule treatment only if bleeding affects most of the section
( ) We schedule treatment only if bleeding affects several miles of the route
( ) Other (write in): ________________________________
( ) Other (write in): ________________________________

11) What information would be useful to you and your maintenance crews regarding sections in your District that show signs of "Raveling and Weathering" (Check all those that apply):

( ) Percent of each sample section (1/10 mile long) that shows the highest severity level.
(X) Percent of each sample section (1/10 mile long) that show high, medium and low severity levels.
( ) Percent of each sample section (1/10 mile long) that show high and medium severity levels.
(X) Where the high severity "raveling and weathering" spots are located so we can repair them.
( ) Data is only useful if available for the complete mile, not just at 1/10 mile intervals.
( ) Information about raveling and weathering is not really useful to us. We don't need it.
( ) Other (write in): ________________________________
( ) Other (write in): ________________________________

12) Do you recommend us to discuss these questions with another person in your District? (Provide contact information and position)
Not at this time

13) Is there anything else you would like to add?
Not at this time

Please provide your contact information below:
Name of person interviewed or responding:
Position: Assistant District Four Engineer - Maintenance
District: District 4
Address: P.O. Box 10 Las Vegas, NM 87701
Email: heather.sandoval@state.nm.us
Phone: 505-454-3663
Date: 6/6/11

Response from District 6

1) How familiar are you with the distress evaluation procedures and criteria for distress ratings (severity and extent) of NMDOT? (Check one)

(X) I am very familiar with the procedures and criteria
(   ) I am somewhat familiar with the procedures and criteria
(   ) I am NOT familiar with the procedures and criteria

2) Do you have access to (or do you receive) the distress ratings (severity and extent) and PSI collected annually in your District? (PSI is the NMDOT's Pavement Serviceability Index, given by a number between 0 to 5)

(X) Yes
(   ) No
If the answer is YES, go to question 4.

3) Are you (or your District) interested in having access to this information in the future for use in your maintenance planning?

(   ) Yes
(   ) No

4) Do you use the distress ratings (severity and extent) and PSI data in any way in your District?

(   ) Yes
(X) No

If YES, please explain in detail how you (or your District) use network-level PSI and distress ratings.

If NOT, please explain why you (or your District) do not use the PSI and distress ratings.

I used these ratings when I was in Technical Support at the District level to further justify road work projects that were planned and needed funding. For Maintenance, I feel that these ratings do not correlate to the actual condition of the roadways. Only a fraction of the roadway is reviewed and the way it is weighted for PSI calculation skews the data which does not provide an accurate overview of the corridor.

In addition, I would not be able to fund all work that would be required. These numbers should also be able to assist me with prioritizing work.

5) Regardless of whether you use the data or not, rate these distress types (for flexible pavements) depending on how well they serve as indicators of the pavement condition and serviceability. (Pavement Condition/Serviceability as used here refers to the structural capacity of the pavement to carry traffic load)

(2) Raveling and Weathering
(4) Bleeding
(2) Rutting and Shoving
(2) Alligator Cracking (or Fatigue Cracking)

(2) Transverse Cracking
(3) Edge Cracking

6) For your District's maintenance planning and budgeting (project level), which pavement condition data do you use?

Not sure if you mean distress data? If so, all those that were rated "2".

7) Do your District personnel collect pavement condition data for your maintenance planning/decisions?

( ) Yes
(X) No

If YES, please provide details about type of data, frequency of collection, locations, etc.

8) List the criteria you use to determine which routes or projects require maintenance (Most important = 1)

(1) Budget Constraints
(2) Roadway Priority
(3) Severity of distress
(4) Magnitude of distress

9) How do you obtain the information/data used to determine the routes or projects that require/will receive maintenance? (Check all those that apply):

( ) Weekly/monthly reports of my maintenance crews.
(X) My own observations when I travel throughout the District.
( ) I send my personnel to inspect sections/projects and they report the condition to me.
( ) Distress ratings and PSI data collected annually by NMDOT.
( ) Roughness (IRI) data collected annually by NMDOT.
(X) Other (write in): *Observations of Maintenance personnel during routine road patrol.*
( ) Other (write in): ________________

10) How do you deal with the maintenance of pavements that show signs of "Bleeding" in your District (Check all those that apply):

(X) We do not schedule treatment based on bleeding alone.
( ) We give priority to bleeding and schedule a treatment on the whole project
( ) We give priority to bleeding and schedule a treatment only on the spots that show bleeding
( ) We look at the severity of bleeding and decide if treatment is a priority
( ) We look at the percentage of the mile or section with bleeding and decide if treatment is a priority
( ) We schedule treatment only if bleeding affects most of the section
( ) We schedule treatment only if bleeding affects several miles of the route

(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

11) What information would be useful to you and your maintenance crews regarding sections in your District that show signs of “Raveling and Weathering” (Check all those that apply):

(   ) Percent of each sample section (1/10 mile long) that shows the highest severity level.
(   ) Percent of each sample section (1/10 mile long) that show high, medium and low severity levels.
(   ) Percent of each sample section (1/10 mile long) that show high and medium severity levels.
(X) Where the high severity “raveling and weathering” spots are located so we can repair them.
(X) Data is only useful if available for the complete mile, not just at 1/10 mile intervals.
(   ) Information about raveling and weathering is not really useful to us. We don’t need it.
(   ) Other (write in): ________________________________
(   ) Other (write in): ________________________________

12) Do you recommend us to discuss these questions with another person in your District? (Provide contact information and position)

13) Is there anything else you would like to add?

The collection of the distress data is subjective which adds to the difficulty of depending on this data alone for developing a maintenance plan. Therefore, even if the methods are improved, we will continue to use our observations to develop projects.

