# AUTOMATED DATA COLLECTION EQUIPMENT FOR MONITORING HIGHWAY CONDITION

**Final Report**

**SPR 332**

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by

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16. Abstract


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.


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## SI* (MODERN METRIC) CONVERSION FACTORS

### APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | LENGTH | | |
| in | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | | AREA | | |
| $in^2$ | square inches | 645.2 | millimeters squared | $mm^2$ |
| $ft^2$ | square feet | 0.093 | meters squared | $m^2$ |
| $yd^2$ | square yards | 0.836 | meters squared | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | kilometers squared | $km^2$ |
| | | VOLUME | | |
| fl oz | fluid ounces | 29.67 | milliliters | mL |
| gal | gallons | 3.785 | liters | L |
| $ft^3$ | cubic feet | 0.028 | meters cubed | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | meters cubed | $m^3$ |
| NOTE: Volumes greater than 1000 L shall be in $m^3$ | | | | |
| | | MASS | | |
| oz | ounces | 28.35 | grams | g |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.907 | megagrams | Mg |
| | | TEMPERATURE (exact) | | |
| °F | Fahrenheit temperature | 5(F-32)/9 | Celsius temperature | °C |

### APPROXIMATE CONVERSION TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | | LENGTH | | |
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.28 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | | AREA | | |
| $mm^2$ | millimeters squared | 0.0016 | square inches | $in^2$ |
| $m^2$ | meters squared | 10.764 | square feet | $ft^2$ |
| $m^2$ | meters squared | 2.47 | square yards | $yd^2$ |
| ha | hectares | 0.386 | acres | ac |
| $km^2$ | kilometers squared | | square miles | $mi^2$ |
| | | VOLUME | | |
| mL | milliliters | 0.034 | fluid ounces | fl oz |
| L | liters | 0.264 | gallons | gal |
| $m^3$ | meters cubed | 35.315 | cubic feet | $ft^3$ |
| $m^3$ | meters cubed | 1.308 | cubic yards | $yd^3$ |
| | | MASS | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.205 | pounds | lb |
| Mg | megagrams | 1.102 | short tons (2000 lb) | T |
| | | TEMPERATURE (exact) | | |
| °C | Celsius temperature | 1.8 + 32 | Fahrenheit | °F |

* SI is the symbol for the International System of Measurement

(12/96 jrl)

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# DISCLAIMER

# AUTOMATED DATA COLLECTION EQUIPMENT FOR MONITORING HIGHWAY CONDITION

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# 1.0 INTRODUCTION

## 1.1 BACKGROUND

Currently the Oregon Department of Transportation (ODOT) has several different groups responsible for collecting various types of data on the state highway system. The types of data range from pavement condition, smoothness testing, and road features to video logs of the highway system. The information collected is an important part of maintaining the road and bridge infrastructure on the highway system in Oregon.

The information collected is used in various management systems such as the Pavement Management System (PMS), the Intermodal Management System (IMS), and the Highway Performance Monitoring System (HPMS). These systems are an integral part of the construction project selection and development process in Oregon and directly support activities such as the Oregon Highway Plan and the State Transportation Improvement Program. Tapes from the ODOT Video Log program are also used to protect ODOT against lawsuits and have helped save millions of dollars in traffic litigation.

Currently, ODOT's data collection processes are a combination of manual and automated methods. These processes are time consuming and labor intensive, and they present numerous safety concerns. Since several groups are responsible for collecting the data, several trips over the same highway section are required to collect the necessary information. Over the past five years, technology advances have brought about a new generation of automated processes for collecting highway data. The use of automated data collection (ADC) equipment could potentially combine several current data collection efforts into one. These types of data include, but are not limited to, pavement condition, road roughness and video logging.

## 1.2 OBJECTIVES

The purpose of this study was to evaluate ODOT's current roadway data collection methods and available automated technology and make a recommendation on how ODOT should collect data in the future.

Specific objectives included the following:

1. Assess ODOT's data needs. What information does ODOT currently collect manually in the field that could be collected with automated equipment?

2. Evaluate the accuracy and consistency of ODOT's current pavement condition data collection methods.

3. Evaluate the accuracy and consistency of available ADC technology.

4. Evaluate video log and other data collection features of automated equipment. How do these features fit into ODOT's data needs?

5. Evaluate the potential to combine data collection efforts using automated technology.

6. Recommend the type of technology ODOT should pursue for data collection. This could include either purchasing equipment or using a service contract and specifications for the type of equipment.

## 1.3 SCOPE

To accomplish the above mentioned objectives several tasks were undertaken. First, a literature search was conducted to assess what information was currently available on this topic. Second, an internal survey was conducted among the Management Systems and the users of the management system data. The intent of the survey was to determine what data is currently being collected, how often it is collected, the uses for the data, and the need for new data that was not currently being collected.

To evaluate the current processes and the automated technology, a series of test sections were established on a variety of pavement surface types and with various pavement conditions. The data collected on the test sections by each process and the participating ADC equipment vendors were then evaluated in a statistical analysis.

The main focus of the data collected on the test sections was the pavement condition information and the quality of the video logs, as these were the main functions performed by the automated equipment.

# 2.0 LITERATURE REVIEW AND STATE SURVEY

## 2.1 AUTOMATED DATA COLLECTION: RESEARCH AND DEVELOPMENT

In recent years, a number of vendors have offered vehicles equipped with multiple automated data collection (ADC) tools for assessing pavement condition. Only a few studies have been completed on the effectiveness of these combined systems. For years, however, researchers have evaluated individual automated components to measure pavement distress, roughness, or other features.

A primary resource for this research was a study completed in 1996 by the Texas Transportation Institute, entitled "Evaluation of Automated Pavement Distress Data Collection Procedures for Local Agency Pavement Management" (*Smith, et al. 1996*). This study, undertaken for the Oregon and Washington Departments of Transportation and several local agencies, evaluated automated and manual methods of collecting pavement distress data. The primary goal of the study was to evaluate automated pavement data collection technology for use in local agency pavement management systems. A detailed manual survey of selected test sections was conducted by personnel experienced in distress data collection, and this survey served to provide "ground truth" values. Researchers then compared these pavement distress surveys conducted by agency staff with results collected by automated equipment.

Different surface types were evaluated, including asphalt concrete (AC) surfaces, asphalt concrete overlays on Portland cement concrete (PCC), slurry seals on asphalt concrete, bituminous surface treatment, and Portland cement concrete. Sections with both sunny and shaded pavements were selected, as were sites with pavements in good, fair and poor condition ranges. Data from four vendors of ADC systems were analyzed. Two systems were able to provide equivalent or better prediction of ground truth data than the current system used for all of the participating governments and for both AC and PCC. One other system was able to provide equal or better predictions for AC and PCC under requirements of the Association of Oregon Counties.

An analysis of video images for evaluating pavement distress was conducted by Kim (*1997*) at Oregon State University, using digital image processing to ODOT Pavement Management System standards. A low cost imaging system was developed and installed on a van, using a video camera, camera mounting device, video recorder deck, monitor, character generator, distance measuring instrument and power inverter. Field tests were conducted, and the video images were converted to digital images for 50 locations. Pavement types included AC pavement, jointed concrete and continuous reinforced concrete pavements.

PicCrack[1] pavement image analysis software was used to analyze the images. Statistical analysis tested the ability of the system to provide consistent, repeatable pavement condition data, considering vehicle speed, camera angle, lighting, time and pavement condition. ANOVA tests showed poor repeatability for AC and PCC images. The analysis software was limited by distortion and blurring of the digitized images, slight changes in location of compared images, and other processing limitations (*Kim 1997*).

The Iowa Department of Transportation evaluated several providers of automated pavement distress data collection services (*Smadi, et al. 1996*). Based on decisions made about pavement types, distresses, and data collection frequency and coverage, an estimate was developed for the level of work required to collect data for the statewide network. To make a selection of a provider Iowa DOT had hoped to use the results of two Federal Highway Administration (FHWA) tests of automated distress data collection equipment in Texas in 1993 and North Carolina in 1994. These test results, however, were insufficient to provide a basis for a selection decision.

Thus, five vendors were screened for the technology they used and their experience, service options and availability. Three were invited to demonstrate their technology in Iowa on eight test sections, each of 0.5 km in length – four AC and four PCC sections. Sixteen criteria were used to evaluate performance, covering types of pavements, distress types and contract performance measures (i.e., cost). Results of the automated system tests were compared to the results of a manual inspection. No one vendor was superior for all distress types and contract performance measures. Comparisons of vendors using the criteria weighted by importance yielded one vendor with the highest score, who was selected for the statewide data collection.

Luhr (*1999*) documented the study of automated crack measuring systems for use in a Pavement Management System. The automated methods addressed four major issues in conducting pavement condition surveys. The four issues were the expense of performing surveys, their difficulty due to the size of the road network, the danger to personnel conducting the surveys, and the difficulty in obtaining results that were accurate, repeatable and reproducible. Luhr proposed an evaluation procedure for surveys using automated crack measurement systems that addresses crack location, length and width, to quantify and validate crack survey results.

A study was done by the University of Arkansas for the design of a new data-collecting vehicle. The vehicle eliminated all the older analog equipment and digitized all applications. This vehicle is still being tested (*Wang 2001*). A new machine with double the resolution for detecting cracks (4096 pixels) was presented at the Road Profilers User Group (RPUG) meeting held in Austin Texas in October 2003.

The Florida Department of Transportation has developed a Class I profiler van equipped with laser profiling, land navigation, and imaging subsystems. The van has passed the first tests of video logging and distress surveys. Further testing was planned (*Gunaratne, et al. 2003*).

The Pennsylvania Department of Transportation contracts for the video logging of its entire pavement network. Experiences from other states and findings from the Long-Term Pavement

[1] Center for Advanced Construction Materials, Department of Civil Engineering, University of Utah, Salt Lake City, Utah 84112

Performance program spurred quality assurance methods to be developed. These will soon be tested (*Stoffels, et al. 2003*).

Technology continues to advance in object recognition. One device can sort M&M's candies by color (*Williams 2003*). Another software product can locate people in large crowds by facial recognition. It may not be long until crack recognition and other pavement distress will be detectable by machines as effectively as they are by the human eye.

## 2.2 CURRENT PRACTICES BY STATE DOT AGENCIES

In 2000 and 2001 a survey was conducted of all state departments of transportation (DOTs) to obtain information on current practices with ADC equipment for monitoring pavement distress, smoothness and logging video data on state highways. A screening questionnaire was first sent to all state DOTs and the District of Columbia to identify those that use ADC equipment and to obtain the names of contact people. A total of 27 states responded to the screening survey, with 25 of them indicating that they did use such equipment. Follow-up surveys were then conducted with the contact people in these states, to collect more detailed information on current practices, such as frequency of data collection, coverage of the highway system, types of data collected, data processing, type of equipment, satisfaction with equipment, and quality control.

### 2.2.1 Smoothness Data Collection

Seventeen states provided responses on collecting pavement smoothness data; all reported using ADC equipment. Most states indicated that they had their own equipment. Satisfaction levels were high. Most collected smoothness data annually, with almost half covering the entire state system per year. The most common technology used was laser sensors, although some used ultrasonic or infrared. A copy of the pavement smoothness data collection survey and the responses are provided in Appendix A.

### 2.2.2 Distress Data Collection

Sixteen states responded to the survey on collecting pavement distress data; of these, ten reported using ADC equipment and six did not. Most collected distress data annually; a few collected data every two years. About 2/3 of those using equipment reported having their own; others contracted for these services. Satisfaction levels were high. Other data collected at the same time usually included both smoothness data and video data. A copy of the pavement distress data collection survey and the responses are provided in Appendix B.

### 2.2.3 Video Data Collection

Sixteen states responded to the survey on collecting video data. All reported use of ADC equipment; thirteen reported using their own video equipment and three did not. Satisfaction levels with the equipment were high. Technologies used included digital images and super VHS. Most collected video data annually, with over half covering only a portion of the highway system per year. A copy of the video data collection survey and the responses are provided in Appendix C.

# 3.0 STUDY DESIGN

The research methods were designed to meet the objectives outlined in Section 1.2. The tasks consisted of a survey of ODOT data managers and users to address the department's data needs (Objective 1), and field testing to meet Objectives 2-4. Specific details of the design are provided in the following sections.

## 3.1 INTERNAL SURVEY

A survey of ODOT data managers and users was conducted to meet Objective 1, to assess ODOT's data needs in terms of:

- What information is currently being collected
- What information should be collected that is not currently collected
- What information can be collected with automated equipment

The responses from the survey were too limited, however, to make any generalizations about ODOT's data needs. A copy of the survey questionnaire is provided in Appendix D.

## 3.2 FIELD TEST

Field tests were designed to meet Objectives 2 through 4:

- Evaluate the accuracy and consistency of ODOT's current pavement condition data collection methods.
- Evaluate the accuracy and consistency of available ADC technology.
- Evaluate video log and other data collection features of automated equipment. How do these features fit into ODOT's data needs?

The field test was designed using a series of test sections to collect video log data, pavement distress, longitudinal profile and transverse profile (rut depth) data. These were the primary data collection activities ODOT was considering combining into one automated data collection vehicle.

### 3.2.1 Test section selection

The test sections were selected to cover a range of pavement types found in Oregon, including dense graded asphalt cement, open graded asphalt cement, bituminous surface treatments, and Portland cement concrete pavement. In addition, the sections covered a variety of pavement conditions ranging from good to poor and included most of the significant distresses rated in Oregon. The location of the test sections was also considered. In order for the vendors to be able to complete the testing within one day, most of the sections were located around Salem. One section was in the Portland area within a two-hour drive of Salem. The test sections evaluated are shown in Table 4.1.

**Table 4.1: Test sections**

| Site | Hwy No. | Begin Mile | End Mile | Direction | # of 0.1 Mile Segments | Pavement Type | Pavement Condition | Light Conditions |
|---|---|---|---|---|---|---|---|---|
| **1** | Airport Rd | 0.0 | 1.12 | south | 12 | AC | Poor | Sun |
| **2/5** | 72 | 0.40 | 3.16 | east | 28 | AC | fair | sun |
| **3** | 064 | 2.0 | 5.00 | east | 30 | CRCP | Poor | Sun/shade |
| **4** | 064 | 1.30 | 4.30 | west | 30 | CRCP | Poor | Sun/shade |
| **6/8** | 150 | 12.5 | 17.55 | south | 51 | AC | Fair | Sun/shade |
| **7** | 30 | 11.70 | 15.30 | east | 36 | AC | good | sun |

As shown in Table 4.1, section 2/5 and 6/8 were the same sections. Data on these sections were collected twice so that a repeatability check could be performed. The dominant PCC pavement type found in Oregon is continuously reinforced concrete pavement (CRCP). Although there are a few jointed concrete pavements in Oregon, its use is very limited. Therefore the study limited the test sections to CRCP only. The CRCP test sections were located on Interstate 205 in Portland.

## 3.2.2 Ground truth

In order to meet Objectives 2 and 3, "ground truth" was established for a percentage of each test section. The intent of the ground truth was to provide a basis for comparison of both the ODOT rating crews and the automated systems. The ground truth data provided an estimate of how well the procedures matched the actual conditions found in the field. The ground truth also helped establish whether or not the automated technologies could provide data that was as good as or better than the current methods. Consistent with the current rating procedures, the ground truth data was generated from 0.1 mile subsections within each test section, rated by experienced ODOT pavement management personnel. These ratings were conducted via a walking survey and use of a measuring wheel to determine distress quantities. Table 4.2 shows a list of the sections for which a ground truth was determined.

**Table 4.2: Ground truth sections**

| Site | Hwy | Number of sections used for ground truth |
|---|---|---|
| 001 | Airport Rd | 3 |
| 002 / 005 | 072 | 6 |
| 003 | 064 | 4 |
| 004 | 064 | 4 |
| 006 / 008 | 150 | 7 |
| 007 | 30 | 5 |

### 3.2.3 Data collection

Each test section was rated by three ODOT rating crews and by the ADC system vendors in August and September 2001. The ODOT rating crews conducted pavement condition ratings on each test section according to the detailed distress survey procedures described in Section 4.3. The data were submitted per ODOT standard operating procedures. A comparison to the ground truth data would provide ODOT with an estimate of how well current procedures matched actual conditions.

The ground truth data also established a baseline to which the vendors' equipment could be compared. The vendors collected data on the test sections using their ADC equipment per the specifications included in the contract documents. The specifications included detailed information regarding the identification and measurement of distresses as well as the required data submission format. A copy of the specifications is included in Appendix E.

The participating vendors included Fugro - BRE[2], Infrastucture Management Services (IMS)[3], Pathway Services[4], and Roadware[5]. The contract specified that all data should be collected in a single pass of the automated equipment. However, the Fugro-BRE equipment required two passes. The first pass was made during the daylight hours to collect video log information. A second pass was made during the evening hours to collect pavement distress data with the aid of artificial light.

[2] Fugro-BRE, Inc., 8613 Cross Park Dr., Austin, TX 78754
[3] Infrastructure Management Services, Inc. 3350 Salt Creek Lane, Ste. 117, Arlington Heights, IL 60005
[4] Pathway Services, Inc., P.O. Box 513, Noble, OK 73068
[5] Roadware, 147 East River Road, PO Box 520, Paris Ontario N3L 3T6 Canada

# 4.0 CURRENT PROCEDURES

This section provides an overview of ODOT's current procedures for collecting pavement condition and video log data.

Pavement condition data consists of pavement distresses and road roughness data. ODOT also collects pavement friction information on a network level for pavement management, but it was not included in this research project. At the time of this study, there were no vendors providing equipment that would collect pavement friction data concurrently with pavement distress and video.

## 4.1 ROAD ROUGHNESS

At the time this research was conducted, ODOT was using a high-speed inertial profiler equipped with three ultrasonic sensors for collecting longitudinal and transverse profiles of the highway system.[6] The data is used to calculate an International Roughness Index (IRI) and a rut depth for each pavement management section. All interstate highways are tested every year, while non-interstate highways are tested every two years. It takes a two-person crew approximately eight weeks to collect this data each year.