Please provide your contact information below:
Name of person interviewed or responding: Lisa Boyd Vega
Position: Assistant District Engineer - Maintenance
District: District 6
Address: PO Box 2160 Milan, NM 87021
Email: lisa.vega@state.nm.us
Phone: (505) 285-3234
Date: January 11, 2011

APPENDIX F

Responses of State DOTs Survey

Agency	**Q1: Is your agency currently providing data for HPMS?**	**Q2: Which HPMS version is your agency reporting in this year?**
Alabama DOT	Yes, but for state roads only	New system
Alaska DOT	No response	
Arizona DOT	Yes	New system
Arkansas DOT	Yes	
California DOT	No response	
Colorado DOT	Yes	New system
Connecticut DOT	Yes	We reported in the old system, not everyone was ready to go with the new version yet.
Delaware DOT	Yes	Old system, haven't added new items yet
District of Columbia DOT	Yes	Old system. We are putting out an RFP for development of software and a database for being able to report in the new
Florida DOT	Yes	We are reporting in the new system, but some data items have to be reported as default values. We don't have the resources available to include things like pavement thicknesses, and some of the locations HPMS wants are
Georgia DOT	Yes	Georgia DOT's official 2010 HPMS submission is in the "old" hpms format which does not contain these items. [50—53] However, we are in the process of working to gather and report these items in the future from available state resources
Hawaii DOT	No response	
Idaho DOT	Yes	Old system, we are in the process of converting.
Illinois DOT	Yes	Old system
Indiana DOT	Yes	Old system
Iowa DOT	Yes	
Kansas DOT	Yes, historically we provided IRI but now we include HPMS data.	
Kentucky KYTC	No response	
Louisiana DOT	Yes	Old system, we're not sure how to report it in the new version yet, not too comfortable with it.
Maine DOT	No response	
Maryland DOT	No response	
Massachusetts DOT	No response	
Michigan DOT	No. We have been gearing up to provide the data for 2010 reporting.	Given delays in the new HPMS reporting software, we will probably be doing trial submittal after the software is available to make sure we're ready for next year.

Agency	**Q1: Is your agency currently providing data for HPMS?**	**Q2: Which HPMS version is your agency reporting in this year?**
Minnesota DOT	Yes	
Mississippi DOT	Yes	Old system
Missouri DOT	No response	
Montana DOT	Yes	Old system
Nebraska DOR	Yes	Old system
Nevada DOT	Yes	Old system
New Hampshire DOT	No response	
New Jersey DOT	No response	
New Mexico DOT	Yes	On June 15, 2010, NMDOT submitted their annual HPMS report to the FHWA Office of Highway Policy Information in HPMS Version 6. That, however, was the last time that NMDOT will do so. Next year NMDOT will submit their
New York State DOT	No response	
North Carolina DOT	Yes	New system
North Dakota DOT	Yes	Old system
Ohio DOT	No response	
Oklahoma DOT	Yes - the surface condition items.	New system
Oregon DOT	Yes	
Pennsylvania DOT	Specifically related to pavements, yes some of the condition data (including IRI) that is collected through our videologging contract is used by our Bureau of Planning and Research (BPR) for HPMS reporting.	The BPR is reporting under the new HPMS requirements but we have not changed how we collect or report pavement condition data for this requirement.
Rhode Island DOT	Yes	New system
South Carolina DOT	No response	
South Dakota DOT	Yes	New system
Tennessee DOT	No response	
Texas DOT	Yes	New system
Utah DOT	Yes	Old system
Vermont DOT	Yes	Old system this year, we don't have enough information
Virginia DOT	Yes	This year we will provide two submissions 1)Official Submission: This will be the old HPMS submission format, 2) Test Submission: This will be an attempt at the new
Washington DOT	Yes	Old system
West Virginia DOT	Yes	Old system
Wisconsin DOT	Yes	New system
Wyoming DOT	Yes, just IRI data and pavement type.	Old system - routes are not finished yet.

Agency	Q3: Does your agency collect data specifically for and according to HPMS guidelines?
Alabama DOT	No. We collect data for our state PMS. We changed procedure and what we collected because we switched to an automated system.
Alaska DOT	No response
Arizona DOT	Yes.
Arkansas DOT	We try to get as close as possible.
California DOT	No response
Colorado DOT	Yes. We changed our collection methods back when HPMS first started. There are some data items that we would not normally collect for our own purposes that we collect for HPMS.
Connecticut DOT	Not specifically. We collect data on the entire network every year. We retrieve HPMS items by querying the network survey.
Delaware DOT	Yes, but we are having section size issues.
District of Columbia DOT	Yes.
Florida DOT	We follow their guidelines as close as we can. Since we have a larger scope this year, we aren't reporting it in every location yet. We also have not started collecting cracking length data. In the past, we have never collected it because we don't have freeze/thaw conditions or similar issues that warranted us to collect data on this type of cracking.
Georgia DOT	At this time we will be using our State's pavement management databases to report these items for samples on our State Route Network. GDOT has 2 different systems for managing and maintaining information regarding the conditions of the pavement on our state owned roads. 1 is for Asphalt pavements and the other for Concrete. We will leverage the information contained and reported in these databases.
Hawaii DOT	No response
Idaho DOT	Yes, we do both.
Illinois DOT	IRI is compatible.
Indiana DOT	Certain elements are collected specifically for HPMS. Others are only for the state highway PMS.
Iowa DOT	We collect data across the entire system, but we are having problems with section lengths.
Kansas DOT	Not exactly. Data items are converted using software.
Kentucky KYTC	No response
Louisiana DOT	Yes
Maine DOT	No response
Maryland DOT	No response
Massachusetts DOT	No response
Michigan DOT	We already routinely collect info for these three items in a manner which will allow us to comply with HPMS requirements.

Agency	Q3: Does your agency collect data specifically for and according to HPMS guidelines?
Minnesota DOT	NO. You can see our distress manual and an overview of how we do our ratings at our website: http://www.dot.state.mn.us/materials/pvmtmgmt.html. For HPMS, we will take that data and do some conversions/estimates.
Mississippi DOT	IRI was in good shape, we are adding new data items in order to comply with new requirements.
Missouri DOT	No response
Montana DOT	Some are - we add extra data when needed.
Nebraska DOT	Some of our data will be collected specifically for HPMS.
Nevada DOT	When needed, we report according to their guidelines. We do our own collection for state specific data.
New Hampshire DOT	No response
New Jersey DOT	No response
New Mexico DOT	The New Mexico Department of Transportation (NMDOT) collects pavement roughness (IRI), rutting, faulting, fatigue cracking, and transverse cracking data. The data is collected in compliance with State law, FHWA recommendations, contractual obligations and to provide information necessary for State highway system oversight and management. NMDOT is collecting the above data now, but not in the format required for HPMS reporting.
New York DOT	No response
North Carolina DOT	Yes. Some data is specific to HPMS and other data is collected as part of our normal pavement survey operations. For instance, we would never collect data on locat (city-owned) roads but do so due to HPMS requirements. We also do not collect cracking data in such a way that it can fulfill all HPMS requirements so we have a special, secondary pavement survey to capture that.
North Dakota DOT	We are collecting data for state PMS and tweaking the numbers to get them to fit.
Ohio DOT	No response
Oklahoma DOT	Data are collected according to AASHTO protocol.
Oregon DOT	We collect IRI, and anticipate what HPMS wants and make assumptions, which can be difficult.
Pennsylvania DOT	No. Our automated pavement condition data survey program (videologging) has been in place since 1997 with manual pavement surveys in the years prior. While some of the data collected fits into HPMS requirements, what we collect and report is not specifically done with HPMS in mind.
Rhode Island DOT	We try to follow their guidelines as closely as possible. We still have some issues since it's a new system.
South Carolina DOT	No response
South Dakota DOT	Kind of. Sample segments off the state system were specifically for HPMS. On state system, we collected in our method, and we are in the process of trying to get data in their format.