## 4.2 ODOT VIDEO LOG PROGRAM

The State Highway Video Log is a pictorial record of state highway features from a driver's perspective. The Digital Video Log (DVL) consists of digital images taken every hundredth of a mile, and continuous video taken in both increasing and decreasing milepoint directions. Approximately one half of the state highway system is logged annually, with emphasis on Interstate and US Routes.

The collection software currently in use was originally built by Thurston County, Washington, then rewritten by Washington State DOT to meet their needs. It was passed to Marion County, Oregon who modified the software to run on Windows NT. ODOT obtained a copy of the software from Marion County, and modified it to meet ODOT's unique LRS needs.

Both the continuous video and digital images are overlaid with highway and milepoint text, and then saved to DVDs.

The continuous video is distributed to library-holders on DVD. The digital images are distributed via an internet site,[7] which allows users to look up the needed images by selecting an image year

[6] Since that time ODOT has upgraded its inertial profiler to a 5-laser sensor system.
[7] https://keiko.odot.state.or.us/whalecome625540f33e0118833db435ae262/whalecom0/SecureKeikoPortalHomePage/

and highway number. The web application also shows a corresponding milepoint log with the digital images. A copy of the hardware specifications is included in Appendix F.

## 4.3 PAVEMENT DISTRESS

ODOT collects pavement condition data on the entire network every two years. The condition ratings are divided into two separate processes. The first is a subjective good-fair-poor rating that is conducted via a windshield survey. This rating procedure is used for the non-National Highway System routes. The windshield survey is conducted by a two-person crew, and consists of driving each pavement management section and assigning a 1 to 5 rating based on pre-defined criteria. A description of this procedure can be found in Appendix G.

The second procedure is an objective detailed distress survey conducted on the National Highway System (NHS) routes. Since the goal of this research project was to compare automated technology to current procedures, only the detailed distress survey is discussed further.

The purpose of the detailed distress survey is to identify and quantify the amount and severity of surface distress in a given segment of pavement. The results of the condition survey are used along with other measured pavement characteristics to establish a condition rating for all segments of roadway within the State Highway System. The survey is conducted by two-person crews trained in surface distress identification procedures via a windshield survey from a slow-moving vehicle operating on the adjacent shoulder. ODOT normally hires and trains eight college students to conduct the ratings. The highway is rated in 0.1 miles increments, and it consists of identifying the type, severity and quantity of each distress type found within the section. More information related to the rating procedure is provided in Appendix H.

# 5.0 DATA ANALYSIS AND RESULTS

The first phase of the analysis was to compare pavement condition index values generated by the different groups. An index value is a weighted summary of all the severity levels for a given distress type considered in the survey. It is the primary indicator used by project planners in deciding which highway sections need attention (*Kim 1997*).

The research methods outlined in Section 3 provided for the following comparisons to be made:

1. Comparisons between the pavement distress rating crews and ground truth. (Do the rating crews agree with ground truth?)

2. Comparisons among the pavement distress rating crews for consistency of observation on a given run. (Do the rating crews agree among themselves?)

3. Comparisons of a test-retest nature within the pavement distress rating crews for the repeatability of observations on the same test segments. (Do the rating crews get the same measurements twice?)

4. Comparisons between the automated systems and ground truth. (Do the ADC systems agree with ground truth?)

5. Comparisons among the automated systems for consistency of observation on a given run. (Do the ADC systems agree among themselves?)

6. Comparisons of a test-retest nature within the automated systems for the repeatability of observations on the same test segments. (Do the ADC systems get the same measurements twice?)

7. Comparisons between the rating crews and the automated systems. (Does the ADC equipment do better than the rating crews?)

## 5.1 PAVEMENT CONDITION DATA EVALUATION

ODOT converts the raw distress data into index values which range from 100 to 0. There are six indices: Overall, Fatigue, No Load, Patching, Raveling, and Rutting. A more detailed explanation of these indices can be found in Appendix I.

Most of the research conducted in the past has focused on how well the automated data identified each distress quantity and severity. In this research, ODOT took a slightly different approach. This evaluation looked at how well the various rating crews and automated systems matched the final processed index values based on the ground truth data.

The data collection involved the variables of Rutting, Patches, Fatigue Cracking, Raveling, Bleeding, Blocking, Punchouts, Longitudinal Cracking, and Transverse Cracking. These were then rendered into the standard formats as described in the ODOT "Objective Rating Pavement Condition Survey Manual" and appeared in the final data set received for analysis as six indices: Overall, Fatigue, No Load, Patching, Raveling, and Rutting.

The analysis was based on data collected on the 28 one-tenth mile segments of highway that were ground truthed.

### 5.1.1 Graphical comparisons

The first step in the data analysis was the graphing of six variables (Overall, Fatigue, No Load, Patching, Raveling and Rutting) for the three rating crews, versus the ground truth standard, for all of the 28 highway segments. These data are shown in Figures 5.1-5.6 below.

A casual examination of the graphs indicates that there was a high degree of agreement among the three rating crews and the ground truth on some indices: No Load (Figure 5.3), Patching (Figure 5.4), Raveling (Figure 5.5) and Rutting (Figure 5.6). There were others in which agreement was much less: Overall (Figure 5.1) and Fatigue (Figure 5.2).

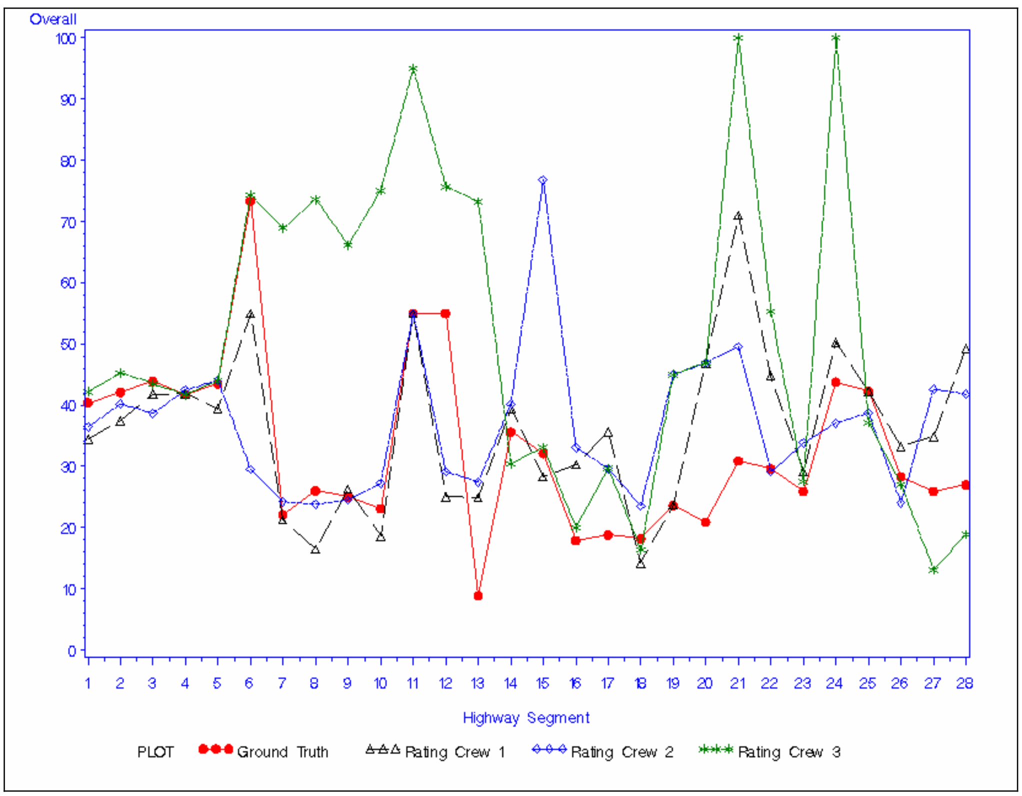


Figure 5.1: Overall Index comparing ground truth and ODOT rating crews

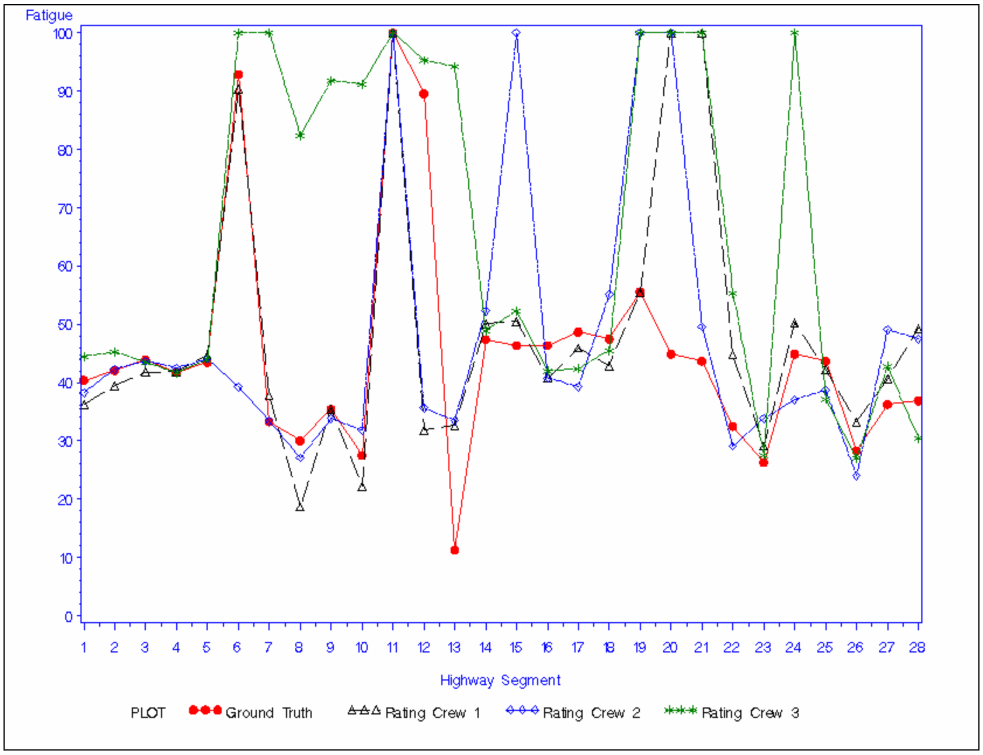


Figure 5.2: Fatigue Index comparing ground truth and ODOT rating crews

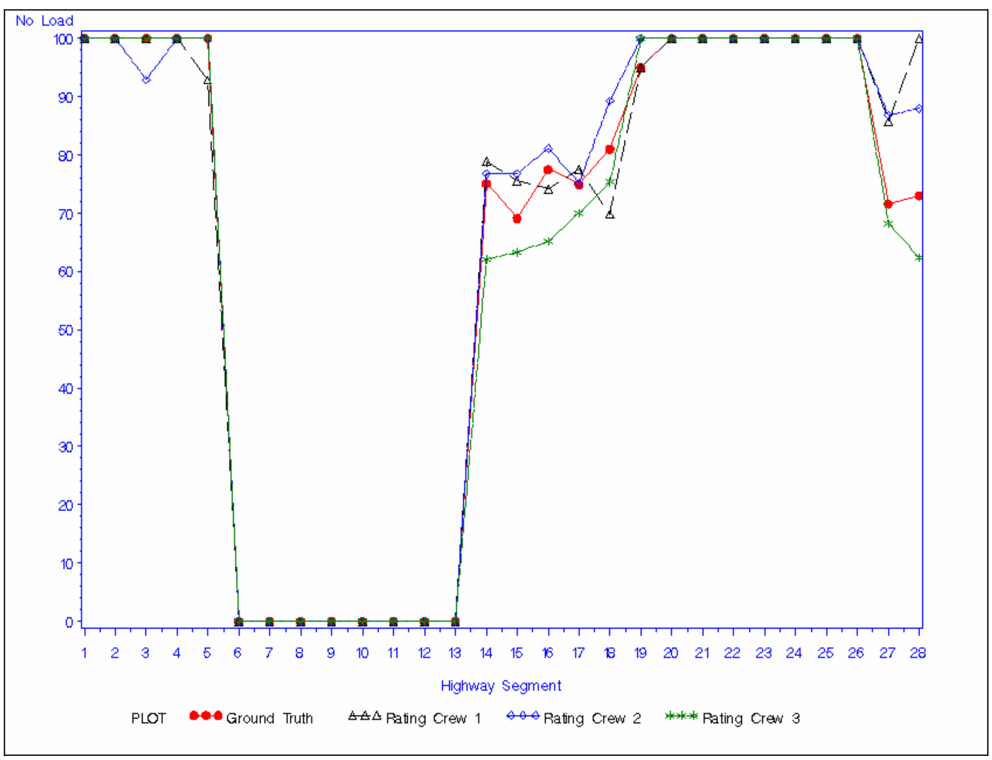


Figure 5.3: No Load Index comparing ground truth and ODOT rating crews

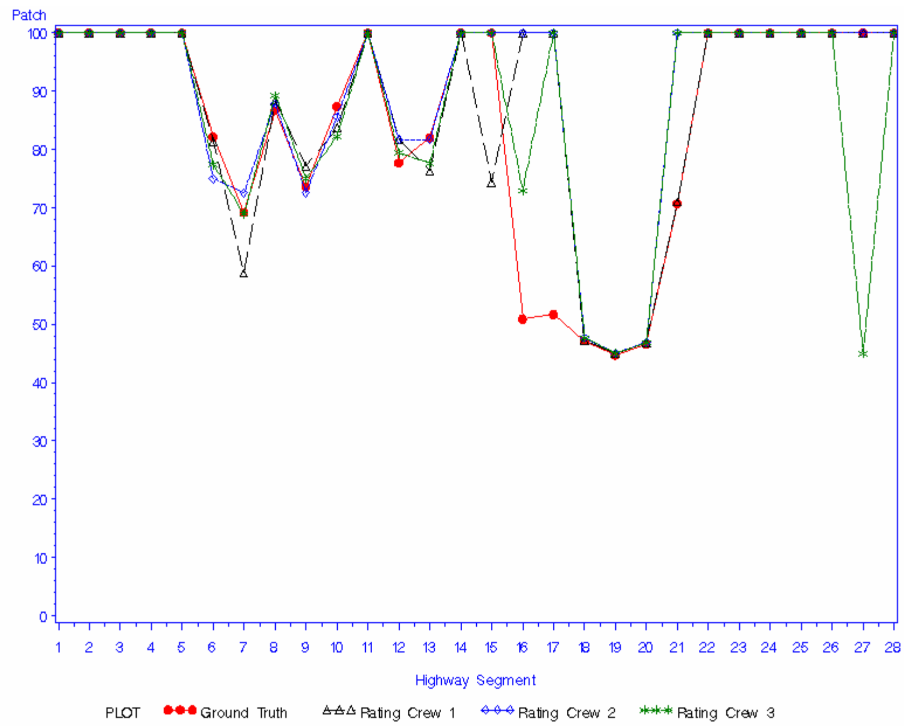


Figure 5.4: Patching Index comparing ground truth and ODOT rating crews

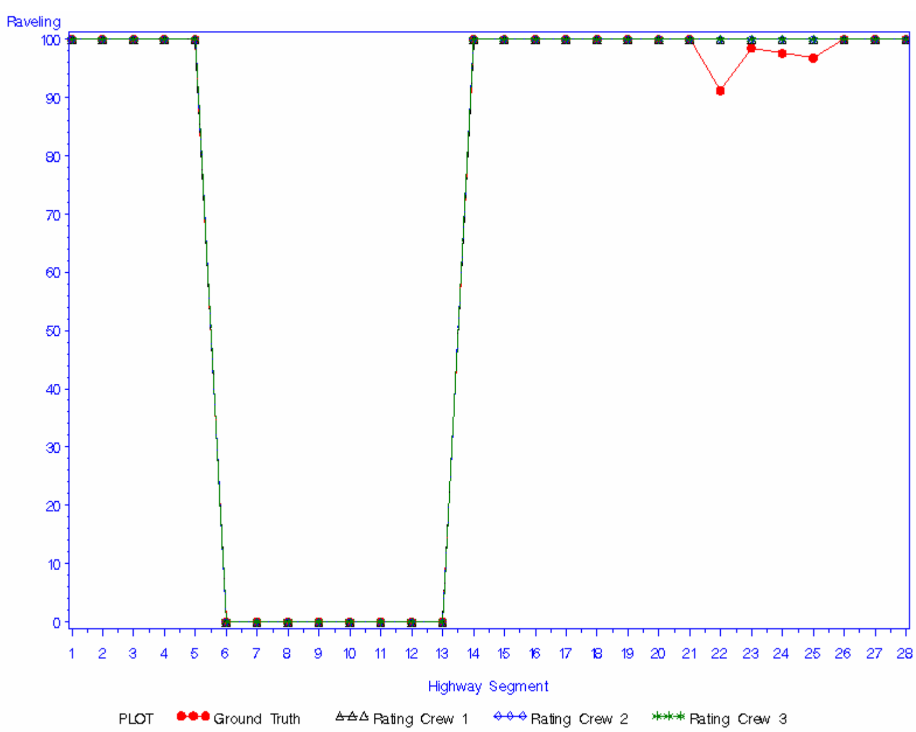


Figure 5.5: Raveling Index comparing ground truth and ODOT rating crews

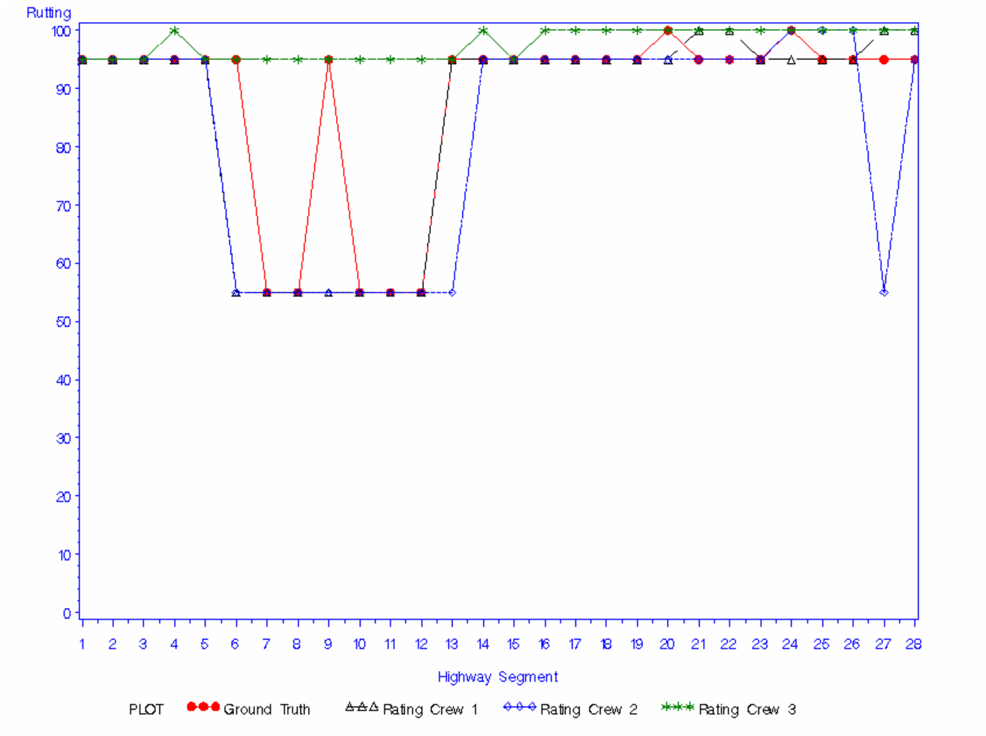


Figure 5.6: Rutting Index comparing ground truth and ODOT rating crews

The second step was the graphing of the same variables for the four ADC equipment vendors (Fugro, IMS, Pathway and Roadware) versus the ground truth standard. These data are shown in Figures 5.7 – 5.12.