Agency	Q3: Does your agency collect data specifically for and according to HPMS
Tennessee DOT	No response
Texas DOT	The pavement data items (50-53) are not specifically done for HPMS, but are part of our annual statewide pavement evaluation survey. The only exceptions are Faulting (which we approximate, and only for HPMS) and IRI (which we measure off-system - city streets and county roads - for HPMS).
Utah DOT	Yes, for the old system
Vermont DOT	We just started on new data items #50-53, so it depends on the item in question.
Virginia DOT	Most of our data comes (or will come) from our annual pavement condition ratings (which cover 100% of our state maintained interstate and primary pavement) – this is collected for reasons beyond HPMS reporting but includes IRI, rutting and cracking values necessary for HPMS submission. For sample sections located outside of our pavement condition ratings (maintained by cities), we measure IRI for HPMS data submission only.
Washington DOT	We collect data according to our state system and provide more data if needed.
West Virginia DOT	Not really. We collect state data for the pavement management system and modify it.
Wisconsin DOT	Both. State specific data is collected, as well as HPMS data in the required format.
Wyoming DOT	We use the guidelines, but if we find something specific to Wyoming that deviates from standard practices, we may do things a little differently. Some things we collect data for are specific to HPMS.

Agency	Q4: How is your (HPMS's pavement condition) data collected?
Alabama DOT	Cracking: In house with detailed instructions, but going to go automated next year; Others using Pathways van. We have a manual workstation set up where evaluators look at the data.
Alaska DOT	No response
Arizona DOT	NHS is done in-house. Off the state system, we gather COG and MPO data to use. We have a pavement group who manually gathers HPMS samples.
Arkansas DOT	We own a data collection vehicle, we use WiseCrax, but have a few issues with it.
California DOT	No response
Colorado DOT	All HPMS Pavement data is collected automatically using Pathways, and we just started collecting faulting data this year. We have a quality control process on both ends that ensures the data is being reported accurately.
Connecticut DOT	We do it in house using 2 Fugro-Roadware vehicles. They collect roughness data and geometric information. Rutting and cracking is done through WiseCrax. We don't collect faulting as of this year because we have very little concrete roads, but will start that data collection next year. We look at a limited set of segments and develop regression equations for calculating crack lengths.
Delaware DOT	IRI- vendor. Automatic data collection, and no field crew exists to verify data collected.
District of Columbia DOT	Contractor, automated survey.
Florida DOT	We do an automated survey for rutting and faulting using privately owned equipment. As for cracking data, such as cracking percent, we perform a windshield survey. We are not reporting cracking length this year.
Georgia DOT	State Route information is collected by GDOT's Office of Maintenance personnel in a manner that meets their business and operating needs.
Hawaii DOT	No response
Idaho DOT	Cracking: visual, manually collected for non-state HPMS roads. We also use Pathways for rutting and faulting data.
Illinois DOT	We consult out data collection and they use software to obtain the numbers.
Indiana DOT	Contracted out, using Pathways van. We have pavement techs who look at the pictures and report values.
Iowa DOT	IRI is automated - done in-house. We use Roadware, they do the conversions for us and give us the correct values.
Kansas DOT	Rutting: automated system; Cracking: windshield survey; Faulting: similar to cracking , but it's not exact - you can't tell exactly where the joint is sometimes.
Kentucky KYTC	No response
Louisiana DOT	All items are collected automatically, using Roadware, contracted out.
Maine DOT	No response
Maryland DOT	No response
Massachusetts DOT	No response
Michigan DOT	Contractor (Pathway currently) Semi-automated (Pathway collects by automated means, then cracking data is manually coded from images)

Agency	Q4: How is your (HPMS's pavement condition) data collected?
Minnesota DOT	#50 - Rutting. We already collect rutting data using INO scanning lasers on the back of our Pathway Services van. We will report average rut depth per mile. #51 - Faulting. We already collect faulting data using the profile lasers on the front of our Pathway Services van using INO scanning lasers. We will report average fault depth per mile. #53 - Cracking_Length. On AC pavements we count the number of transverse cracks. For HPMS we will multiple the number by 12 to get Cracking_Length. On PCC pavements we will take the percent of "cracked" slabs and report them as Cracking_Length.
Mississippi DOT	No response
Missouri DOT	No response
Montana DOT	No response
Nebraska DOR	In house
Nevada DOT	No response
New Hampshire DOT	No response
New Jersey DOT	No response
New Mexico DOT	NMDOT collects pavement roughness and rutting data in-house on an on-going basis. Pavement roughness data are measured electronically in accordance with AASHTO Designations PP37-04 and R 43-07 using a K. J. Law built, Dynatest T6600 High Speed Profilometer with infra-red displacement sensors and accelerometers mounted on a Ford E350 van. Pavement rutting data is collected concurrently in accordance with AASHTO Designation R48-08. NMDOT annually collects pavement distress data by means of a manual/ visual survey. Since 2006, NMDOT has employed Civil Engineering students from the University of New Mexico (UNM) and New Mexico State University (NMSU) to perform the surveys. NMSU collects pavement distress data in the southern half of New Mexico and UNM collects data in the northern half. This program has been very successful in terms of cost, data quality and deliverables, QA/QC procedures and timely completion.
New York State DOT	No response
North Carolina DOT	All data is collected by in-house personnel or other DOT employees. Our data collection (for cracking) is manual. We are using high speed profilers for IRI, rutting and (soon) faulting. We have a goal of going automated in the not too distant future.
North Dakota DOT	Rutting: measured with equipment, except for non state roads. We are using Pathways for the new HPMS system, but we are not sure how to make it fit the new format with RouteIDs.
Ohio DOT	No response
Oklahoma DOT	IRI, rutting, faulting: automated using Pathways vehicle. Distress data is semi-automated, we look at pictures and determine the correct values.
Oregon DOT	We use in house personnel, get an automated distress survey. IRI and rutting data are collected with our own equipment. Cracking is done via windshield survey.
Pennsylvania DOT	Our videologging vendor (Fugro-Roadware) provides pavement condition data for our entire state network on a 2-year cycle. We use in-house equipment and personnel to collect IRI data on our Interstate system and on routes that have new pavement placements.