In this case, casual examination of the graphs seems to indicate a high degree of agreement between the ADC equipment and the ground truth data for No Load (Figures 5.9), Raveling (Figure 5.11) and Rutting (Figure 5.12). There was much less agreement in Overall (Figures 5.7), Fatigue (Figure 5.8) and Patching (Figure 5.10).

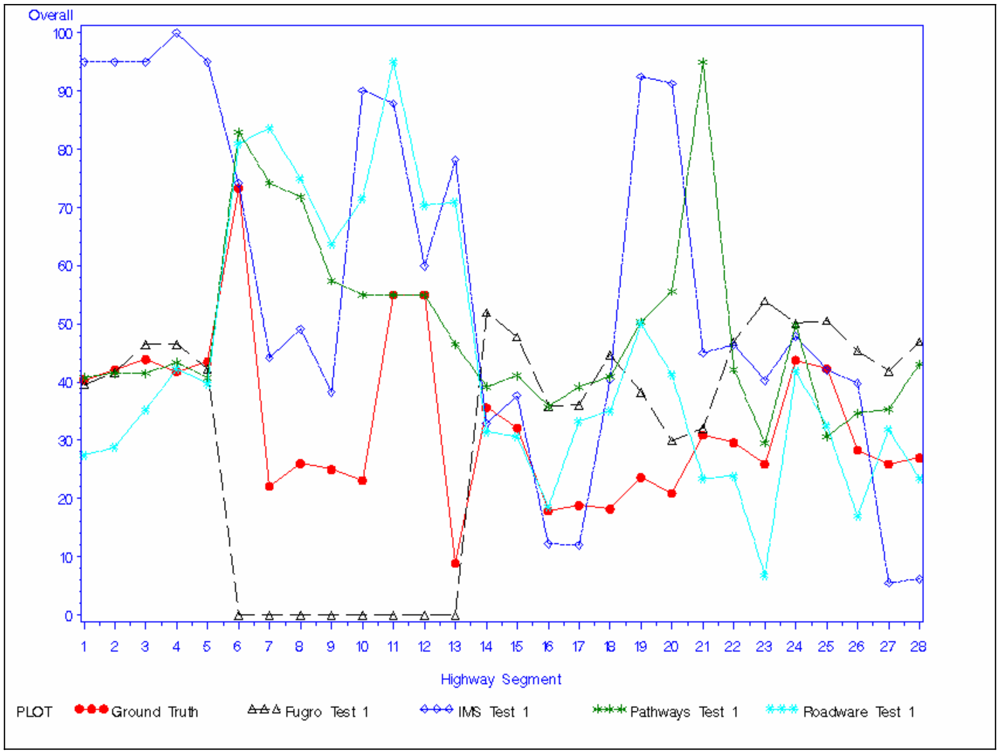


Figure 5.7: Overall Index comparing ground truth and ADC equipment

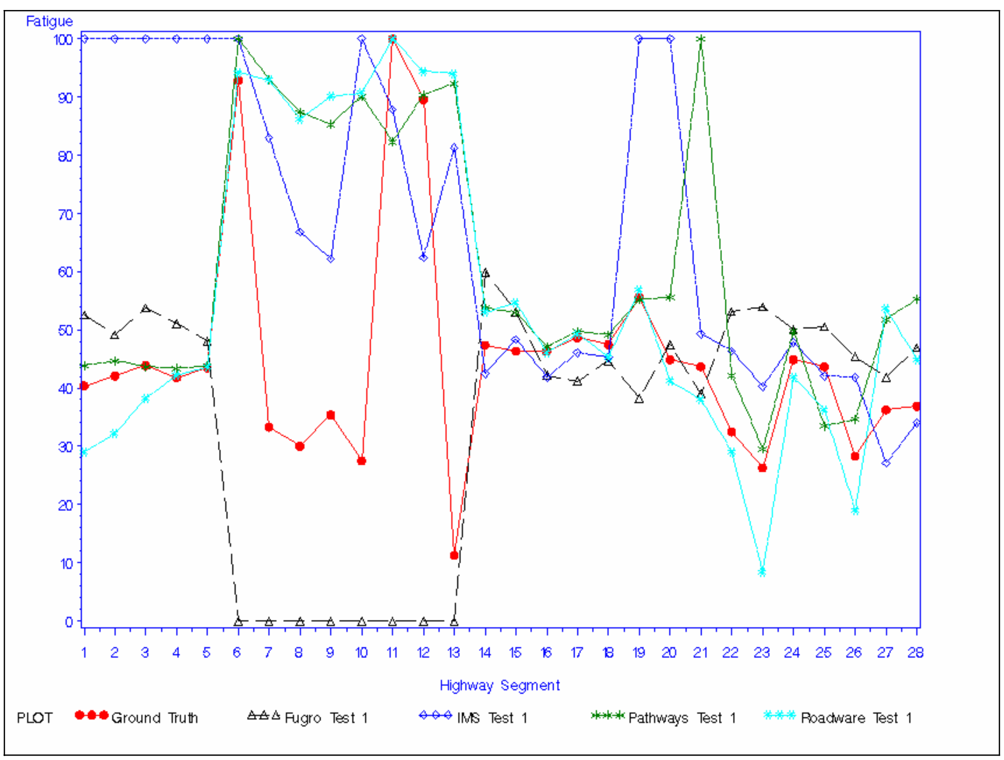


Figure 5.8: Fatigue Index comparing ground truth and ADC equipment

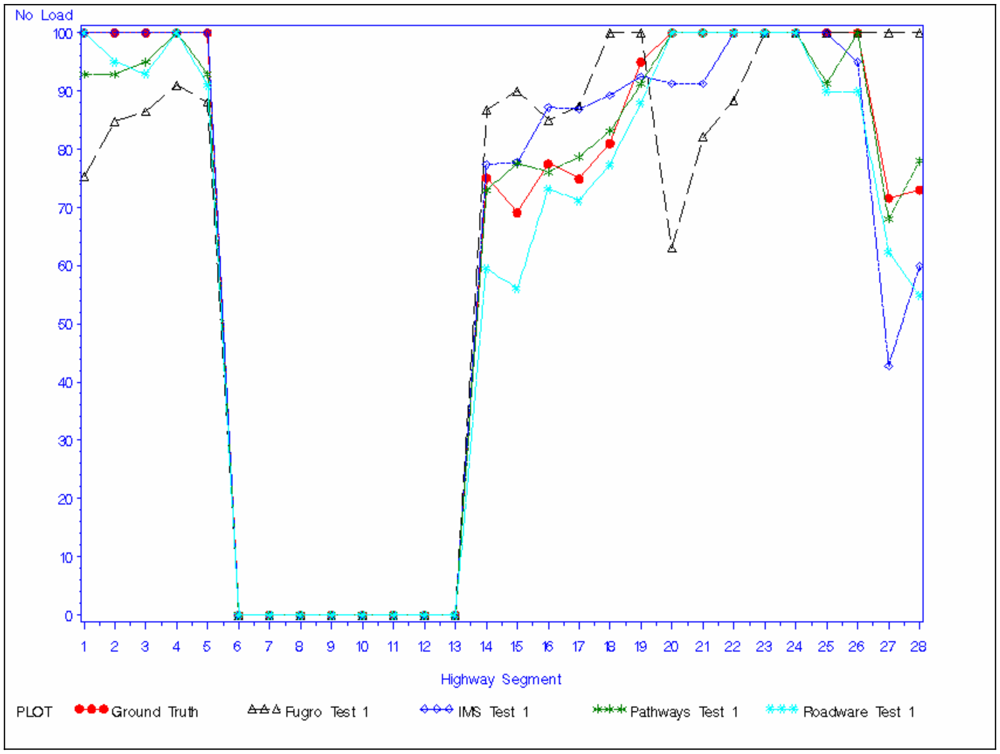


Figure 5.9: No Load Index comparing ground truth and ADC equipment

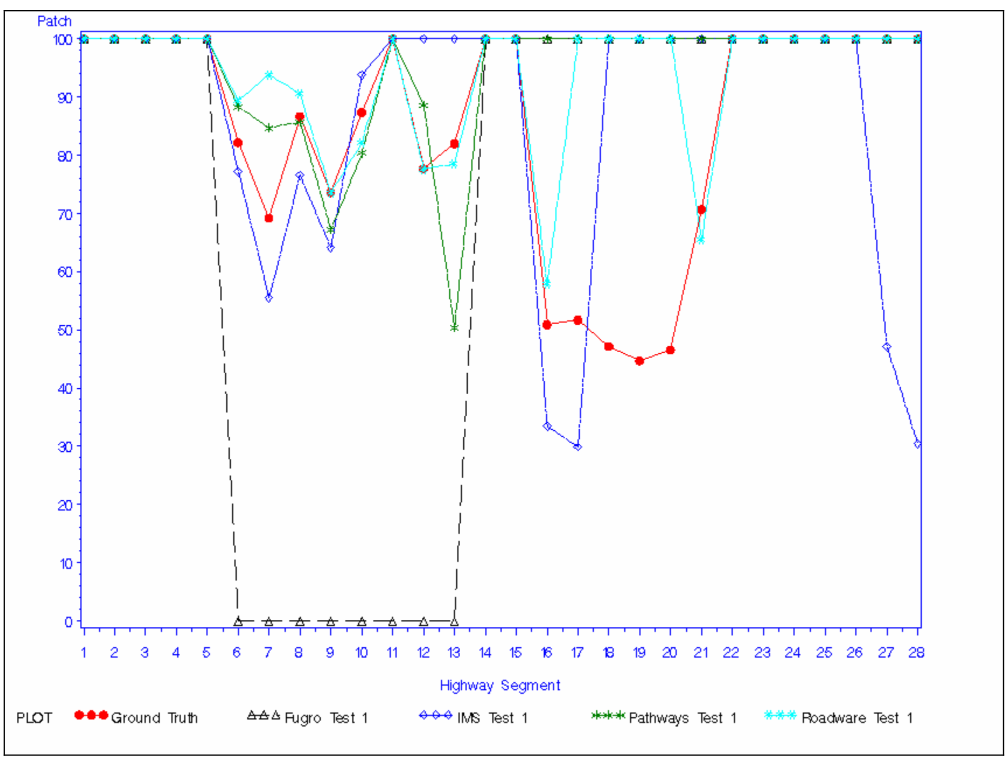


Figure 5.10: Patching Index comparing ground truth and ADC equipment

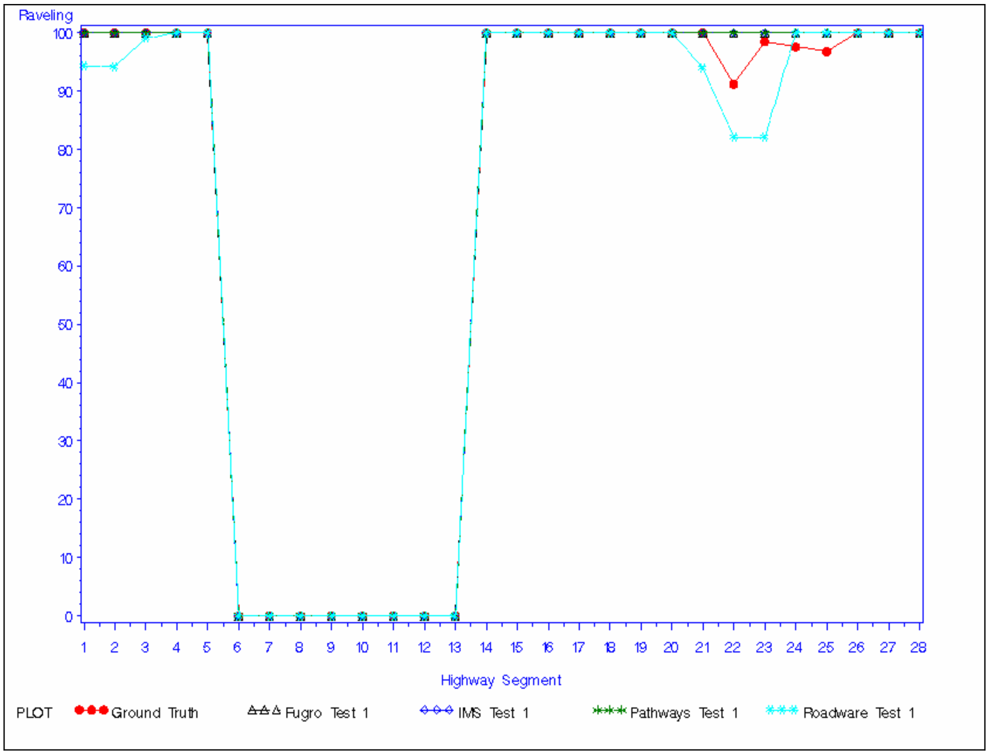


Figure 5.11: Raveling Index comparing ground truth and ADC equipment

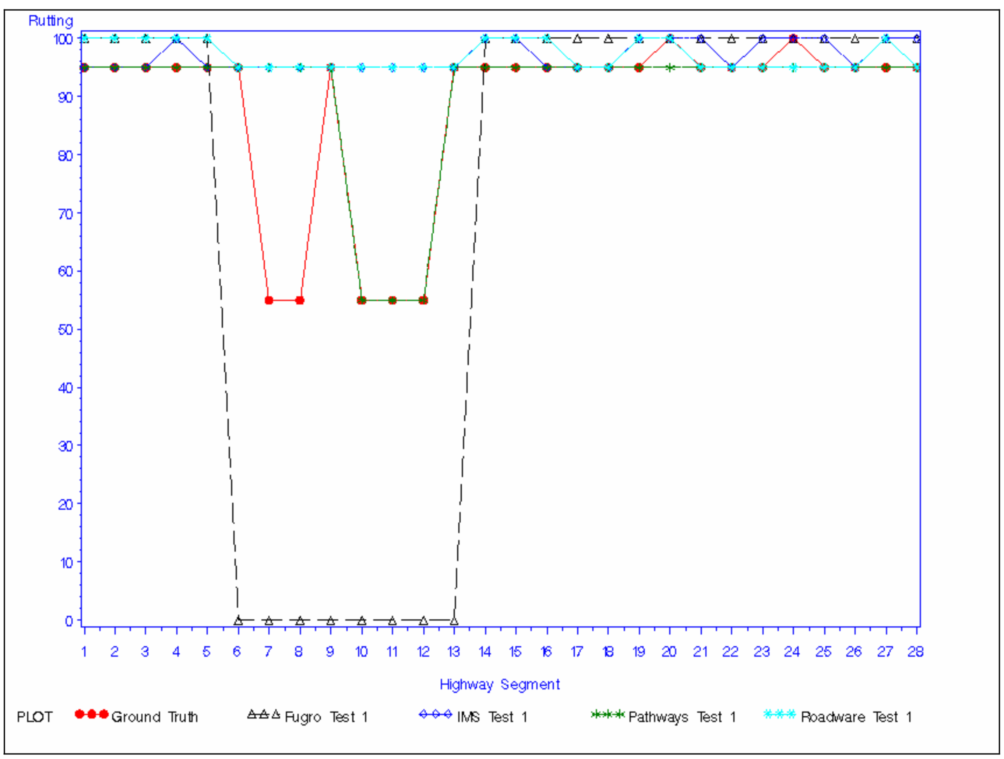


Figure 5.12: Rutting Index comparing ground truth and ADC equipment

### 5.1.2 Correlation analysis

To substantiate the above observations a correlation analysis was done comparing each of the rating crews and each of the ADC equipment vendors to the ground truth, for each of the six variables. The results of this analysis are shown in Table 5.1.