Agency	Q4: How is your (HPMS's pavement condition) data collected?
Rhode Island DOT	Rutting:contacted out, using laser profilers; Cracking: collected for PMS, but data must be reviewed before we know if it will work. No concrete pavements in RI.
South Carolina DOT	No response
South Dakota DOT	Manually using college students in the summer for faulting, rutting, and cracking. IRI is collected using a Pathways van.
Tennessee DOT	No response
Texas DOT	We do IRI, Rutting, and Faulting with in-house personnel. We do Cracking with contractor personnel. Our IRI and Rutting are automated using equipment developed in-house. We rate Faulting and Cracking visually (not automated).
Utah DOT	State system data collection is automated, using Roadware. Off state system data is collected manually, where a staff crew goes out.
Vermont DOT	Contractors do automated regular cycle data collection using Roadware. In house data items are special requests. We have in-house personnel review the data using pre-measured sections.
Virginia DOT	Annual pavement condition ratings are through a contractor (Fugro-Roadware), which are independently QA'ed by a separate QA/QC vendor as well as Central Office VDOT staff. Additional sample section data collection is collected in-house by Central Office VDOT staff
Washington DOT	Rutting, Faulting: Pathways automated system; Cracking: semi-automated - images of pavement surface are recorded and manually classified.
West Virginia DOT	Manually using in-house personnel, and contracted through GeoDecisions, who pull in data, convert it to HPMS, and clean it up.
Wisconsin DOT	Semi automated. Distress survey van uses Pathways.
Wyoming DOT	Automated, using Pathways vans. We have 5 districts, and hand-check samples in 1-2 districts per year.

Agency	Q5: Does your agency already collect similar data in a compatible format to the one required for HPMS?
Alabama DOT	Yes, since we changed the system in 2002, but we get linear feet in transverse and longitudinal cracking in the wheel path.
Alaska DOT	No response
Arizona DOT	Yes, but we have to change the way the data fit into the linear referencing system.
Arkansas DOT	Yes
California DOT	No response
Colorado DOT	Yes, we changed our system to ensure there wouldn't be too much of an issue, but some of our codes are different, like surface type, but are easy to change. We added new data items this year that the new version wants, and collected them by what we thought were the most accurate specs. We won't know how close we actually got until we get some feedback.
Connecticut DOT	It's really close to the required format. We just need to rearrange data, update queries.
Delaware DOT	Yes, but we do have to modify it slightly because of the section lengths. We met 2009 HPMS requirement, for 2010 new requirement, we need to assign new resources. We plan to have a meeting soon to discuss and inform our FHWA official, some items like IRI for 2010 information may not be available.
District of Columbia DOT	We have begun to collect data in the new format.
Florida DOT	Some data items were being collected already, but not in the way that HPMS wants. Our pavement physical attributes are not the same either.
Georgia DOT	Codes, values and methodologies are not always consistent with those asked for in HPMS and may/will require some conversions and translations.
Hawaii DOT	No response
Idaho DOT	Rutting and faulting we do only for HPMS using the profiler van.
Illinois DOT	Yes.
Indiana DOT	Not really. Most database items do not match.
Iowa DOT	No response
Kansas DOT	Has to be modified.
Kentucky KYTC	No response
Louisiana DOT	It's really close, since everything is automated.
Maine DOT	No response
Maryland DOT	No response
Massachusetts DOT	No response
Michigan DOT	Rutting: Compatible. Faulting: In our data, we cannot distinguish between faulting at joints and faulting at a mid-panel crack. Collection itself is compatible. Cracking: Not compatible directly. We record individual distresses by length and number of occurrences.

Agency	Q5: Does your agency already collect similar data in a compatible format to the one required for HPMS?
Minnesota DOT	Yes. Similar, but not identical. We will be doing some conversions of our data to get it into the HPMS cracking format.
Mississippi DOT	Yes, for distress data, but IRI was actually really close. We have had to run queries and add new things.
Missouri DOT	No response
Montana DOT	No, data is collected for our pavement management system.
Nebraska DOR	Yes
Nevada DOT	Yes
New Hampshire DOT	No response
New Jersey DOT	No response
New Mexico DOT	NMDOT is already collecting pavement roughness (IRI), in a format compatible to the one required for HPMS. NMDOT is collecting Pavement Management System (PMS) data but that data is not in a compatible format for NMDOT to comply with the new FHWA Office of Highway Policy Information HPMS pavement cracking data federal reporting requirements.
New York State DOT	No response
North Carolina DOT	Yes and no. Most of our data is collected in a tabular format but we include references that allow it to be easily added to shape files provided by our GIS unit. The data is then effectively spatially located.
North Dakota DOT	Sort of, the numbers we get do need adjustments.
Ohio DOT	No response
Oklahoma DOT	For the most part, it is similar.
Oregon DOT	We are in the process of changing our systems to match more closely.
Pennsylvania DOT	We have not changed our data collection and reporting methods for the new HPMS requirements.
Rhode Island DOT	It's close, but will need some adjustments to fit.
South Carolina DOT	No response
South Dakota DOT	For the most part, but had to adjust some items.
Tennessee DOT	No response
Texas DOT	IRI is very close to the HPMS requirement, but the other types are only somewhat similar.
Utah DOT	Yes, for the most part, but it does need to be adjusted in order to fit.
Vermont DOT	Yes, our data is collected regularly and we have added new items spefically geared toward HPMS.

Agency	Q5: Does your agency already collect similar data in a compatible format to the one required for HPMS?
Virginia DOT	Our data collection is compatible with HPMS with minor calculation required (e.g. using sum of linear feet of various transverse cracking types/severities divided by total section length in miles to develop ft. Trans cracking / mile) – in future collections we are adding one additional field to allow for direct calculation of HPMS Concrete “Fatigue” cracking
Washington DOT	It's close.
West Virginia DOT	Not really.
Wisconsin DOT	State IRI is consistent with the old system, Pathways produces data that fits HPMS format already.
Wyoming DOT	Our current system doesn't mesh well with the old HPMS system. We are building a new system that includes new HPMS items into our old system so that it meshes better.

Agency	Q6: How does your agency share these data with HPMS?
Alabama DOT	Pass the data on to the transportation bureau, and they report it.
Alaska DOT	No response
Arizona DOT	We are still waiting on the new software.
Arkansas DOT	We input what we have according to what they want.
California DOT	No response
Colorado DOT	Database extraction.
Connecticut DOT	Their software.
Delaware DOT	Old system, their database software.We get the help of our Information Technology Section (OIT) to convert data to meet HPMS requirement where necessary.
District of Columbia DOT	No response
Florida DOT	We are building tables in Oracle, using SQL translation programs to convert our data to the formay HPMS wants.
Georgia DOT	The Office of Maintenance will now be sharing this information with me and our group allowing us to access it for our reporting needs.
Hawaii DOT	No response
Idaho DOT	HPMS software.
Illinois DOT	No response
Indiana DOT	Access database.
Iowa DOT	No response
Kansas DOT	No response
Kentucky KYTC	No response
Louisiana DOT	Database extraction.
Maine DOT	No response
Maryland DOT	No response
Massachusetts DOT	No response
Michigan DOT	Rutting and faulting will be reported per 0.1 mile segments, which is how we normally report the data. We send this to another area of MDOT which will do the actual submittal, so they may summarize in some fashion. Cracking will be reported as totals for the HPMS segment, but may be subdivided if surface type changes between flexible and rigid.
Minnesota DOT	I send them via spreadsheet to our HPMS coordinator.
Mississippi DOT	Given to them in Access/Excel, imported using their software.
Missouri DOT	No response
Montana DOT	They extract data from our databases and convert it into their format.
Nebraska DOR	We convert our data into a format that compatible with HPMS.
Nevada DOT	Populate tables in house through HPMS, export to Roadway
New Hampshire DOT	No response
New Jersey DOT	No response
New Mexico DOT	NMDOT is conducting a research project to develop methods for estimating HPMS data in a compatible format from the PMS data that NMDOT is collecting now. The successful completion of this research will allow NMDOT to comply with the new FHWA Office of Highway Policy Information HPMS pavement cracking data federal reporting requirements.

Agency	Q6: How does your agency share these data with HPMS?
New York State DOT	No response
North Carolina DOT	We will be submitting via the new submittal tool. Data will be in a geospatial and/or tabular format as required.
North Dakota DOT	We use their software.
Ohio DOT	No response
Oklahoma DOT	No response
Oregon DOT	No response
Pennsylvania DOT	Pavement condition data is loaded into our Roadway Management System (RMS). The Bureau of Planning and Research pulls what data they need for their HPMS reporting along with traffic data, pavement history, etc., from other areas of the RMS.
Rhode Island DOT	No response
South Carolina DOT	No response
South Dakota DOT	Give them access to our populated table.
Tennessee DOT	No response
Texas DOT	This is underway right now. Our Planning division is trying to spatially merge the pavement data into their GIS geodatabase. I'm not exactly sure how they're managing right now. They're loading up the rest of the HPMS data, too, and that's keeping them busy.
Utah DOT	No response
Vermont DOT	No response
Virginia DOT	The FHWA is creating an on-line software and web site where we can submit the specified file formats. Until that software is available, the FHWA will likely provide an FTP site for submissions.
Washington DOT	No response
West Virginia DOT	Old COBOL system for this year, will convert to SQL server for next year.
Wisconsin DOT	Access database, imported into Oracle.
Wyoming DOT	No response

Agency	How do you (your agency) convert your data to the HPMS format?
Alabama DOT	Linear feet * width gets area of cracking.
Alaska DOT	No response
Arizona DOT	Since we don't have the new software yet, this is still in progress.
Arkansas DOT	We are still unclear on the reporting of some items and are working to resolve the issues.
California DOT	No response
Colorado DOT	We go item by item. All we really have to do is perform simple conversions, like code changes, or convert measurement systems (meters-feet, or feet-miles) to make it work. We don't have any documentation on this.
Connecticut DOT	We summarize cracking by orientation and zone. We are coming up with formulas that accurately report cracking. These are still in progress. [Will be sent when finished.]
Delaware DOT	We will have to, it is a work in progress, not enough people have had access to the new system to be able to document any changes that have to be made.
District of Columbia DOT	Nothing yet. We are in the process of development.
Florida DOT	We have to take the data we have and convert our codes to match HPMS codes. Everything else is being reported as close as we can get it. We don't use the same codes or database structure.
Georgia DOT	Data conversions and business rules associated with these data are in the process of being developed. We have no formal documentation to provide at this time.
Hawaii DOT	No response
Idaho DOT	Rutting and faulting: We haven't worked on it yet. IRI is reported as a weighted average for cracking data. We plan on getting work done in the next couple of months regarding the new system.
Illinois DOT	We use simple arithmetic conversions for most of the items.
Indiana DOT	Pathways data comes to us ready to go. We do use scripting and batch formatting to get the items to match.
Iowa DOT	No response
Kansas DOT	IRI data is close, conversions on other items are done variable by variable.
Kentucky KYTC	No response
Louisiana DOT	We have to convert formats, but the data we get is correct.
Maine DOT	No response
Maryland DOT	No response
Massachusetts DOT	No response
Michigan DOT	Faulting and cracking require translation. Documentation for all three items in your inquiry are attached.
Minnesota DOT	Simple formulas involving adding up different cracking types to get the values they want. For example, we count transverse cracks. They want the lineal feet so we multiply the number of cracks by 12 to get lineal feet.
Mississippi DOT	We are working on it. We need FHWA to provide more clarification on some of the data items.
Missouri DOT	No response