**Table 5.1: Correlations between ground truth measurements and pavement raters for pavement variables**

| Index | | Fugro | IMS | Pathway | Roadware | Rating Crew 1 | Rating Crew 2 | Rating Crew 3 |
|---|---|---|---|---|---|---|---|---|
| **Overall** | Pearson's R | -0.08 | 0.37 | 0.21 | 0.26 | 0.49 | 0.21 | 0.34 |
| | Significance | 0.693 | 0.053 | 0.282 | 0.183 | 0.008* | 0.285 | 0.079 |
| **Fatigue** | Pearson's R | -0.26 | 0.2 | 0.27 | 0.37 | 0.56 | 0.4 | 0.33 |
| | Significance | 0.186 | 0.302 | 0.164 | 0.056 | 0.002* | 0.033* | 0.086 |
| **No Load** | Pearson's R | 0.94 | 0.98 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| | Significance | <0.001* | <0.001* | <0.001* | <0.001* | <0.001* | <0.001* | <0.001* |
| **Patching** | Pearson's R | 0.07 | 0.29 | 0.12 | 0.38 | 0.73 | 0.74 | 0.68 |
| | Significance | 0.707 | 0.139 | 0.548 | 0.046* | <0.001* | <0.001* | <0.001* |
| **Raveling** | Pearson's R | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| | Significance | <0.001* | <0.001* | <0.001* | <0.001* | <0.001* | <0.001* | <0.001* |
| **Rutting** | Pearson's R | 0.74 | 0.39 | 0.74 | 0.37 | 0.8 | 0.68 | 0.52 |
| | Significance | <0.001* | 0.036* | <0.001* | 0.049* | <0.001* | <0.001* | 0.005* |

* Indicates a statistically significant correlation at or less than the .05 level.

Two distinct patterns emerge from the data in Table 5.1. First, all seven of the groups, (the four ADC systems and the three rating crews), were significantly correlated with ground truth for three variables—No Load, Raveling, and Rutting. That is, all of the ADC systems and the rating crews showed statistically significant agreement with the ground truth evaluations of the 28 highway segments.

Second, the rating crews did as well as or better than the ADC systems in matching to ground truth measurements. Three of the ADC systems had three statistically significant correlations to ground truth data, and one ADC system had four. One of the rating crews had statistically significant correlations to ground truth across all six variables; one rating crew had five such correlations; and the third rating crew had four significant correlations.

Thus, all of the rating crews performed at least as well as or better than any of the ADC systems. These relationships are clearer when shown in the matrix in Table 5.2.

**Table 5.2: Statistically significant correlations to ground truth data by group and variable group**

| Index | Fugro | IMS | Pathway | Roadware | Rating Crew 1 | Rating Crew 2 | Rating Crew 3 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **Overall** | | | | | * | | |
| **Fatigue** | | | | | * | * | |
| **No Load** | * | * | * | * | * | * | * |
| **Patching** | | | | * | * | * | * |
| **Raveling** | * | * | * | * | * | * | * |
| **Rutting** | * | * | * | * | * | * | * |

* indicates a statistically significant correlation at or less than the .05 level.

The table shows that the measurements provided by all raters (crews and ADC systems) were significantly correlated with the ground truth for the No Load, Raveling, and Rutting Indices. Only one ADC system, however, provided measurements correlated with the ground truth for the Patching Index, while all three of the rating crews' measurements correlated with ground truth on this index. None of the ADC systems provided measurements correlated with the Fatigue Index or the Overall Index. Two of the rating crews provided measurements that correlated well with the Fatigue Index, and one crew provided measurements that correlated well with the Overall Index.

### 5.1.3 Comparison of mean values to ground truth

Dunnett's Two-tailed T-test compares the means of the data groups against the mean of a control group. This technique differs from that of correlation analysis, which looks at the strength of the relationship between variables. The data consisted of the mean values across the 28 highway segments for each of eight data groups (4 ADC systems, 3 rating crews and 1 ground truth), for each of the six pavement condition indices. Hence the comparisons are of the mean values for seven groups against the mean values for the ground truth data (the control group).

Table 5.4 presents the results of the analysis. Listed in each column are the groups whose means are <u>not</u> statistically different from the ground truth mean.

**Table 5.4: Dunnett's Two-tailed T-test results**

| Overall | Fatigue | No Load | Raveling | Patching | Rutting |
|---|---|---|---|---|---|
| Rating Crew 1 | Rating Crew 1 | Rating Crew 1 | Rating Crew 1 | Rating Crew 1 | Rating Crew 1 |
| Rating Crew 2 | Rating Crew 2 | Rating Crew 2 | Rating Crew 2 | Rating Crew 2 | Rating Crew 2 |
| Fugro | Fugro | Rating Crew 3 | Rating Crew 3 | Rating Crew 3 | Rating Crew 3 |
| Roadware | Pathway | Fugro | Fugro | Fugro | IMS |
| | Roadware | IMS | IMS | IMS | Pathway |
| | | Pathway | Pathway | Pathway | Roadware |
| | | Roadware | Roadware | Roadware | |

The results of this analysis may be summarized as follows for each pavement condition index:

<u>Overall:</u> Only the means of IMS, Pathway and Rating Crew 3 were significantly different from the mean of the ground truth control.

Fatigue: Only the means of IMS and Rating Crew 3 were significantly different from the mean of the ground truth control.

No Load: No group was significantly different from the mean of the ground truth control.

Raveling: No group was significantly different from the mean of the ground truth control.

Patching: No group was significantly different from the mean of the ground truth control.

Rutting: Only the Fugro mean was significantly different from the mean of the ground truth control.

Although the Rating Crew 3 and IMS means differed significantly from the ground truth in two cases, there is an absence of any consistency in the results that would show differentiation among the ADC systems or indicate that any one ADC system was superior to any other system, or superior to the rating crews. The reason for this may be that the amount of data available for the analysis was limited.

### 5.1.4 Comparisons among raters for agreement

To test for agreement among the rating crews and among the ADC systems, Duncan's Multiple Range Test was used. This test examines the means for each variable and groups the means in "runs" where the mean values are not statistically different from each other.

The data consisted of the mean values across the 28 highway segments for each of eight raters (four ADC systems, three rating crews and the ground truth), for each of the six pavement condition indices. The results of the analysis are shown in Table 5.3. The vertical dotted lines under each index show the raters whose mean values had no statistically significant difference from one another.

**Table 5.3: Duncan Multiple Range Test results**

| Overall | Fatigue | No Load | Raveling | Patching | Rutting |
|---|---|---|---|---|---|
| IMS | IMS | Rating Crew 2 | Fugro | Pathway | Rating Crew 3 |
| Rating Crew 3 | Rating Crew 3 | Rating Crew 1 | IMS | Roadware | IMS |
| Pathway | Pathway | Ground Truth | Rating Crew 1 | Rating Crew 2 | Roadware |
| Roadware | Roadware | Fugro | Rating Crew 2 | Rating Crew 1 | Pathway |
| Rating Crew 2 | Rating Crew 1 | IMS | Rating Crew 3 | IMS | Ground Truth |
| Rating Crew 1 | Rating Crew 2 | Pathway | Pathway | Rating Crew 3 | Rating Crew 1 |
| Ground Truth | Ground Truth | Rating Crew 3 | Ground Truth | Ground Truth | Rating Crew 2 |
| Fugro | Fugro | Roadware | Roadware | Fugro | Fugro |

The results of the Duncan Multiple Range Test are summarized below for each variable.

Overall: Rating Crews 1 and 2 showed agreement with each other in two different runs along with the ground truth. No more than two of the four ADC systems showed agreement with each other in any given run.

Fatigue: Rating Crews 1 and 2 showed agreement with each other in two different runs along with the ground truth. Three of the four ADC systems showed agreement with one another, although not with the ground truth.

No Load: There were no statistically significant differences among the group means. Thus, there was good consistency among all raters, both rating crews and ADC systems.

Raveling: There were no statistically significant differences among the group means. Thus, there was good consistency among all raters, both rating crews and ADC systems.

Patching: There were no statistically significant differences among the group means, except for Fugro. Thus, there was good agreement among rating crews and agreement among three of the four ADC systems. The Fugro mean value showed a statistically significant difference from the others.

Rutting: In one run the mean ratings of Rating Crews 1 and 3 showed no statistically significant difference. In another run Rating Crews 1 and 2 showed agreement with each other and with the ground truth. Among ADC systems three out of four showed agreement with one another and with the ground truth. The Fugro system showed a statistically significant difference from the others.

The analysis using Duncan's Multiple Range Test shows that the agreement among the rating crews was limited, with all three rating crews showing agreement with one another in only three of the pavement condition indices and two out of three rating crews showing agreement in the other three indices. Rating Crews 1 and 2 showed agreement between each other across all indices.

The analysis shows that the agreement among the ADC systems was also limited, with all four systems agreeing with one another in only two indices, three out of four in agreement with one another in three indices, and agreement between only two systems in one of the indices. The IMS, Pathway and Roadware systems showed agreement among one another across five of the six indices.

### 5.1.5 Test of repeatability

Test sections 2 and 6 were rated twice by each rater. An analysis was conducted to determine how repeatable the measurements were from each of the ADC systems and ODOT rating crews. The analysis results showed fair to good repeatability. However, due to the small number of data points and the fact that not all of the raters had data for every variable, it was determined that the results were inconclusive.

### 5.1.6 Summary of Results

The approach used in the above analysis is different than that used in previous studies. Past studies have focused on the automated equipment's ability to accurately measure various distress types and severities. The analyses in this study, however, compared ADC system measurements to a ground truth measure to evaluate the automated equipment's ability to provide index values that are as good as or better than ODOT's current data collection methods.

The correlation analysis showed that the rating crews varied in their agreement with the ground truth data. One rating crew agreed with the ground truth on all six pavement condition indices; one crew agreed on five of the indices; and one crew agreed on four of the indices.

The correlation analysis also showed that the ADC systems varied in their agreement with the ground truth, although not doing as well as the rating crews. The Roadware system data correlated significantly with ground truth on four of the six indices; the Fugro, IMS and Pathway system data correlated significantly on only three of the six indices.

The conclusion reached on the basis of the Dunnett test was that there was no evidence that any of the four ADC systems matched the ground truth data consistently, nor that the ADC systems were consistently more accurate than the pavement condition rating crews in matching to ground truth data.

The Duncan Multiple Range Test showed that the agreement among all three rating crews was limited, although Rating Crews 1 and 2 showed good agreement on all six pavement condition indices. The agreement among all ADC systems was also limited. Three of the automated systems did show good agreement across five of the six pavement condition indices.

These analyses confirmed that, 1) overall, the rating crews were usually better, and always as good as, the chosen ADC systems in being able to match to ground truth data; and 2) the ADC systems were not consistently able to match to ground truth measurements.

There are a couple of key issues that should be mentioned. First, the Overall Index is heavily weighted on Fatigue cracking and Patching; thus any errors in identifying severity levels and quantity in those indices will have a large impact on the Overall Index. The second issue is that it appears from an examination of the data that the Fugro automated system's rating of the CRC pavement sections was likely incorrect, apparently from incorrectly using the distresses for asphalt pavements. Therefore on the CRC sections the Fugro ratings compared poorly with the ground truth and other raters.

## 5.2 RAW DATA ANALYSIS

An investigation was also conducted on how well the raters were able to accurately measure individual distress types and severities. For each distress type and rating method, a comparison was made for each severity level and for total distress quantity with the ground truth ratings. The following analysis presents some casual observations on how well the rating methods were able to match the ground truth quantities.

Table 5.5 below shows the results of fatigue cracking measurements for each group.

**Table 5.5: Fatigue cracking measurements**

| | Low Severity | % of Ground Truth | Moderate Severity | % of Ground Truth | High Severity | % of Ground Truth | Total Quantity | % of Ground Truth |
|---|---|---|---|---|---|---|---|---|
| **Ground Truth** | 6,243 | | 3,792 | | 0 | | 10,018 | |
| **Rating Crew 1** | 4,669 | 75% | 3,612 | 95% | 0 | | 8,261 | 82% |
| **Rating Crew 2** | 3,960 | 63% | 3,937 | 104% | 0 | | 7,872 | 79% |
| **Rating Crew 3** | 5,162 | 83% | 2,759 | 73% | 15 | | 7,907 | 79% |
| **Roadware** | 3,615 | 58% | 3,494 | 92% | 1,985 | | 9,080 | 91% |
| **Pathway** | 5,647 | 90% | 1,512 | 40% | 0 | | 7,126 | 71% |
| **Fugro-BRE** | 978 | 16% | 1,744 | 46% | 179 | | 2,900 | 29% |
| **IMS** | 9610 | 154% | 1,822 | 48% | 0 | | 11,402 | 114% |

For low severity fatigue cracking, the ODOT rating crews identified 63% to 83% of the ground truth quantity. The ADC systems identified 16% to 154%. For moderate severity fatigue cracking, the rating crews ranged from 73% to 104% of the ground truth quantity. The ADC systems ranged from 40% to 92%. There was no high severity fatigue cracking identified in the ground truth survey. One of the rating crews identified a small quantity of this severity; two of the automated systems identified a much larger quantity. In terms of the total quantity of fatigue cracking, the ODOT rating crews ranged from 79% to 82% of the ground truth quantity. The automated systems ranged from 29% to 114%. Roadware was able to perform better than the rating crews in total crack identification; however, it had mixed results in the identification of individual severity levels. The other vendors did not compare well with the rating crews for total distress quantity.

Tables 5.6 and 5.7 below show the results for patching quantity for each group. The first table is for asphalt pavements and the second is for concrete pavement.

**Table 5.6: Patching quantity for asphalt pavements**

| | Low Severity | % of Ground Truth | Moderate Severity | % of Ground Truth | High Severity | % of Ground Truth | Total Quantity | % of Ground Truth |
|---|---|---|---|---|---|---|---|---|
| **Ground Truth** | 44,292 | | 0 | | 214 | | 44,506 | |
| **Rating Crew 1** | 41,300 | 93% | 0 | | 0 | 0% | 41,300 | 93% |
| **Rating Crew 2** | 38,454 | 87% | 0 | | 0 | 0% | 38,454 | 86% |
| **Rating Crew 3** | 45,505 | 103% | 0 | | 0 | 0% | 45,505 | 102% |
| **Roadware** | 5,367 | 12% | 22 | | 9 | 4% | 5,407 | 12% |
| **Pathway** | 2,831 | 6% | 4,409 | | 0 | 0% | 7,240 | 16% |
| **Fugro-BRE** | 0 | 0% | 0 | | 0 | 0% | 0 | 0% |
| **IMS** | 12,438 | 28% | 7,059 | | 960 | 449% | 21,417 | 48% |

The ODOT rating crews measured 87% - 103% of the ground truth quantity for low severity patching on AC pavements. The automated systems ranged from 0% to 28%. There was no moderate severity asphalt patching identified in the ground truth survey. The rating crews all had the same quantity as the ground truth. The ADC systems identified various quantities of moderate severity asphalt patching, ranging from 22 to 7,059 $ft^2$. None of the rating crews identified high severity asphalt patching compared to 214 $ft^2$ in the ground truth. Two vendors identified quantities of high severity patching. The rating crew measurements of the total asphalt patch quantity ranged from 86% to 102%. The ADC systems ranged from 0% to 48% of the total quantity. This suggests that the automated equipment is probably inadequate for patch identification on asphalt pavements.

**Table 5.7: Patch quantity for CRC pavements**

| | Low Severity | % of Ground Truth | Moderate Severity | % of Ground Truth | High Severity | % of Ground Truth | Total Quantity | % of Ground Truth |
|---|---|---|---|---|---|---|---|---|
| **Ground Truth** | 7,478 | | 0 | | 212 | | 7,690 | |
| **Rating Crew 1** | 9,275 | 124% | 0 | | 0 | 0% | 9,275 | 121% |
| **Rating Crew 2** | 7,550 | 101% | 0 | | 0 | 0% | 7,550 | 98% |
| **Rating Crew 3** | 8,300 | 111% | 0 | | 0 | 0% | 8,300 | 108% |
| **Roadware** | 5,355 | 72% | 0 | | 9 | 4% | 5,373 | 70% |
| **Pathway** | 2,831 | 38% | 4,409 | | 0 | 0% | 7,240 | 94% |
| **Fugro-BRE** | 0 | 0% | 0 | | 0 | 0% | 0 | 0% |
| **IMS** | 10,219 | 137% | 742 | | 0 | 0% | 10,961 | 143% |

The rating crews tended to overestimate low severity patch quantities on CRC pavements with measurements ranging from 101% to 124% of the ground truth quantity. The automated system results ranged from 0% to 137% of the ground truth quantity. There was no moderate severity concrete patching identified in the ground truth survey. All of the rating crews and two ADC systems matched the ground truth; the other two automated systems identified large quantities. Neither the rating crews nor the automated systems did very well in the identification of high severity concrete patching. ODOT rating crews ranged from 98% to 121% of the total concrete patch quantity. The automated systems ranged from 0% to 143% of the ground truth measure. Pathway did the best out of the automated systems in total patch quantities, but did not do well in terms of each individual severity level.

The transverse crack quantities are shown in Table 5.8. This analysis was only conducted for AC pavements. The reason is that transverse cracks are a normal occurrence in CRC pavements and in general are not considered a distress.

**Table 5.8: Transverse crack quantity**

| | Low Severity | % of Ground Truth | Moderate Severity | % of Ground Truth | High Severity | % of Ground Truth | Total Quantity | % of Ground Truth |
|---|---|---|---|---|---|---|---|---|
| **Ground Truth** | 34 | | 94 | | 19 | | 147 | |
| **Rating Crew 1** | 66 | 194% | 88 | 94% | 9 | 47% | 163 | 111% |
| **Rating Crew 2** | 67 | 197% | 42 | 45% | 2 | 11% | 111 | 76% |
| **Rating Crew 3** | 13 | 38% | 158 | 168% | 8 | 42% | 179 | 122% |
| **Roadware** | 75 | 221% | 144 | 153% | 48 | 253% | 267 | 182% |
| **Pathway** | 197 | 579% | 58 | 62% | 2 | 11% | 257 | 175% |
| **Fugro-BRE** | 96 | 282% | 58 | 62% | 25 | 132% | 179 | 122% |
| **IMS** | 192 | 565% | 25 | 27% | 0 | 0% | 217 | 148% |

All of the rating groups had a tendency to overestimate transverse cracking. The rating crews ranged from 38% to 197% of the ground truth for low severity. The automated systems ranged from 221% to 579%. For moderate severity, the rating crews ranged from 45% to 168% of the ground truth. The automated systems ranged from 27% to 153%. For high severity transverse cracks the rating crews ranged from 11% to 47%. The automated systems ranged from 0% to 253% of the ground truth. For total transverse crack quantity the rating crews ranged from 76% to 122%. The automated system results ranged from 122% to 182%. Thus the results were mixed for each of the rating methods on individual severity levels, but they indicate that most raters tended to overestimate transverse crack quantities.