Agency	**How do you (your agency) convert your data to the HPMS format?**
Montana DOT	Rutting and IRI is easy to convert. Cracking data will have to be converted with a routine of some sort, but we don't have it yet. Next year we will.
Nebraska DOR	We do not have a conversion system in place yet.
Nevada DOT	We are collecting according to standards, so there is no need to change it.
New Hampshire DOT	No response
New Jersey DOT	No response
New Mexico DOT	NMDOT is conducting a research project to develop methods for estimating HPMS data in a compatible format from the PMS data that NMDOT is collecting now. The successful completion of this research will allow NMDOT to comply with the new FHWA Office of Highway Policy Information HPMS pavement cracking data federal reporting requirements.
New York State DOT	No response
North Carolina DOT	Our GIS unit is acting as collator of data. Units providing data are submitting the information in either shapefile format or tabular format. GIS has written a tool to verify datasets. Because we have stored our data using a linear reference that can be easily attached to route shapes, there has been minimal conversion.
North Dakota DOT	Some items we have to manually input, others are electronic transfer, which may or may not work and we will have to convert it. We want to see their version of the data after it's submitted and get it back to see if it works properly.
Ohio DOT	No response
Oklahoma DOT	We are still developing formulas. We take raw info and accumulate it in a new method using an in-house conversion.
Oregon DOT	This is a work in progress.
Pennsylvania DOT	The BPR does appear to be doing some conversion of the pavement condition data we supply to get the proper HPMS format for items 50-53.
Rhode Island DOT	We are not sure on this yet. We have to see how much "massaging" the data will need and work out something to adapt it and get it as close as possible.
South Carolina DOT	No response
South Dakota DOT	Have to convert the data, but not sure how it's done. We are still in the process of writing documentation. Not sure on how well it will work until we get the new software, which we haven't received yet.
Tennessee DOT	No response
Texas DOT	I have the attached pdf containing our proposed conversion algorithms, but don't know yet if Planning division will be able to merge them into their geodatabase. This is the first year for the new HPMS requirements, so we don't know how smoothly it will work.

Agency	How do you (your agency) convert your data to the HPMS format?
Utah DOT	Data collected is used for our pavement management system, and then it is converted. We haven't discussed how we are going to make changes until this summer when when we actually meet with FHWA to see how we should adapt our system.
Vermont DOT	Pavement rating data is aready in the needed format. We don't have anything for the new version yet.
Virginia DOT	Our data is a near match; generally simple formulas that sum various severities/types of cracking before averaging by section length (or slab count) suffice for HPMS reporting requirements (see example above). Currently the procedures are still being finalized so no documentation is yet available.
Washington DOT	Data is ready for HPMS after Pathways is done.
West Virginia DOT	Really haven't gotten into it yet, need more training and research.
Wisconsin DOT	It doesn't need to be, only database formats are converted.
Wyoming DOT	The old system - yes, but not exactly sure how they do it. We shoudn't have conversion troubles with the new system we are working on.

APPENDIX G

Implementation Plan

IMPLEMENTATION PLAN FOR PROPOSED METHODS OF PROJECT No. NM10MNT-01

SCOPE

The scope of this document is to describe the resources and steps needed to implement or apply the Proposed Protocol for visual distress surveys and the recommended methods to estimate distress data for HPMS reporting and for NMDOT's PMS use described in the body of this report. The target audience of this document includes pavement presentation engineer, pavement management engineer and, most especially, computer and IT staff of NMDOT.

LIMITATIONS

The recommendations provided in this document were based on a combination of results of field tests, statistical analysis of the available data and the experience of the authors on pavement distress evaluation and analysis. If the format of the pavement condition data and/or methodology of data collection changes in the future, the results and recommendations presented here could be affected. The rating criteria and factors provided here may need to be refined or confirmed as new data become available.

DETERMINE NMDOT'S PMS PARAMETERS FROM RATERS' DATA

This section describes the steps to calculate the distress parameters that NMDOT needs for their PMS using raters' data from visual (walk) distress surveys (Proposed Protocol). The PMS parameters needed are extent rating of transverse cracking and extent rating of alligator (fatigue) cracking in each sample section, which are used in the calculation of PSI values for flexible pavements.

<u>Note</u>: Sample sections for distress surveys are different and have different length compared to PMS sections. These calculations are for the sample sections. Weighted averages should be calculated for the PMS sections.

Step 1: Determine Extent Rating of Transverse Cracking

1.1 Definition of variables:

SEV: severity rating of transverse cracks
EXT1: extent rating of transverse cracks of severity 1
EXT2: extent rating of transverse cracks of severity 2
EXT3: extent rating of transverse cracks of severity 3
SEV, EXT1, EXT2 and EXT3: these variables can take values of 0, 1, 2 and 3 only
TC1: count of transverse cracks of severity 1 (number of cracks, integer)
TC2: count of transverse cracks of severity 2 (number of cracks, integer)

TC3: count of transverse cracks of severity 3 (number of cracks, integer)

1.2 For each sample section, use the following criteria to determine the extent rating of transverse cracks of each severity level:

If SEV = 0, make EXT1 = 0, EXT2 = 0, EXT3 = 0 (This means that the sample section has no transverse cracks of any severity level), and go to Step 2. Otherwise, continue with the criteria below.

For SEV = 1, make EXT1 = 0 if TC1 = 0;
or make EXT1 = 1 if $1 \leq TC1 \leq 8$;
or make EXT1 = 2 if $9 \leq TC1 \leq 16$;
or make EXT1 = 3 if $17 \leq TC1$.

For SEV = 2, make EXT2 = 0 if TC2 = 0;
or make EXT2 = 1 if $1 \leq TC2 \leq 8$;
or make EXT2 = 2 if $9 \leq TC2 \leq 16$;
or make EXT2 = 3 if $17 \leq TC2$.

For SEV = 3, make EXT3 = 0 if TC3 = 0;
or make EXT3 = 1 if $1 \leq TC3 \leq 8$;
or make EXT3 = 2 if $9 \leq TC3 \leq 16$;
or make EXT3 = 3 if $17 \leq TC3$.

Note: A sample section may have transverse cracks of one or more severity levels; raters report crack count for each severity level. If the crack count for a given severity is 0, assign an extent 0 to that severity level.