Longitudinal cracking was divided between AC and CRC pavements. Table 5.9 shows the data for Asphalt pavements.

**Table 5.9: Longitudinal Crack Quantity for AC Pavement**

| | Low Severity | % of Ground Truth | Moderate Severity | % of Ground Truth | High Severity | % of Ground Truth | Total Quantity | % of Ground Truth |
|---|---|---|---|---|---|---|---|---|
| **Ground Truth** | 241 | | 135 | | 0 | | 376 | |
| **Rating Crew 1** | 440 | 183% | 57 | 42% | 0 | | 497 | 132% |
| **Rating Crew 2** | 270 | 112% | 0 | 0% | 0 | | 270 | 72% |
| **Rating Crew 3** | 2,685 | 1114% | 0 | 0% | 0 | | 2,685 | 714% |
| **Roadware** | 222 | 92% | 309 | 229% | 0 | | 531 | 141% |
| **Pathway** | 479 | 199% | 12 | 9% | 0 | | 491 | 131% |
| **Fugro-BRE** | 2,125 | 882% | 3,444 | 2551% | 313 | | 5,882 | 1564% |
| **IMS** | 4,665 | 1936% | 0 | 0% | 0 | | 4,665 | 1241% |

The performance of the raters for longitudinal cracking for AC pavements was very similar to that of transverse cracking in that most raters tended to overestimate the quantity of cracking. For low severity longitudinal cracking the rating crews ranged from 112% to 1114% of the ground truth quantity. The ADC systems ranged from 92% to 1936%. For the moderate severity longitudinal cracking the rating crews ranged from 0% to 42%. The ADC systems ranged from 0% to 2551%. There was no high severity longitudinal cracking identified in the ground truth. All raters matched this quantity except for one. For total longitudinal cracking, the ODOT rating crews ranged from 72% to 714% of the ground truth. The automated systems ranged from 131% to 1564%.

Table 5.10 shows the data for longitudinal cracking on CRC pavement.

**Table 5.10: Longitudinal crack quantity for CRC pavement**

| | Low Severity | % of Ground Truth | Moderate Severity | % of Ground Truth | High Severity | % of Ground Truth | Total Quantity | % of Ground Truth |
|---|---|---|---|---|---|---|---|---|
| **Ground Truth** | 276 | | 80 | | 164 | | 520 | |
| **Rating Crew 1** | 315 | 114% | 45 | 56% | 65 | 40% | 425 | 82% |
| **Rating Crew 2** | 45 | 16% | 165 | 206% | 50 | 30% | 260 | 50% |
| **Rating Crew 3** | 230 | 83% | 0 | 0% | 0 | 0% | 230 | 44% |
| **Roadware** | 237 | 86% | 0 | 0% | 0 | 0% | 246 | 47% |
| **Pathway** | 304 | 110% | 0 | 0% | 0 | 0% | 304 | 58% |
| **Fugro-BRE** | 281 | 102% | 630 | 788% | 187 | 114% | 1098 | 211% |
| **IMS** | 1349 | 489% | 530 | 663% | 0 | 0% | 1879 | 361% |

The rating crews ranged from 16% to 114% of the ground truth quantity for low severity longitudinal cracking on CRC pavement. The ADC systems ranged from 86% to 489% of the ground truth quantity. Roadware, Pathway and Fugro were all closer to the ground truth than the rating crews were. The rating crews ranged from 0% to 206% of the ground truth for moderate severity cracking. The automated systems ranged from 0% to 788%. Two of the systems did not identify any moderate severity cracking, while the other two greatly exceeded the ground truth quantity. For high severity longitudinal cracking, the rating crews ranged from 0% to 40% of the ground truth quantity. Three of the ADC systems did not identify any high severity distress while the fourth reported 114% of the ground truth quantity. For total longitudinal cracking on CRC pavement, the rating crews ranged from 44% to 82%. The ADC systems ranged from 47% to 361%. Roadware and Pathway performed similarly to the rating crews, while Fugro and IMS reported much larger quantities.

The last distress to be evaluated was punchouts on CRC pavement. The ground truth identified a total of 31 punchouts of various severity levels. The ODOT rating crews reported a total of 0, 35, and 53 punchouts respectively. None of the automated systems identified any punchouts.

### 5.2.1 Summary of raw data analysis

The results for each distress type are mixed when the rater quantities are compared to the ground truth values by individual severity levels. However, the following general observations may be made.

- Ratings crews tended to be better than the ADC systems at identifying patching by severity level on AC pavements.
- The rating crews tended to report more patch quantities by severity level on CRC pavement, but they generally provided values closer to the ground truth than the ADC systems did.
- Transverse and longitudinal cracking reports were mixed for all raters by severity level.
- The automated equipment was not able to identify punchouts on CRC pavement.

In terms of measuring total distress quantities for individual distresses, the following observations can be made:

- The Roadware system appeared to be as good as or better than the rating crews at measuring the total quantity of fatigue cracking in this study.
- The ADC systems were unable to adequately measure patching on asphalt pavements.
- The Pathway Services system seemed to be slightly better at identifying total patch quantities on CRC pavements than the rating crews but showed mixed results for each severity level.
- The ADC systems tended to report larger totals of transverse and longitudinal crack quantities than the ground truth showed.
- Overall, the rating crews appeared to provide data that better matched the ground truth than the automated system data did.

## 5.3 VIDEO LOG EVALUATION

As part of the contract, each vendor was required to provide ODOT with a video log of each test section. Each video log was evaluated by ODOT staff members according to the criteria shown below.

Image Quality

- Mandatory Items
  - How much of the road can be seen? (lanes, shoulders, signs on right of way mandatory)
  - Is there enough data on the image for legal use in court? (Date, location) (Yes, No)
  - Ability to create a continuous video, which can be put on VHS tape, from snapshots. (Yes, No)

- Other
  - Is the view adjustable? (Yes, No)
  - Is the image stable, no jittering? (Rate 1-10)
  - Are signs legible? (Rate 1-10)
  - Is this continuous video or snapshots taken at intervals? If these are snapshots taken at intervals, is the distance selectable? (Yes, No)

Location/referencing method

- Mandatory Items
  - Is the index by highway number and milepoint, or something else like latitude/longitude?

- Other
  - Is the video on a tape that must be fast-forwarded, or is there digital indexing or both?

- Will we be able to merge the video with current GIS efforts/tools? (Not sure how to measure this. Although subjective, a "Yes, No" may be best)

Availability of video to the rest of the world

- Mandatory Items
  - Do users need to purchase special software/hardware? (Yes, No)
  - Can we make copies of the video without additional cost/licensing? (Do we own it?) (Yes, No)
  - What will be the update cycle on the highways?

- Other
  - Is video delivered only on VHS? (not on CD or DVD) (Yes, No)

Other Uses

- Mandatory Items
  - Is a rear and/or side view video available so we can avoid driving in both directions on most highways? (Yes, No)

- Other
  - Can we measure features from the video image?

The contract specifications allowed the vendors to submit video log images on VHS, CD, or DVD. One vendor provided images on VHS; two vendors provided CDs; and one vendor provided data on DVD. At the time, DVD technology was just becoming a popular item on personal computers. Due to the limitations of the ODOT computer system, however, we were unable to view and evaluate the DVD images. Therefore, only three of the four vendors' video log images were evaluated.

All of the vendors were able to meet the test criteria for technical issues such as indexing and GIS capabilities. Evaluation of the images, however, showed that while they were adequate, the image quality was lower than ODOT was currently getting using its custom built video logging system. Sign legibility was a major issue. Signs that were close to the roadway were legible, but the farther away from the roadway they were located, the less distinct the lettering became.

# 6.0 DISCUSSION OF RESULTS

The intent of this research project was to determine if automated data collection equipment could provide data as good as or better than ODOT's current methods. Overall the analysis indicates that at the time of this evaluation, ODOT's current methods for video logging and pavement condition data collection yield superior results to those provided by the ADC equipment. In terms of pavement condition data collection, the ADC systems were not able to consistently match the ground truth data. The main problems with the video log data was image stability and overall quality. Thus the evaluators conclude that ODOT's current technology provides an equal or better quality product.

Although the results of this research suggest that at the time of this study the automated technology did not provide the quality of data desired by ODOT, the survey responses from other states indicate that most of the states using automated data collection technology for pavement distress surveys are satisfied with the results it provides. There are several advantages to automated data collection that cannot be dismissed.

1. Automated equipment has the potential to consolidate several current data collection activities. These activities include the ODOT video log, pavement smoothness evaluation, and pavement condition evaluation. Consolidating these efforts could greatly improve the efficiency of ODOT's data collection efforts by reducing the number of trips required over the same segment of highway to collect various data elements.

2. ADC systems improve data collection safety by reducing the number of ODOT employees exposed to the hazards of traffic. It currently requires 12 ODOT employees to collect the data noted in No. 1 above. By using automated equipment, this number could be reduced to two people. That is a significant reduction in the number of people on the highway exposed to traffic. In the past several years, at least three roll-over accidents have occurred in the course of pavement and video data collection.

3. ADC systems provide a permanent visual record of the pavement surface. Although this may not sound like a big advantage, it can reduce travel and the effort involved in validating pavement condition information. The permanent record would allow raters or other pavement management staff to check the video to verify data prior to having to travel to the field to make this verification.

4. ADC systems provide a database of roadside features such as signs, guardrail, median barrier, etc. Currently ODOT has a corporate database for highway inventory information. However, many of the various data managers also have their own databases which are not always available to others in the department. If the data is available, it is typically scattered or inaccurate. Having a centralized database for accurate roadside feature information would provide a significant benefit in project selection and scoping.

The advantages listed above could provide a significant benefit to the department in terms of efficiency, cost savings and improved safety. However, before these can be realized, the following obstacles need to be overcome:

1. Quality of the video log images.

2. Quality of pavement distress data.

3. Setting up the system to collect all of the information required by the pavement and video log groups. Currently, the video logs are recorded for both directions of the highway, whereas the pavement data is collected in one direction only.

Although these obstacles are very important, and solutions are required prior to making a long term commitment to using ADC technology, there are steps that can be taken to overcome them.

# 7.0 RECOMMENDATIONS

The recommendations provided herein are targeted at overcoming the obstacles presented in the previous section.

1. Develop specifications that will provide the required video log quality. The video log evaluation criteria used in this research project and our current system provide a suitable starting point for developing specifications for automated equipment. The specification should include all of the mandatory items from the evaluation criteria and address image resolution, sign legibility, etc.

2. Pavement distress data accuracy is a very critical element of using automated equipment. Although this analysis shows that the automated equipment does not provide the required data quality at this time, there may be ways that ODOT can change the way distresses are defined or measured that could improve the quality of automated data. AASHTO is developing distress data protocols aimed at improving automated data quality. ODOT should evaluate the use of these protocols for improved automated data quality. In addition, ODOT should consult with states that are currently using this technology to determine how they have overcome data quality issues.

The recommendations provided above are the first next steps in exploring the use of automated data collection technology and should be completed prior to moving forward to develop a service contract with a selected vendor. The purpose of the service contract would be to allow ODOT to:

- Evaluate the video log specifications developed in recommendation No. 1.
- Evaluate pavement condition data quality using the methods developed under recommendation No. 2.
- Evaluate the efficiency and cost effectiveness of the data collection process as it pertains to obstacle No.3.
- Fine tune video log quality specifications.
- Fine tune pavement condition data collection procedures to achieve desired quality.
- Develop specifications for a future service contract or equipment purchase.

The contract could be set up to collect data on a series of 100-mile groups. The service contract would be conducted in conjunction with ODOT's current data collection process. A 100-mile group would be rated and evaluated. After evaluation, ODOT and the vendor would work together to make modifications to the technology or specifications in an effort to achieve the desired data quality. After modification, the next 100-mile group of highways would be rated and evaluated to determine the effect of the modification. In this way an automated data collection system could be refined sufficiently for use on Oregon highways.

# 8.0 REFERENCES


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# APPENDICES

# APPENDIX A: SMOOTHNESS DATA COLLECTION SURVEY

## States Survey on Automated Data Collection
## Smoothness Data

The Oregon Department of Transportation is evaluating automated data collection as part of a research project. The project is evaluating automated equipment that can collect pavement distress, smoothness and right-of-way video data in a single operation. As part of the study, we are collecting information on the practices of other states.

Please complete the survey and return to: Joni Reid, Oregon Department of Transportation, 200 Hawthorne, SE, Suite B-240, Salem, OR 97310-5192, fax to 503-986-2844, or e-mail to joni.e.reid@odot.state.or.us

Please complete the table below for the types of **Smoothness** data you collect:

| Completed by: | State: | Phone: |
|---|---|---|
| 1. How frequently do you collect **smoothness** data? | | |
| 2. What percent of the system is surveyed annually? ___________<br>Annual Amount: ____________ Lane miles or __________ Centerline miles<br>Surveys are based on a ______ percent sample, where 100% means that the entire length of the highway is surveyed; 10% means that 1/10th of each mile is surveyed, etc.<br>*If you survey a 100% sample, what percentage is used for smoothness calculations?* __________<br>Which lane or lanes are surveyed? ____________________<br>Are surveys conducted in one direction or both directions? ____One ____Both<br>Total System Miles: ____________ Lane miles or __________ Centerline miles | | |
| 3. Time Required to Collect Data: | | |
| 4. Data Collected: How satisfactory are the results?<br>_____ by a service Excellent Good Fair Poor<br>*Who?* ____________________<br>_____ use DOT equipment Excellent Good Fair Poor<br>*Manufacturer:* ____________________<br>_____ other: ____________________ Excellent Good Fair Poor<br>a) How long have you owned the equipment or used the service?<br>b) Does the system collect GPS data? ____yes ____no | | |

**States Survey on Automated Data Collection**
**Smoothness Data**

| |
|---|
| 5. What other data are collected at the same time?<br><br>____ Video of highway/features ____ Distress Data<br>____ Other: ________________________________ |
| 6. Sensors Information:<br><br>\# of Wheelpath sensors: ____ optical, ____ ultrasonic, ____ laser, ____other<br>\# of other sensors: ____ optical, ____ ultrasonic, ____ laser, ____ other<br><br>a) What is the longitudinal distance between measures? ________________________________<br><br>b) How many sensors are used for collecting rut measurements? __________________________ |
| 7. What Quality Control measures do you use for<br>a) Data Collection:<br><br>b) Data Processing |

**If your agency has recently purchased automated equipment for smoothness/ride data collection, please attach copies of RFP's and/or equipment specifications.**

Thank you for completing this survey.

Questions? Call Joni Reid at 503-986-5805

# RESPONSES TO SMOOTHNESS DATA COLLECTION SURVEY

| | | | How many miles? | | | | | | | Data Collected | | | | | | | Sensors | | | | Quality Control | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STATE | How frequently data is collected | % of system annually | # Lane Miles | # C/L Miles | Based on a ____% sample? | What % used for smoothness calculations? | Which lanes are surveyed | one or both directions | Total System Miles | Time required to collect | Use a service | Use DOT equipment/ manufacturer | How satisfactory are results? | How long owned or used? | Collect GPS data? | What data collected at the same time | # of Wheelpath sensors | # of other sensors | Longitudinal distance between measures | How many sensors for rut measures | for Data Collection | for Data Processing |
| Arizona | Yearly | 100% | | 7,500 | 100% | 100% | travel lane | One on non-divided highway Both on divided highway | 7,500 centerline miles | 6 months | | yes/ K.J. Law | good | since 1989 | no | rut | 2 infrared sensors | 1 infrared sensor | one inch | three | year to year comparison | logic checks |
| California | Annually under our Pavement Condition Survey w/ high speed profiler. Sporadically as a spec requirement on construction projects w/ profilograph. | 80% | 40,000 | 15,000 | | | Both directions on two lane, outside two lanes and HOV lane on multi lane. | both | | varies from route to route, district to district. All measuring performed in a calendar year. | | yes/ Pathway | excellent | bought in 1999, began collecting in March 2000. | yes | video of highway/features | 2 laser | 1 laser | 3 inches (0.25 feet) | "other" laser sensor used for rut measuring. | Annual calibration, annual training update of operators. | Software used to check data for coverage, errors, etc. |
| Iowa | yearly on 1/2 Federal Aid system All primary and participating city & county. | 50% | | 10,000 | 100% | Average for Sections | N and E for 2-lane, inside for 4 lane. | one/both | 20,000 centerline miles | We don't set limits. We expect our data in time to update our PMIS by mid January | Iowa, based on SD guides | yes/ Iowa | good | 2 years for total system, ours for 10 years. | yes | distress data/ we collect other data with other vehicles. | 2 laser | 15 ultrasonic | 3 inches +/- | all | our own equipment | our own program, we were entering this data before. We hired a service, now we download their information directly. |
| Louisiana | every other year | 100% | | 16,000 | 100% | 100% | outside lane | one on undivided hwy, both on divided hwy | 16,000 centerline mile | one year | Roadware | | excellent | 3 cycles | yes | video of highway-features/ distress data | 2 laser | 1 laser | 2 inches | 3 | Vendor has designated sites in each district for quality control rerun each week; also DOTD has setup calibration sites where all equipment has to be calibrated before they start any new district. We compare equipment results from these calibration sites with our results done by our research center's equip. | Data received on IRI is checked using computer to highlight any thing less than 50 inch/mile or greater than 570 inch/mile. Both numbers come from HPMS. This doesn't mean values are incorrect, it is a warning, or need to check DVD's for equipment malfunction. Use 50 as perfect road, and 570 as very bad. Check left wheel path against right wheel path of greater than 100 inch/mile. |
| Massachusetts | Annually | 40-50% | 6,000-8,000 | | 100% | 100% | outside | one on one lane roadways, both on multilane roadways | 3,000 centerline miles | 5-6 months | | yes/ TXDOT | excellent | Used profilers for past 5 yrs. Before that we used SiOmeters; Before that we used Mays Ride Meters | yes | | 2 laser | | 6 inches | 5 | Calibrate equipment annually at TTI Annex. Run Control sections daily to verify calibration. | Field check prior to submission. Final check in Division - compare to last years data. |
| Minnesota | half of each district a year | 60-70% | | 7,000 | 100% | 100%, each mile is rated separately | outer lane | both | 12,500 centerline miles | start when snow and frost are gone & are done by late summer/early fall. It takes about 3-4 days per District, have 9 Districts, so about 8-9 weeks field time. | | yes/ Pathways Services | excellent | since 1996. Purchased another last summer, so have 2. | yes | video of highway-feaures/ distress data | 2 laser / (old van 2 laser) | 3 laser / (old van 1 laser) | We store the average of the laser readings every 3 inches (about 24 readings, one every 1/8 inches or so. | 3 on old van, 5 on new van | nothing formal beyond occasional calibration. | Nothing formal. We have 2 raters who work close together with the data collector. |
| Mississippi | 2 years | 0 | 13,000 | | 100% | 100% | outside lane | both | 13,000 lane miles | 3-4 months | Pathway Services | yes/ ICC South Dakota Profiler, used for calibration and QA | excellent | 10 years | yes | video of highway-features/ distress data | 3 laser | | 6 inches to 1 foot | 3 | Hard and soft calibration while contractor collects data-sites including each pavement type. We sample of 5% of each pavement type, 5% of each distress type, and 5% of short analysis sections (1/2 mile or shorter) | Same as above, the two go hand-in-hand |
| Montana | annually | 100% | 24,000 | | 100% | 100% | all | both | 24,000 lane miles | 2 machines, 3 months | | yes/ ICC | excellent | 10 years | no | rut | 2 laser | 1 laser | | 3 | manufacturers and MDT recommended calibration and verification procedures | there are some built in controls and checks in our upload program that loads the data into Oracle tables |
| Nebraska | annually | 100% | | 10,000 | 100% | 100% | usually the outside lane. Interstate roads are tested in the driving lane on PCC pavement. 4-lane interstate bituminous or composite roads are tested in all lanes. | one | | 3 months | | yes/ International Cybernetics Corporation | good | Used the Laser Profiler since 1997. Used the acoustic profiler 1989-1996. Before that we used the Mays Ride Meter. | yes, starting in 2000 | video of highway-features | 2 laser | 1 laser | approx. 3 inches | three | The lasers are calibrated with a straight edge at least annually. The lasers are calibrated every time they are removed or moved on their bumper mountings. The operation of the sensors and accelerometers are checked at least twice daily. The units test our special correlation sites before and after the testing season and monthly during the testing season. | A program has been set up to flag unusually high readings. The rest of the data is checked on a random sampling basis comparing it to the previous years data |