Step 2: Determine Extent Rating of Alligator Cracking

2.1 Definition of variables and units:

SEV: severity rating of alligator cracking
EXT1: extent rating of alligator cracking of severity 1
EXT2: extent rating of alligator cracking of severity 2
EXT3: extent rating of alligator cracking of severity 3
SEV, EXT1, EXT2 and EXT3: these variables can take values of 0, 1, 2 and 3 only
PC1: cumulative rater's pace count of alligator cracking of severity 1
PC2: cumulative rater's pace count of alligator cracking of severity 2
PC3: cumulative rater's pace count of alligator cracking of severity 3
PACE: rater's pace, in feet.
L1: cumulative length of alligator cracking of severity 1 (from rater's pace)
L2: cumulative length of alligator cracking of severity 2 (from rater's pace)
L3: cumulative length of alligator cracking of severity 3 (from rater's pace)
L1, L2 and L3 are given in feet.
A1: area of alligator cracking of severity 1

A2: area of alligator cracking of severity 2
A3: area of alligator cracking of severity 3
A1, A2 and A3 are given in square feet.
A1%: percentage of area of alligator cracking of severity 1
A2%: percentage of area of alligator cracking of severity 2
A3%: percentage of area of alligator cracking of severity 3
A1%, A2% and A3% are given in percent.
WP: assumed width of wheel path, equal to 2 ft.
TA: total surface area of sample section, equal to 6,336 ft^2.

2.2 If this is not provided, calculate the total "length" of alligator cracking for each severity present:

If SEV = 0, make L1 = 0, L2 = 0, L3 = 0 (This means that the sample section has no alligator cracking of any severity level), and go to Step 2.3. Otherwise, continue with the criteria below.

For SEV = 1, make L1 = PC1 × PACE

For SEV = 2, make L2 = PC2 × PACE

For SEV = 3, make L3 = PC3 × PACE

2.3 Calculate the area of alligator cracking and percentage of section with alligator cracking for each severity:

If SEV = 0, make A1 = 0, A2 = 0, A3 = 0, A1% = 0, A2% = 0, A3% = 0 (This means that the sample section has no alligator cracking of any severity level), and go to Step 2.4. Otherwise, continue with the criteria below.

For SEV = 1, make A1 = L1 × WP; and A1% = (A1 / TA) × 100%

For SEV = 2, make A2 = L2 × WP; and A2% = (A2 / TA) × 100%

For SEV = 3, make A3 = L3 × WP; and A3% = (A3 / TA) × 100%

Note: TA = 528 ft × 12 ft = 6,336 ft^2, for a sample section that is 528 ft long and 12 ft wide.

2.4 Determine severity rating of alligator cracking for each severity:

If SEV = 0, make EXT1 = 0, EXT2 = 0, EXT3 = 0 (This means that the sample section has no alligator cracking of any severity level), and the calculation ends. Otherwise, continue with the criteria below.

For <u>SEV = 1</u>, make EXT1 = 1 if $0 < A1\% \leq 11\%$;
or EXT1 = 2 if $11\% < A1\% \leq 22\%$;
or EXT1 = 3 if $22\% < A1\% \leq 33\%$.

For <u>SEV = 2</u>, make EXT1 = 1 if $0 < A2\% \leq 11\%$;
or EXT1 = 2 if $11\% < A2\% \leq 22\%$;
or EXT1 = 3 if $22\% < A2\% \leq 33\%$.

For <u>SEV = 3</u>, make EXT1 = 1 if $0 < A3\% \leq 11\%$;
or EXT1 = 2 if $11\% < A3\% \leq 22\%$;
or EXT1 = 3 if $22\% < A3\% \leq 33\%$.

ESTIMATE OF HPMS DATA FROM RATERS' DATA

This section describes the steps to calculate the distress data to be reported to HPMS annually using the raters' data from visual (walk) distress surveys (Proposed Protocol). The HPMS distress data needed are 1) total length of transverse cracking (aggregate of all severity levels) and total area of alligator (fatigue) cracking (aggregate of all severity levels) for flexible pavements, and 2) total percentage of slabs with fatigue cracking and average vertical displacement between adjacent jointed concrete panels or slabs in the direction of the travel only.

<u>Notes</u>: Sample sections for visual distress surveys are different and have different length compared to PMS sections. These calculations are for the sample sections.

Flexible Pavements

Step 1: Total Length of Transverse Cracking (Aggregate of all Severities)

1.1 Definition of variables:

SEV: severity rating of transverse cracks (this variable can take values of 0, 1, 2 and 3 only)
TC1: count of transverse cracks of severity 1 (number of cracks, integer)
TC2: count of transverse cracks of severity 2 (number of cracks, integer)
TC3: count of transverse cracks of severity 3 (number of cracks, integer)
LTC: total length of transverse cracks, aggregated of all severity levels, in feet.
LW: assumed lane width (or width of sample section), equal to 12 ft.
MF: multiplying factor to correlate raters' data to field measurements for length of transverse cracks, equal to 1.25 (from linear correlation of data)

1.2 For each sample section, calculate the total length of transverse cracks (aggregated of all severity levels):

If SEV = 0, make LTC = 0 (This means that the sample section has no transverse cracks of any severity level), and go to Step 2. Otherwise, continue with the calculations below.

$$LTC = (TC1 + TC2 + TC3) \times LW \times MF = (TC1 + TC2 + TC3) \times 12 \times 1.25$$

$$LTC = 0.64 \times (TC1 + TC2 + TC3)$$

Step 2: Total Area of Fatigue (Alligator) Cracking (Aggregate of all Severities)

2.1 Definition of variables:

SEV: severity rating of alligator cracking (this variable can take values of 0, 1, 2 and 3 only)
A1: total area of alligator cracking of severity 1
A2: total area of alligator cracking of severity 2
A3: total area of alligator cracking of severity 3
AAC: total area of fatigue (alligator) cracking, aggregate of all severity levels
AAC, A1, A2 and A3 are given in square feet.
MF: multiplying factor to correlate raters' data to field measurements for area of alligator cracking, equal to 1.31 (from linear correlation of data, Figure 34)

2.2 For each sample section, calculate the total area of fatigue (alligator) cracking (aggregated of all severity levels):

If SEV = 0, make AAC = 0 (This means that the sample section has no fatigue (alligator) cracking of any severity level), and the calculation ends. Otherwise, continue with the calculations below.

$$AAC = (A1 + A2 + A3) \times MF = AAC = 1.31 \times (A1 + A2 + A3)$$

Note: Areas of alligator cracking for each severity level were calculated earlier for PMS parameters.