# RESPONSES TO SMOOTHNESS DATA COLLECTION SURVEY

| STATE | How frequently data is collected | % of system annually | How many miles? # Lane Miles | # C/L Miles | Based on a ____% sample? | What % used for smoothness calculations? | Which lanes are surveyed | one or both directions | Total System Miles | Data Collected: Time required to collect | Use a service | Use DOT equipment/ manufacturer | How satisfactory are results? | How long owned or used? | Collect GPS data? | What data collected at the same time | Sensors: # of Wheelpath sensors | # of other sensors | Longitudinal distance between measures | How many sensors for rut measures | Quality Control: for Data Collection | for Data Processing | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nevada | Odd years, the entire system. Even years, NHS, only. Odd years also include HPMS. | 100% in odd years/ 39% in even years | | HPMS, not on maintained system, 399 cl miles. Maintenance system 5,439 cl miles, NHS only 2,147 cl miles. | 100% | 100% | most outside lane - travel lane | both | 2 X above centerline miles | odd years -14.5 weeks + an additional 2.5 weeks for HPMS that is off system. Even years - 3 weeks. | | yes/ International Cybernetics Corporation | Good | 8 years | no, however, it has the capability of doing so as their units are set up modularly. | can collect distress data on the fly if you want to, with use of an alternate key board, but we do not. | 2 ultrasonic with old unit. 2 laser with new unit to receive in March. | 1-3 ultrasonic with old unit. 1 laser with new unit to receive in March | approx. 1 foot | 3-5 (5 for specific Interstate projects). | compare to Dipstick, or low volume road that was previously done. | Our end result is IRI. We ensure that the data breaks are correct, uploaded data is correct, and that all segments have values that look correct for the age of the pavement. | |
| New York | once every two years for HPMS reporting | about 45% (every 2 years) | | 7,200 | 100% | In past, IRI calculated on entire section (varied from hundredths of a mile to 5 miles). Last year, used summary intervals of 0.1 mile for 100% of data. For 2001, plan to collect IRI on entire network (16,000 clm) at 0.1 mile summary intervals. | right travel lane | one | 40,000 lane miles, 16,000 centerline miles | about 3 months to collect data on 7,000 clm. Our 2001 contract offers a monetary incentive to the vendor to collect all the data in a single construction season, which would be 16,000 clm in about 7 months. | last vendor was CGH Pvt Eng. (formely PASCO USA) | | good | contracted for HPMS data collection biennially since 1989. | no | 2001 survey will collect some rut depth data | 2 laser | | 6 inches | 5 | Pre-collection validation at sites with known roughness and rutting; comparison of production data collected to known sites, and comparison of new data to historical data. | Manual review of data using GIS plots. | |
| North Dakota | yearly in the fall | 99-100% | 8,500 | | 100% | 100% | driving lane | one/ both - two lane highways are collected in the opposite direction of the previous year. | 8500 lane miles | 3 months of good weather - Sept - Dec. Jointed concrete miles collected after freeze-up to record faulting of joints at their worst condition. | | yes/ Pathway Service Inc. | Good | Since 9/96. Previously (1991-) had a Pavetech system from Rudy Blanco, now with Pathway. | yes, but not used for our GIS maps | video of highway/ features/ rutting/ faulting/ other distress data is evaluated from the pavement videos | 2 laser | 1 laser | 2.986 inches | 3 | Training drivers, try to use the same drivers each season. Calibrate the rut sensor height to a water-pan plain. Calibrate the DMI to a surveyed mile. Use a set test route to compare profile values to the previous week/season data. | In-house programs perform some edit checks. Extreme or missing profile data is verified and may be replaced with previous year data when the master file is uploaded to the mainframe information system database. | Road profile data used to calculate IRI, rutting, faulting and a RIDE index. Pathway software also has analysis tools which we use for IRI and rutting data. |
| Ohio | Annually for the network. Various or research/ projects | 100% less sections under construction | 23,500 | 19,300 | 100% | Essentially the entire network but only "typical" sections are considered. Bridges, RR crossings, culverts, etc are marked and not considered. | outside lane or "preferred" lane | on on undivided, both on divided | 48,200 lane miles, 19,300 centerline miles | two 2-man profilers operating roughly 40 hours/ week from April to Sept. or Oct. | | One ICC laser MDR 4040 profiler, one KJLaw infrared T-6450 profiler. | ODOT employees do an excellent job. The ICC is excellent equip., the KJLaw is fair to poor. | ICC profiler since the 1997 season and have put the equip. into a new van 2 years ago. We have had our KJLaw infrared profiler since Dec 1995. | no | nothing now, we hope to collect GPS as surface macro texture data with a new profiler. | ICC - 2 laser, KJL - 2 infrared | ICC - 1 laser, KJL - 1 infrared | ICC about 3 inches KJLaw at 6 inches | Each profiler sensor bar has 3rd center sensor for 3 pt. rut measures but we have no confidence in either 3 pt. data or readings from the 3rd sensor. | Standardize "raw" indices from each network profiler to "standard" KJLaw 690 DNC incandescent light profilometer. Profile a "measured" mile each week to track. One experienced staff there for all operations. Routinely adjust snesors to their vertical "sweet spots" as suspensions sag and tires wear to keep sendors within standoff adn operating ranges. | ICC profiler allows a summary view of "out of range" sensor efforts. For last 3 years, each data collection run has been scrutinized carefully. | Roughness data collected back to the BPR roughometer or the Mays ridemeter. Currently working on specs for new high speed profiler. |
| Oregon | annually | 50% | | 4,500 | 100% | 100% | truck lane | one | 8,437 | 6 weeks | | yes | good | 10 years | no | | ultrasonic | | 1.087 feet | 3 | Daily calibration using manufacturers recommendations | | |
| Pennsylvania | Annually on Interstate and NHS routes Every other year for non-NHS routes | 60% | | 23,000 | 100% | 100% | travel lane for network testing | one direction for undivided roadways, both directions for divided roadways. | 40,000 centerline miles | NHS data collected in-house - about 8 months needed, but testing is not continuous. Non-NHS data collected by contractor - 7 months of continuous work. | Roadware | yes/ International Cybernetics Corp. | Good (service & equipment) | Roadware contracted since 1997. PADOT owned ICC Profilers since late 1980's. In 2000 acquired 3 new profilers that replaced units acquired in 1996. | yes | video of highway-features/ distress data/ GPS, horizontal and vertical geometry, roadway feature locations. | 2 laser | 1 laser | 6 inches | 3 currently; the new profilers have capability to collect 5 point rutting, but have not implemented the additional 2. | Weekly tests over standard "reference" sites compared to historical data. Accelerometer and laser system check performed daily, tire pressures and air shock pressures checked weekly, Distance Measuring Instrument calibration monthly. | Results are programmatically compared to past results for the same location. Anomalies must be addressed. | |
| Texas | Annually | 100% | 186,000 | 76,000 | 100% | 100% | outside | one | | 3-4 months | | yes/ TxDOT | excellent | Used profilers for past 5 yrs. Before that used SiOmeters; before that Mays Ride Meters. | yes | | 2 laser | | less than 6 inches | 5 | Calibrate equip. annually at TTI Annex. Run Control sections daily to verify calibration. | Field check prior to submission. Final check in Division - compare to last years data. | |
| Virginia | Eventually it will be annually on Interstates and Primaries | 10% (13K/122K) | 13,000 defined as pass miles | | 100% | 20%, the first 10 feet of every 1/100th of a mile | rightmost lane but have provision to collect other lanes if desired by specifying which lane | one on non-divided primaries / both on interstates | 13,000 pass miles | 4-5 months | subcontractor to our prime contractor. Other: also have an academia involved research facility | yes, on project level analysis basis | vendor is fair but improving | 2 years now trying to get data delivered from vendor. The research facility has been collecting for years now and the VDOT equipment started within the last 3 years. | yes for vendor, no for VDOT and VTRC | video highway-features/ distress data | 2 laser | 3 laser | 45 mm | 5 | Another subcontractor performs the QC. VDOT performs a parallel QC and also performs a QA. | The subcontractor confirms that the processing is done properly, also VDOT has done linear referencing checks and identified problems to be addressed. | |

# APPENDIX B: DISTRESS DATA COLLECTION SURVEY

# States Survey on Automated Data Collection
# Distress Data

The Oregon Department of Transportation is evaluating automated data collection as part of a research project. The project is looking at automated equipment that can collect pavement distress, smoothness and right-of-way video data in a single operation. As part of the study, we are collecting information on the practices of other states.

Please complete the survey and return to: Joni Reid, Oregon Department of Transportation, 200 Hawthorne, SE, Suite B-240, Salem, OR 97310-5192, fax to 503-986-2844, or e-mail to joni.e.reid@odot.state.or.us

Please complete the tables below for the types of **Distress** data you collect:

| Completed by: | State: | Phone: |
|---|---|---|

1. How frequently do you collect **distress** data?

2. What percent of the system is surveyed annually? __________

Annual Amount: ___________ Lane miles or _________ Centerline Miles

Surveys are based on a ______ percent sample, where 100% means that the entire length of the highway is surveyed; 10% means that 1/10$^{th}$ of each mile is surveyed, etc.

*If you survey a 100% sample, what percentage is used for distress calculations?* ____________

Which lane or lanes are surveyed? ____________________________________________________

Are surveys conducted in one direction or both directions? ____One ____Both

Total System Miles: ___________ Lane miles or _________ Centerline Miles

3. Time Required to Collect Data:

4. Data Collected: How satisfactory are the results?

______ by a service — Excellent Good Fair Poor
*Who?* ________________________________________

______ use DOT equipment — Excellent Good Fair Poor
*Manufacturer:*__________________________________

______ other: ________________________________ — Excellent Good Fair Poor

a) How long have you owned the equipment or used the service?

b) Does the system collect GPS data? ____yes ____no

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## Distress Data

5. What other data are collected at the same time?

____ Video of highway/features ____ Smoothness/Ride Data

____ Other: ________________________________

6. What type of **asphalt pavement distress data** do you collect with automated equipment? (check all that apply)

| Asphalt Distress Data | Type of Measure | | | | # of Severity Levels |
|---|---|---|---|---|---|
| | Linear (✓) | Area (✓) | Other (✓) | If other, please explain: | |
| Fatigue Cracking | | | | | |
| Block Cracking | | | | | |
| Edge Cracking | | | | | |
| Longitudinal Cracking | | | | | |
| Reflection Cracking at Joints | | | | | |
| Transverse Cracking | | | | | |
| Patch/Patch Deterioration | | | | | |
| Potholes | | | | | |
| Rutting | | | | | |
| Shoving | | | | | |
| Bleeding | | | | | |
| Polished Aggregate | | | | | |
| Raveling | | | | | |
| Lane-to-Shoulder Dropoff | | | | | |
| Water Bleeding and Pumping | | | | | |
| Other: | | | | | |

7. What type of j**ointed portland cement concrete pavement distress data** do you collect with automated equipment? (check all that apply)

| JPCC Distress Data | Type of Measure | | | | # of Severity Levels |
|---|---|---|---|---|---|
| | Linear (✓) | Area (✓) | Other (✓) | If other, please explain: | |
| Corner Cracks | | | | | |
| Corner Breaks | | | | | |
| Durability Cracking ("D" cracking) | | | | | |
| Longitudinal Cracking | | | | | |
| Transverse Cracking | | | | | |
| Tranverse Joint Seal Damage | | | | | |
| Longitudinal Joint Seal Damage | | | | | |
| Spalling of Longitudinal Joints | | | | | |

## States Survey on Automated Data Collection
## Distress Data

| JPCC Distress Data | Type of Measure | | | | # of Severity Levels |
|---|---|---|---|---|---|
| | Linear (✓) | Area (✓) | Other (✓) | If other, please explain: | |
| Spalling of Transverse Joints | | | | | |
| Map Cracking | | | | | |
| Scaling | | | | | |
| Polished Aggregate | | | | | |
| Popouts | | | | | |
| Blowups | | | | | |
| Faulting of Transverse Joints and Cracks | | | | | |
| Lane-to-Shoulder Dropoff | | | | | |
| Lane-to-Shoulder Separation | | | | | |
| Patch/Patch Deterioration | | | | | |
| Water Bleeding and Pumping | | | | | |
| Rutting | | | | | |
| Other: | | | | | |

8. What type of **continuously reinforced concrete pavement distress data** do you collect with automated equipment? (check all that apply)

| CRCP Distress Data | Type of Measure | | | | # of Severity Levels |
|---|---|---|---|---|---|
| | Linear (✓) | Area (✓) | Other (✓) | If other, please explain: | |
| Durability Cracking ("D" cracking) | | | | | |
| Longitudinal Cracking | | | | | |
| Transverse Cracking | | | | | |
| Map Cracking | | | | | |
| Scaling | | | | | |
| Polished Aggregate | | | | | |
| Popouts | | | | | |
| Blowups | | | | | |
| Transverse Construction Joints Deterioration | | | | | |
| Lane-to-Shoulder Dropoff | | | | | |
| Lane-to-Shoulder Separation | | | | | |
| Patch/Patch Deterioration | | | | | |
| Punchouts | | | | | |
| Spalling of Longitudinal Joints | | | | | |
| Water Bleeding and Pumping | | | | | |
| Longitudinal Joint Seal Damage | | | | | |
| Rutting | | | | | |
| Other: | | | | | |

## States Survey on Automated Data Collection
## Distress Data

9. If the distress data collection is video,

   *what format is it in?* ____ VHS

   ____Super VHS

   ____ Digital Image *at what spacing?* ________

   ____ Other:______________________________________

10. Do you collect overhead clearance measurements? ____ yes ____ no

11. How is the datum processed? ____ automated (software processes the data)

    ____ manually (visual inspection of video /digital image)

    ____ both

    a) Data processing time requirements:

    *How many (miles/km) per day per crew*? ________________________________

    *How many on a crew?* _________

    b) Data processing equipment needs: ____ Special Computer Terminal

    ____ VCR

    ____ Monitor

    ____ Other: ________________________________

12. What Quality Control measures do you use for:

    a) Data Collection:

    b) Data Processing:

**If your agency has recently purchased automated equipment for distress data collection, please attach copies of RFP's and/or equipment specifications.**

Thank you for completing this survey.

Questions? Call Joni Reid at 503-986-5805

# RESPONSES TO DISTRESS DATA COLLECTION SURVEY

| STATE | How often data is collected | % of system annually | How many miles are surveyed? | Based on a ____% sample? | Which lanes are surveyed | Total System Miles | Data Collected: Time required to collect | Use a service | Use DOT equipment | How satisfactory are results? | How long owned or used? | Collect GPS data? | What data collected at the same time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arizona | yearly | | 7,500 C/L | 2% sample | travel lane, one on non-divided, both on divided | 7500 cl miles | 6 months | | yes/ K.J.Law | good | since 1989 | no | none |
| Iowa | every year | 50% | 10000 C/L | 100% sample. Use average for sections for distress calcs. | N and E for 2 Lane inside for 4 lane. One direction | 20,000 | December each year | yes | yes/ Manual | | 2 yr / 20 yr. | yes | Smoothness-Ride/ Other equip for other conditions |
| Louisiana | every other year | 100% | 16000 C/L | 100% sample. Use 100% for distress calcs. | Rt. outside lane with control direction on undivided hwy. On divided hwy, do outside lanes in both direction. | 16,000 | 12 months (one year) | yes/ Roadware | | good | three data collection cycles | yes | video of highway-features/ smoothness-ride |
| Massachusetts | Annually | 40-50% | 6,000-8,000 Lane | 100% rut data w/ auto. equip. Collect cracking, etc. visually at 1/2 mile increments. | worst - usually outside. One direction for 1-lane rdwys - both for multi-lane rdwys. | 3,000 centerline miles | 6 months | Contract Visual by 5 Regions | yes/ TXDOT Rut equip | contracts-good/ DOT-excellent | statewide contracts began this year. Several districts had been contracting. | yes | video of highway/features, smoothness/ride data |
| Minnesota | every year collect data on about half of each district | 60-70% | 7000 C/L | 10% / Survey 100% for ride but rate the first 500 feet/mile for distress | Outer lane. One direction for undivided roads. Both directions for divided roads. | 12,500 Centerline Miles | After snow/ frost to summer/ early fall. Takes about 3-days/district; for 9 districts, so 8-9 wks of field time. Also do research sections, HPMS, some county roads. | | Yes/ Pathways Services | Excellent | Pathways van since 1996. We purchased new one last summer so, now we have two of them | yes | video of highway/features, smoothness/ride data |
| Mississippi | every 2 years | 0 | | 100% sample with 20% or 2 samples/mile used for distress, if the analysis section is 1/2 mile or less, the entire section is analyzed for distresses | Outside lane, north & eastbound. On non-divided highways, ride/roughness data & video on south & westbound, but do not use data for distress analysis. On divided highways, the outside lanes, both directions and used for distress | 13,000 | 3-4 months | Pathway Services | yes, for calibration /QA | Both excellent | 10 years | yes | video of highway features, smoothness/ride |
| Montana | distress data is collected manually in Montana | | | | | | | | | | | | |
| Nebraska | annually | 3% automated rating | 300 C/L | 25-30% sample | Generally the driving or outside lane. One direction on 2-lane roads, both on 4-lane roads. | 10,000 C/L | about two weeks | | Yes/ International Cybernetics Corp. | Good | 1 year | yes, GPS capability started in 2000. | smoothness-ride data |

Asphalt Distress: L=linear, A=area, O=other / explanation / # of severity levels

| STATE | Fatigue Crack | Block Crack | Edge Crack | Longitud.Crack | Reflection Crack | Transverse Cracking | Patch/Patch Deterioration | Potholes | Rutting | Shoving | Bleeding | Polished Aggregate | Raveling | Lane-to-Shoulder Dropoff | Water Bleeding and Pumping | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arizona | O/ percentage | | | | | | | | L, inch/ Profiler/ none | | | | | | | |
| Iowa | L/ 3 | A/ 3 | | L/ 3 | | L/ 3 | A/ 3 | L/ 3 | L/ 3 | | | | | | | |
| Louisiana | | | | | | | | | | O/ inch | | | | | | Other: IRI / inches/mile |
| Massachusetts | | | | | | | | | L/ 5 | | | | | | | |
| Minnesota | L/ 1 | L/ 1 | | L/ 3 | | O/ we count them, 3 | | | L/ 1 | | | | L/ 1 | | | |
| Mississippi | (Alligator cracking) L/ l,m,h | A/ l,m,h | L/ l,m,h | L/ l,m,h | composite types/ l,m,h | L/ l,m,h | A/ l,m,h | O/ Count/ 1 | O/ Avg. rut depth and rut %ages/ l,m,h | | A/ l,m,h | | A/ l,m,h | | | |
| Montana | | | | | | | | | | | | | | | | |
| Nebraska | A/ 3 | A/ 4 | A/ 3 | L/ Centerline joint between wheelpath and wheelpath/ 3 | A/ 3 | O/ number of TC's/mile / 4 | A/ 2 | A/ failures present or absent, we rate extent of failures/ 1 | collected with profiler, in MM | A/ 3 | A/ 3 | | A/ 3 | A/ presence or absence of shoulder dropoff/ 1 | | Weathering of surface: A/ 3. Surfaced shoulder rating: O/ 10. Unsurfaced shoulder rating: O/ presence or absence of drop off, drainage or erosion/ 1. |

JPCC Distress Data: L=linear,

| STATE | Corner Cracks | Corner Breaks | Druability Cracking | Longitudinal Cracking | Transverse Cracking | Tranverse Joint Seal Damage | Longitudinal Joint Seal Damage | Spalling of Longitudinal Joints | Spalling of Transverse Joints | Map Cracking | Scaling | Polished Aggregate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arizona | | | | | | | | | | | | |
| Iowa | | | A, O/ 1-5 scale/ 3 | L/ 3 | L/ 3 | | | | | | | |
| Louisiana | | | | L | L | | | | | | | |
| Massachusetts | | | | | | | | | | | | |
| Minnesota | | | O/ # of slabs with the defect/ 1 | | | | | O/ # of slabs with the defect/ 2 | O/ # of slabs with the defect/ 2 | O/ # of slabs with the defect/ 2 | | |
| Mississippi | | O/ Count/ l,m,h | A/ l,m,h | L/ l,m,h | L/ l,m,h | O/ Count/ l,m,h | O/ Count don't distiguish between trans and long joint seal damage | L/ l,m,h | L/ m,h | A/ l,m,h | | |
| Montana | | | | | | | | | | | | |
| Nebraska | A/ included in joint condition rating/ 3 | A/ included in joint condition rating/ 3 | A/ included in joint condition rating/ 3 | included with transverse cracking | [illegible] TC's/ 10 | O/ presence or absence of joint seal/ 1 | O/ presence or absence of joint seal/ 1 | O/ number of spalled joints/ 10 | O/ number of spalled joints/ 10 | A/ 3 | | |

# RESPONSES TO DISTRESS DATA COLLECTION SURVEY

| STATE | How often data is collected | % of system annually | How many miles are surveyed? | Based on a ____% sample? | Which lanes are surveyed | Total System Miles | Data Collected: Time required to collect | Use a service | Use DOT equipment | How satisfactory are results? | How long owned or used? | Collect GPS data? | What data collected at the same time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nevada | Do not use automated system. In 1992, did a study with CalTrans and ADOT and determined video logging was not accurate enough to meet the needs | | | | | | | | | | | | |
| New York | Annually | 100% | 40,000 Lane. 16,000 C/L | 100% sample. All 100% used for distress calcs. | all lanes. One direction | 40,000 lane miles; 16,000 centerline miles | 2-3 months | | Use manual windshield survey | Fair | since 1980 | No, but we are working on it | |
| North Dakota | every year | 100% | 8,500 Lane | 10% sample | Driving lane. Both directions, alternating direction each year. | 8,500 Lane | depending on weather - 3 to 4 months | | yes/ Pathway Services Inc. | good | 9 years | yes | video of highway/ features, smoothness/ ride data |
| Ohio | annually | 100% | 48,200 Lane. 19,300 C/L | 100% sample. 100% used for distress | poorest lane. One direction on 2-lane, both on divided. | 48,200 lane miles, 19,300 C/L miles | 3 individuals approx. 9 months each, do manual/visual surveys. Each PCR rater is equipped with a touch screen laptop with a survey sheet encoded into software. The software automatically calculates the rating/score and stores all distress data. | | | | | | |
| Oregon | every 2 years | | 8,437 C/L | 100% sample | truck lane. One direction | 8,437 | 12 weeks | | | | | | |
| Pennsylvania | 100% of NHS every year; 50% of non-NHS every year so we complete the cycle every 2 years | | 27,000 Lane | 100% sample. All is used for distress | Outside travel lane (in most cases). Collect both directions on divided highways, one direction on undivided. | 44000 Lane | April 1 - November 30 each year | Roadware Group | | Good | second contract and our fifth year with Roadware | yes | video of highway-features/ smoothness-ride data/ Geometry, Road attributes |
| Texas | Annually | 100% | 186,000 Lane. 76,000 C/L | 100% rut data with automated equip; collect cracking, potholes, etc. visually at 1/2 mile increments | worst lane, usually outside. Collected in one direction per roadbed. If 4 lane divided -collect in two directions | | 6 months | Contract visual by Region - 5 regions | TXDOT Rut equipment | Contract - good/ equip.- excellent | Statewide contracts began this year. Several districts had been contracting. | yes | video or highway/ features, smoothness/ ride data |
| Virginia | Eventually will be annually on Interstates and primaries | 10% | 13,000 pass | 100% sample with 20% for distress (first 10 ft of every 1/100th of a mile) | depends on which one specified. One on nondivided primaries. Both on divided primaries and interstates | 13,000 pass | Same 4-5 months as smoothness | same subcontractor as collects smoothness | separate division is attempting to do same as subcontractor | contractor fair and imporving | Attempting to get vendor to deliver data for 2 years now, VDOT recently acquired equipment to do itself | vendor yes, VDOT no | Video of highway/ features, smothness/ ride data |

Asphalt Distress: L=linear, A=area, O=other / explanation / # of severity levels

| STATE | Fatigue Crack | Block Crack | Edge Crack | Longitud.Crack | Reflection Crack | Transverse Cracking | Patch/Patch Deterioration | Potholes | Rutting | Shoving | Bleeding | Polished Aggregate | Raveling | Lane-to-Shoulder Dropoff | Water Bleeding and Pumping | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nevada | | | | | | | | | | | | | | | | |
| New York | | | | | | | | | | | | | | | | |
| North Dakota | A | A | | L | | L | L | | L | | L | | L | | | |
| Ohio | | | | | | | | | | | | | | | | |
| Oregon | L/ 3 | A/ 3 | | L/ 3 | | O/ # of cracks/ 3 | A/ 3 | A/ 3 | Ave. Depth/ 4 | | O/ yes or no | | A/ 3 | | | |
| Pennsylvania | L/ 3 | L/ 3 | L/ 3 | | | O/ # of cracks and length/ 3 | A/ Plus area/ None | | L/ Left & right WP/ 3 | | | | L/ 2 | L/ we collect this manually/ 3 | | |
| Texas | | | | | | | | | L/ 5 | | | | | | | |
| Virginia | | L/ 2 | | L/2 | Trans. & Long: L/ 3 | L/2 | Local and Surface: A/ 1 and # | O/ # | O/ %/ 3 and average | | L & A/ 2 | | | | | Crack seal fully sealed. Alligator crack: L & A/ 3. Delamination: A & #. IRI Left, Right, Average: L |

JPCC Distress Data: L=linear,

| STATE | Corner Cracks | Corner Breaks | Druability Cracking | Longitudinal Cracking | Transverse Cracking | Tranverse Joint Seal Damage | Longitudinal Joint Seal Damage | Spalling of Longitudinal Joints | Spalling of Transverse Joints | Map Cracking | Scaling | Polished Aggregate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nevada | | | | | | | | | | | | |
| New York | | | | | | | | | | | | |
| North Dakota | | O/ # of corner cracks | O/ % of joints | O/ % of slabs | O/ % of slabs | | | O/ % of long. joint | O/ % of trans. joints | | | |
| Ohio | | | | | | | | | | | | |
| Oregon | O/ # of cracks/ 3 | O/ # of breaks/ 3 | | L/ 3 | O/ # of cracks/ 3 | O/ ave. severity/ 3 | O/ ave. severity/ 3 | | | | | |
| Pennsylvania | | | | O/ # of slabs cracked/ 3 | O/ # of slabs cracked/ 3 | | | L/ 2 | O/ # of joints with spalling/ 3 | | | |
| Texas | | | | | | | | | | | | |
| Virginia | | O/ count/ 2 | | O/ #/2 | O/ #/2 | O/ # | O/ # | O/ #/2 | O/ #/2 | | | |

# RESPONSES TO DISTRESS DATA COLLECTION SURVEY

| STATE | A=area, O=other / explanation / # of severity level: Popouts | Blowups | Faulting of Transverse Joints and Cracks | Lane to Shoulder Dropoff | Lane to Shoulder Separation | Patch/Patch Deterioration | Water Bleeding and Pumping | Rutting | Other |
|---|---|---|---|---|---|---|---|---|---|
| Arizona | | | O/ Ave. fault height/ none | | | | | | |
| Iowa | | | O/ height | | | A/ 3 | | | |
| Louisiana | L | L | L | | | L | | | Other: IRI / inches/mile |
| Massachusetts | | | | | | | | our concrete doesn't rut | |
| Minnesota | | | O/ # of slabs with the defect/ 1 | | | O/ # of slabs with the defect/ 1 | | | Other: Broken and Cracked Slabs/ # of slabs with the defect/ 1 |
| Mississippi | | O/ Count/ l,m,h | | | | O/ Count/ l,m,h | L/ l,m,h | | |
| Montana | | | | | | | | | |
| Nebraska | | | O/ measured with profiler, in MM | O/ presence of absence of shoulder dropoff/ 1 | O/ presence of absence of shoulder separation included w/previous item/ 1 | | | PCC does not rut | Long. Crack Fault: L/ 3. Other structural crack seal damage: O/ Presence-absence of joint seal/ 3. Joint Repairs: O/ # of Joint repairs/ 10. Panel repairs: O/ # of panel repairs/ 10. Rutting Surfaced Shoulder: O/ 10. Unsurfaced shoulder rating: O/ presence-absence of drop off, drainage or erosion. |

| STATE | CRCP Distress Data: L=linear, A=area, O=other / explain / # of severity levels: Druability Cracking | Longitudinal Cracking | Transverse Cracking | Map Cracking | Scaling | Polished Aggregate | Popouts | Blowups | Transverse Construction Joints Deterioration | Lane to Shoulder Dropoff | Lane to Shoulder Separation | Patch/Patch Deterioration | Punchouts | Spalling of Longitudinal Joints | Water Bleeding and Pumping | Longitudinal Joint Seal Damage | Rutting | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arizona | | | | | | | | | | | | | | | | | | |
| Iowa | A, O/ 1-5 scale | L/ 3 | L/ 3 | | | | | | | | | A/ 3 | | | | | | |
| Louisiana | | L | L | | | | L | L | | | | | L | | | | | Other: IRI / inches/mile |
| Massachusetts | | | | | | | | | | | | | | | | | no rutting | |
| Minnesota | L/ 1 | L/ 1 | L/ 1 | | | | | | | | | L/ 1 | | | | | | |
| Mississippi | A/ l,m,h | L/ l,m,h | L/ m,h | A/ | | | | O/ Count/ | | | | A/ l,m,h | O/ Count/ l,m,h | | | | | |
| Montana | | | | | | | | | | | | | | | | | | |
| Nebraska | We have no CRCP exposed. All has been resurfaced with asphalt. | | | | | | | | | | | | | | | | | |

| STATE | Video data format | Collect overhead clearance measurements? | How is the datum processed | DP time requirements | DP equipment needs | Quality Control: Data Collection | Quality Control: Data Processing |
|---|---|---|---|---|---|---|---|
| Arizona | | no | | | | | |
| Iowa | VHS/ Digital image | no | automated, QC/QA manually | Did not supervise their operations. Cost is on a per mile basis. | | none | visual inspection of digital images |
| Louisiana | digital image at 10.5 feet | yes | both automated and manual | 100 miles/day/crew, 30 people total, three shifts, 24 hours/day | special computer terminal/ Monitor/ DVD player and copier | Vendor delivers DVD's collected weekly, we view all DVD's for image quality, correct header info, and missing or incomplete sections. | Check DVD's on weekly basis, keep logs of things needing fixing, or returns. Check weekly corrections. Check vendor drate randomly (between 1-10%). Add penalty for delays $100/day , $300/day penalty if the contract is not complete in one year. drate: raters mark cracks and patches on screen, which can be checked to see if marked or not. |
| Massachusetts | digital image | no | manually | | special computer terminal | 5% audit of contract using TTI personnel | |
| Minnesota | Super VHS | No | Manually | 40-50 miles/day/ person, 2 people & 2 workstations | Special Computer Terminal | Nothing formal. We compare the last rating to the new one if there is a question | nothing formal. We have 2 raters who work close together with the data collector. |
| Mississippi | Digital image at 50 feet | no | both automated and manual | unknown / 1 contractor, 1 DOT person | Special computer terminal, vcr | Hard and soft calibration while contractor collects data, sites including each pavement type. Sample 5% of each pavement type, and 5% of short analysis sections (1/2 mile or shorter) | goes hand in hand with above. |
| Montana | | | | | | | |
| Nebraska | digital image at 0.05 mile | no | manually | 30 miles/day by 1 person crew | monitor/ PC with removable 27 GIG hard drive | we conduct a rating school for our raters before each rating season. The field ratings are verified on a sampling basis for accuracy by the supervisor. | They are compared to the previous years ratings on a sampling basis. |