Rigid Pavements

Step 1: Total Percentage of Slabs with Fatigue Cracking (Aggregate of all Severities)

1.2 Definition of variables:

NFC: rater's count of concrete slabs with fatigue cracking (integer), aggregate of all severity levels.
TSLB: total number of slabs in the sample section (integer); $NFC \leq TSLB$
FC%: total percent of slabs with fatigue cracking, given in percent.

1.2 For each sample section, calculate the total percent of slabs with fatigue cracking (aggregated of all severity levels):

$$FC\% = \frac{NFC}{TSLB} 100\%$$

Step 2: Average Vertical Displacement between Adjacent Jointed Concrete Panels or Slabs in the Direction of the Travel

2.1 Definition of variables:

SEV: severity rating of "Faulting of Transverse Joints and Cracks"
EXT1: extent rating of "Faulting of Transverse Joints and Cracks" of severity 1
EXT2: extent rating of "Faulting of Transverse Joints and Cracks" of severity 2
EXT3: extent rating of "Faulting of Transverse Joints and Cracks" of severity 3
SEV, EXT1, EXT2 and EXT3: these variables can take values of 0, 1, 2 and 3 only
A1%: percentage of area of the sample section with severity 1
A2%: percentage of area of the sample section with severity 2
A3%: percentage of area of the sample section with severity 3
A1%, A2% and A3% are given in percent
D: average vertical displacement between adjacent jointed concrete panels or slabs in the direction of the travel, given in inches

Note: A1%, A2% and A3% represent upper limits for the extent ratings of "Faulting of Transverse Joints and Cracks"

2.2 Determine percentage of the sample section affected by each severity level:

If SEV = 0, make EXT1 = 0, EXT2 = 0, EXT3 = 0, A1% = 0, A2% = 0, A3% = 0 (This means that the sample section has no "Faulting of Transverse Joints and Cracks" of any severity level), and go to Step 2.3. Otherwise, continue with the criteria below.

For SEV = 1, if EXT1 = 1, make A1% = 30%;
or if EXT1 = 2, make A1% = 60%;
or if EXT1 = 3, make A1% = 100%.

For SEV = 2, if EXT2 = 1, make A2% = 30%;
or if EXT2 = 2, make A2% = 60%;
or if EXT2 = 3, make A2% = 100%.

For SEV = 3, if EXT3 = 1, make A3% = 30%;
or if EXT3 = 2, make A3% = 60%;
or if EXT3 = 3, make A3% = 100%.

2.3 For each sample section, calculate the average vertical displacement between adjacent jointed concrete panels or slabs:

$$D = \frac{(0.0625 \times A1\%)(0.25 \times A2\%)(0.5 \times A3\%)}{100\%}$$

REVISED FACTORS AND EQUATION TO CALCULATE NMDOT'S DISTRESS RATE (DR) AND PAVEMENT SERVICEABILITY INDEX (PSI)

Current Formulation

The NMDOT's Distress Rate (DR) and PSI are currently calculated from pavement roughness, rutting and distress ratings, through one of the following empirical expressions (restated here):

$$\text{PSI} = 0.041666\ \text{X}, \quad \text{if X} \leq 60 \tag{1}$$

or

$$\text{PSI} = [0.0625(\text{X} - 60)] + 2.4999, \quad \text{if X} > 60 \tag{2}$$

where the interim value X is given by

$$\text{X} = 100 - \left[\frac{0.6(\text{IRI} - 25) + (0.4\text{DR})}{2.9}\right] \tag{3}$$

where IRI is International Roughness Index, and DR is the Distress Rate defined as

$$\text{DR} = \sum_{i=1}^{n}\left[(\text{Severity Rating}_i)(\text{Extent Factor}_i)(\text{Weight Factor}_i)\right] = \sum_{i=1}^{\text{n}}(\text{DR}_i) \tag{4}$$

in which *i* denotes one of the eight types of distresses of flexible or rigid pavements (n = 8), and DR_i is the component of the distress rate (DR) value corresponding to the distress type *i* for a given pavement section.

Proposed DR Formula

The recommended approach preserves the current PSI formulation and the equation of the interim X value (Equations 1 through 3), but modifies the formula to calculate Distress Rate (DR).

Step 1: Obtain the Input Data and Ratings

1.1 Before calculating DR and PSI, the raters' data from distress surveys should be obtained.

1.2 Convert transverse crack counts and "paces" of alligator cracking into severity and extent ratings, for each severity level and each sample section, as described earlier. Combined these ratings with rater's data in an input file.

1.3 Automated IRI and rut depth data should be available for the corresponding data collection cycle. Convert automated rut depth data into equivalent severity and extent ratings.

Step 2: Convert Automated Rut Depth into Equivalent Rutting Ratings

Calculate the distress rate (DR) for flexible sections as follows:

$$\mathrm{DR} = \sum_{i=1}^{n=5}\left\{\left(\text{Weight Factor}_{i}\right)\sum_{j=1}^{m=3}\left[\left(\text{Severity Rating}_{j}\right)_{i}\left(\text{Extent Rating}_{j}\right)_{i}\right]\right\} + \left[\left(\text{Severity Rating}_{n=6}\right)\left(\text{Extent Factor}_{n=6}\right)\left(\text{Weight Factor}_{n=6}\right)\right]$$

in which *i* denotes one of the 5 types of distresses of flexible pavements to be evaluated with the proposed protocol (n = 1, 2…, 5), including 1) raveling and weathering, 2) bleeding, 3) alligator cracking, 4) transverse cracks and 5) longitudinal cracks. The weight factors for these five distress types are given in Table 5.

The severity and extent ratings for these five distresses are obtained from the raters' data, and take values of 0, 1, 2, or 3. Note that m = 3 because there may be data (severity and extent ratings) for each of the three severity levels of each distress type.

The second term of the equation corresponds to rutting and shoving. The Severity Rating for n = 6 corresponds to the severity rating determined for the sample section from the automated rut depth data. The Extent Factor and Weight Factor for n = 6 are those for rutting and shoving in Table 5. Note that the Extent Factor is determined from the extent rating deduced from the automated rut depth data. Finally, the Weight Factor for n = 6 is 14 (Table 5).

APPENDIX H

Multimedia Presentation

Presentation Title:

Improving NMDOT's Pavement Distress Survey Methodology and Developing Correlations between FHWA's HPMS Distress Data and PMS Data

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