# RESPONSES TO DISTRESS DATA COLLECTION SURVEY

| STATE | Popouts | Blowups | Faulting of Transverse Joints and Cracks | Lane to Shoulder Dropoff | Lane to Shoulder Separation | Patch/Patch Deterioration | Water Bleeding and Pumping | Rutting | Other |
|---|---|---|---|---|---|---|---|---|---|
| | A=area, O=other / explanation / # of severity level | | | | | | | | |
| Nevada | | | | | | | | | |
| New York | | | | | | | | | |
| North Dakota | O/ # of occurences | | O/ # of faults and height | | | O/ % of slabs | | | Broken slabs: O/ % of slabs |
| Ohio | | | | | | | | | |
| Oregon | O/ Number | O/ Number | | | | A/ | | O/ Ave. depth | |
| Pennsylvania | | | O/ # of joints faluted/ 2 | L/ we collect this manually | L/ we collect this manually | A/ plus # - Bit. & Conc./ none | | L/ left & right WP/ 3 | Broken Slab: # of slabs (4 pieces/20 ft.) /3 |
| Texas | | | | | | | | our concrete doesn't rut | |
| Virginia | | O/ # of slabs | O/ # slabs/ 3 and average | | | O/ # slabs/ 3 | | | Divided slabs: O/ #. Asphalt patch: O/ # slabs/1. IRI Left, Right, Average: L |

| STATE | Druability Cracking | Longitudinal Cracking | Transverse Cracking | Map Cracking | Scaling | Polished Aggregate | Popouts | Blowups | Transverse Construction Joints Deterioration | Lane to Shoulder Dropoff | Lane to Shoulder Separation | Patch/Patch Deterioration | Punchouts | Spalling of Longitudinal Joints | Water Bleeding and Pumping | Longitudinal Joint Seal Damage | Rutting | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CRCP Distress Data: L=linear, A=area, O=other / explain / # of severity levels | | | | | | | | | | | | | | | | | |
| Nevada | | | | | | | | | | | | | | | | | | |
| New York | | | | | | | | | | | | | | | | | | |
| North Dakota | L | L | L | | | | | | | | | L | | L | | | | Trans. Crack Spall: O/ % of cracks |
| Ohio | | | | | | | | | | | | | | | | | | |
| Oregon | | L/ | [illegible] severity | | | | | | | | | A/ | O/ # | | | O/ Severity | O/ Ave. depth | |
| Pennsylvania | We collect this data manually since we have so few miles (<300) | | | | | | | | | | | | | | | | | |
| Texas | | | | | | | | | | | | | | | | | No rutting | |
| Virginia | | L/ 3 and # | L/ 3 and average space | | | | | | | | | A/ 3 | A/ 1 and # | L/ 2 | | L/ 1 | | Cluster cracking: L/3 and # at 3 severities. Asphalt patch: O/ #. IRI Left, Right, Average: L |

| STATE | Video data format | Collect overhead clearance measurements? | How is the datum processed | DP time requirements | DP equipment needs | Quality Control: Data Collection | Quality Control: Data Processing |
|---|---|---|---|---|---|---|---|
| Nevada | | | | | | | |
| New York | | No | | | | | |
| North Dakota | Super VHS | No | both | no requirements/ 2 crew | special computer termianl./ VCR/ Monitor | n/a | n/a |
| Ohio | | | manually | | touch screen laptop with survey sheet encoded into software | | |
| Oregon | | | | | | | |
| Pennsylvania | VHS (previously). Negotiating digital images now at continous spacing | no | both | The vendor does this and I am not sure of the numbers | | A contractor is developing a plan for us now. | compare dollars needs per segment based on treatment matrix and unit costs for each distress. |
| Texas | digital image | no | manually (visual inspection of video/ digital image) | | special computer terminal | 5% audit of contract using TTI personnel | |
| Virginia | digital image. First ten feet of every 1/100th of a mile | No | Manually | Rater productivity varies from 10 to 20 miles per 8 hour shift at this piont 10 raters are anticipated and due to epuip. They are done in multiple shifts | dual monitors | There is another vendor for the prime contractor performing the QC, a well as some VDOT performed QC that will complement that effort. VDOT will also follow a QA plan to identify problems | The prime contractor vendor doing the QC ensures that the processing is done correctly by spot checking results. This has been augmented by VDOT performing various other checks such as linear referencing problems. |

# APPENDIX C: VIDEO DATA COLLECTION SURVEY

# States Survey on Automated Data Collection
# Video Log Data

The Oregon Department of Transportation is evaluating automated data collection as part of a research project. The project is evaluating automated equipment that can collect pavement distress, smoothness and right-of-way video data in a single operation. As part of the study, we are collecting information on the practices of other states.

Please complete the survey and return to: Joni Reid, Oregon Department of Transportation, 200 Hawthorne, SE, Suite B-240, Salem, OR 97310-5192, fax to 503-986-2844, or e-mail to joni.e.reid@odot.state.or.us

Please complete the table below for the types of **Video Log** data you collect:

| Completed by: | State: | Phone: |
|---|---|---|
| 1. How frequently do you collect **video log** data? | | |
| 2. What percent of the system is surveyed annually? ___________<br>Annual Amount: ____________ Lane miles or __________ Centerline Miles | | |
| 3. Time Required to Collect Data: | | |
| 4. Data Collected: How satisfactory are the results?<br>______ by a service — Excellent Good Fair Poor<br>*Who?* ________________________________________<br>______ use DOT equipment — Excellent Good Fair Poor<br>*Manufacturer:*__________________________________<br>______ other: ___________________________________ — Excellent Good Fair Poor<br>How long have you owned the equipment or used the service? ______________________________<br>Does the system collect GPS data? ____yes ____no<br>Are surveys conducted in one direction or both directions? ____ one direction ____ both directions | | |
| 5. What other data are collected at the same time?<br>____ Pavement Distress ____ Smoothness/Ride<br>____ Other: __________________________________ | | |

## States Survey on Automated Data Collection
## Video Log Data

6. For your video log of highways/features:

   a) Are the video logs used to inventory roadside features? ____yes ____no

   *If yes, indicate which features*: ____ Signs

   ____ Guardrail

   ____ Barrier

   ____ Curbs / Sidewalks

   ____ Pavement / Lane information

   ____ Other: ________________________________

   b) How is the datum referenced? ___highway milepoint ___GPS coordinates ___other

   c) What format is used to collect the data?

   ____VHS

   ____Super VHS

   ____ Digital Image: *at what spacing?* ________________________

   ____ Other:______________________________________________

   d) Who are the users? ____ Right of Way ____ Legal

   ____ Road Design ____ Maintenance

   ____ Other. If other, please list:

   __________________________________________________

   e) How do the users access the data:

   ____ Network server

   ____ CD

   ____ Videotape

   ____ Other: ______________________________________

   f) Are there special equipment and/or software needs to access the video logs?

**If your agency has recently purchased automated equipment for video log recording, please attach copies of RFP's and/or equipment specifications.**

Thank you for completing this survey.

Questions? Call Joni Reid at 503-986-5805

# RESPONSES TO VIDEO DATA COLLECTION SURVEY

| STATE | 1. How frequently data is collected | % of system annually | How many miles? # Lane Miles | # C/L Miles | Data Collected 3. Time required to collect | Use a service | Use DOT equipment?/ Manufacturer | How satisfactory are results? | How long owned or used? | Collect GPS data? | One or both directions? | What data collected at the same time | Video Log Used to Inventory which roadside features? | how is the datum referenced | What format is used to collect the data | Who are the users | How do the users acces the data? | Are there special equipment/software needs? | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Arizona | Annually | 100% | | 6,300 | 5 months +/- | | yes/ Mandli, "modified" Trigg | excellent | 1990-1999 | yes | | none | Signs/ Guardrail/ Pavement-Lane information/ Striping and Condition | highway milepoint/ GPS coordinates | Digital Image at 52.8 ft. | ROW/ Road Design/ Legal/ Maint./ Consultants/ Environmental/ Developers | CD | CD reader/ Reader software is on each CD. Expanded reader with options also available separately. | |
| California | 1/3 of state each year, 10 days/mo, 10 mo/year | 33.30% | | | 1 FTE | Mandli converts photos to laserdisks & digitize to Quicktime movies.CD's | yes/ 35mm film, 3 cameras (very dependable) | excellent | 25 years | | both | none | | 3 Regions/ 12 Districts | 500 pictures/5 miles (25 mb) | | CD's/ film/ photolog | Unix silicon graphics server stores the photolog fo intranet access. Private users view with Quicktime | Combining collection with pavement condition considered a couple of years ago. PCS stayed in one lane, while video often changed to catch features, accesses, etc. so wasn't compatible. Film is not editable, holds up in court. |
| Connecticut | Annually | 100% | 7,800 | | 5-6 months | | Roadware Group | Excellent | 5 years | yes | | Pavement distress/ Smoothness-ride/ I+R3nertial guidance (with GPS) grade, crossfall, rutting, pavement images | signs/ guardrail/ pavement/ lane information/ bilboards/ RR crossings | highway milepoint/ GPS coordinates | Super VHS (pavement images)/ digital images at 10 m/ digital video 30 fps | ROW/ road design/ legal/ maint/ traffic/ planning/ pavement mgmt/ state police/ university system | network server/ DVD | DVD and LAN/WAN photolog roadway image and data retrieval system has been developed by and is operational at ConnDOT. 1st, processing software prepares ground-based images and engineering data collected by photolog operations for desktop retrieval. 2nd, Waypoint-Based Linea Referencing software matches traditional linear referenced locations to van-collected GPS coordinates. 3rd, a software package called DigitalHIWAY enables users to view forward and side facing roadway images with interactive links to engineering data and traditional linear reference locations. | Addtl mapping, horizontalcurve analysis & virtual measurement software available. DigitalHIWAY geared towards user-base that includes traffic, planning, maintenance, construction, rights of way, & incident managment. |
| Iowa | Bi-Annually | 50% | 10,000 | | four to five months per year | | yes/ Mandli Communication | good | 2 years | yes | | | no | highway milepoint/ GPS coordinates | Digital Image at 26.4 feet | ROW/ Road Design/ Legal/ Maint./ Planning Div, Highway Development, Consultants on State Contract, and Traffic & Safety. | Network server/ CD/ Videotape | | |
| Kansas | every summer | 33% | 6600 | | all summer, and process it all winter | | yes/ Mandli Communication | excellent | 7 years | yes | | | signs/ pavement-lane information | highway milepoint | digital image at 10 m | ROW/ Road Design/ Legal/ Maint./ Planning (Corridor Mgmt, Billboard Control). | Network server/ CD | Network access requires only a web-browser. For engineering access, high-end PC/ Mac hardware and a software package are required. | Videolog is collected using county mileage, is easier than keeping statewide mileages synchronized over the 3-year cycle. Data from a single county can take 2-5 CD's. Changing to DVD storage next year. Will have all Photolog & Analog Videolog records transcribed to DVDs. The network server that supports the web-based videolog requires 300 Gb of storage for one complete survey of the state. The web-based viewer is popular. Don't intend to keep historical videologs on-line. The Videolog workstations are the fastest desktop computers available on our contract, with a high-end video card, double the RAM of our 'recommended desktop configuration', and a CD changer. These machines run the manufacturer's software, Oracle database for roadway data, and Intergraph Microstation for a clickable map. Buy large monitors (21") for these machines. |
| Louisiana | every other year | 100% | | 16,000 | 12 months | Roadware | | excellent | 3 cycles | yes | | Pavement Distress/ Smoothness-Ride/ Rutting, Faulting | Signs/ Bridge location, horizontal and vertical | highway milepoint | Digital Image at 10.5 ft. | Road Design/ Maintenance/ Traffic section/ Bridge section/ Highway needs | Network server/ CD | DVD player and Visidata and Surveyor software | |
| Minnesota | Every year about half of the system. Twin Cities area done every year. This year will change to 1/2 of each District/year from all of half the Districts/yr | 60-70% | | 7,000 | Old van (Mandlii) all spring and summer. Hope shorter with new van (Pathway Service) | | yes/ Pathway Services | | less than 1 year | yes | | Pavement Distress/ Smoothness-Ride | no | highway milepoint/ GPS coordinates | Digital Image at 25 feet | ROW/ Road Design/ Legal/ Maint./ Materials, State Patrol, Traffic | Network server | Special software but not any special equipment other than a PC | |

# RESPONSES TO VIDEO DATA COLLECTION SURVEY

| STATE | 1. How frequently data is collected | % of system annually | How many miles? | | Data Collected | | | | | | | | Video Log | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | # Lane Miles | # C/L Miles | 3. Time required to collect | Use a service | Use DOT equipment?/ Manufacturer | How satisfactory are results? | How long owned or used? | Collect GPS data? | One or both directions? | What data collected at the same time | Used to Inventory which roadside features? | how is the datum referenced | What format is used to collect the data | Who are the users | How do the users acces the data? | Are there special equipment/software needs? | |
| Mississippi | every two years | 0% | | | 3-4 months | Pathway Services | | excellent | 10 years | yes | | Pavement Distress/ Smoothness-Ride | no, but Planning Division is looking into this | highway milepoint | Digital Image at 50 ft | Research Division (Pavement Management) | Videotape/ Transport. Mgmt. Info. System | Pathway Services has a proprietary software program to run the video. Research Div. has an Image Processing Workstation to view video. The proprietary software was installed in TMIS to drive the video there. | |
| Nebraska | Yearly | 33.30% | 6,700 | | 12 weeks/ year | | yes/ Mandli Communications | good | 8 years | no | | | no | highway milepoint | Digital Image at .01/mile | ROW/ Road Design/ Legal/ Maint./ Pavement Mgmt, Materials & Research/ Traffic Engineering/ Accident Records | Network server | Digilog requires special equipment | |
| Nevada | Annually | 33% | | 3,600 | 12 weeks/ year | | yes/ Mandli Communications | good | 2 years | yes | both | | yes/ signs | highway milepoint/ GPS coordinates | Digital Image at 26 ft. or 52 ft. | ROW/ Road Design/ Legal/ Maint. | Network server/ CD | yes | In 1992 study done with CalTrans and ADOT. All 3 states determined video logging with Pavement Mgmt System not accurate enough. |
| North Dakota | Yearly, usually in the Fall | 99-100% | 8500 | | 3 months of good weather , mid Sept-Dec. | | yes/ Pathway Services Inc. | good | Sep-96 | yes, but not used for GIS mapping | | Smoothness-ride/ rut/ faulting | used a visual ref. only. Data is in the roadway info mgmt system by ref. point and GPS coord./ signs, guardrail, barrier, some curb/sidewalks, pavement/lane information, haul road before and after views, new construction | Highway mile piont | Super VHS. Some ROW inventory is hard to see due to camera angle & video quality. Looking to get digital cameras & image storage next bienium. | ROW/ Road design/ Legal/ Maint./ Materials & Research/ Construction | Videotape/ PC Workstation | In order to use the database mile reference search to indetify the video frame, researchers must use the PC workstation with the Pathway Surface Condition software. | |
| Ohio | We video our entire state on a four year cycle. | 25% | | 10,000 | April - October | | yes/ Mandli Communications | excellent-good | 6 years | no. Buying new videolog system from Mandli which will include GPS | | None | no, not while collecting, but often are extracted from the images at a later time.(ex. posted speed limits) | highway milepoint | super VHS used only for special requests/ Optical Discs | ROW/ Road Design/ Legal | Workstation created by Mandli. | Mandli Workstations | In process of purchasing new equipment/ RFP and specifications are being drafted. |
| Oregon | Approx. 1/3 of the state highway system is collected yearly | 0 | | 5,300 | Collection & taping: 6 months (2 FTE) Editing & distribution: 6 mo. (1 FTE) | | variety | good | We are beginning collection this summer for the first time with this new system, based on WashDOT and Marion County systems. | no | both | | Used to verify features as needed. | highway milepoint | Super VHS/ Digutal Image at 52.8 feet | ROW/ Design/ Legal/ Maintenance/ Crash Reporting/ State Police/ Private Legal Firms | Network server/ CD/ Videotape | no | |
| Pennsylvania | 100% of NHS every year/ 50% of non-NHS every year, complete cycle every two years | 100% NHS, 50% other | 27,000 | | April 1 - November 30 | Roadware Group | | Good | Second contract, 5th year with Roadware. | yes | | Pavement Distress/ Smoothness-Ride/ Geometry, Roadway Attributes | Pavement-Lane Information/ Intersections, Overpasses, Overhead Signs, Structures, RR Crossings, Traffic Signals, Rumble Strips | hwy mp (use a segment/ offset reference that matches milepoints on Interstate)/ GPS coordinates | Super VHS at 26 ft., Currently negotiating digital images | ROW/ Road Design/ Legal/ Maint./ County level maint./ Highway Safety | Network server through our GIS unit/ CD | If using CD's the software VisiData is required in order to view data with the images. | |
| Virginia | Eventually will be annually for Interstates and Primaries | 10% | 13,000 pass | | 4-5 months | Subcontractor to a prime | yes | were good, now fair | VDOT has been 2 yrs at getting vendor to provide data | yes | | Pavement Distress/ Smoothness-Ride | ? Prime does Inventory Collection & Assessment System, pavement data collection is only a small part of it, unsure of what other uses of ROW images. | Milepoint for pavement management system reporting GPS coordinates for eventual integration with the total overall ICAS mentioned above/ | Digital Image/ the RWO image is snapped simultaneously with the downward distress image, the 1st 10 ft of every 52.8 ft | Whoever wants them | Eventually network server, currently we use DLT tapes due to volume | no, images are in jpeg format | all referencing systems used by VA are inter-related, with route specific milepoint & a link/node/offset used as well. The LRS is the single most important and confusing thing that hinders all progress. |
| Wisconsin | WI video logs all State, US, & Interstate highways in both directions, approx. 24,000 miles, in a three year cycle. | 33% | 8,000 + | | four days per week during April through mid November | | yes/ Mandli Communications | good | Vehicle was outfitted in 1995 and first used for data collection in 1996 | yes | | mileage | signs/ curbs-sidewalks/ pavement-lane information | highway milepoint | digital image at 1 image every 1/100th mile | ROW/ road design/ legal/ maintenance/ forecasting | CD | a special player was developed by Mandli Comm. for WDOT's needs. | |

# APPENDIX D: SURVEY OF ODOT DATA MANAGERS

**Letter e-mailed February 20, 2002:**

To: Interested Parties

From: Dave Ringeisen
Transportation Data Section Manager

RE: ODOT Data Needs

The ODOT Research Group in conjunction with the Transportation Data Section and the Pavement Services Unit are conducting a research project to evaluate Automated Data Collection Equipment. The project is evaluating equipment that can collect pavement distress, smoothness and Video Log in a single operation. As part of this study, we are collecting information from other parts of the organization regarding the types, sources and uses of data in your unit.

Data collection is an important part of ODOT operations. The technology we are researching has the potential to combine some of these efforts into one operation to increase efficiency and provide information previously unavailable in a database format. There are opportunities to collect other data elements in addition to those mentioned above. Your response to this survey will help us determine which items would be most beneficial to collect using this technology.

Please take a few minutes to fill out and submit the survey on the Research web page, http://www.odot.state.or.us/tddresearch/auto_data_survey.htm, by March 1, 2002. I also encourage you to pass this along to others in your area who you know collect data, or to coordinate your response with them. If you have any questions, call Joni Reid at (503) 986-5805 or via e-mail at joni.e.reid@odot.state.or.us.

**Follow-up letter e-mailed March 07, 2002:**

A couple of weeks ago, I sent out a survey designed to help ODOT identify data needs and to determine if any of the various data collection efforts could be combined into an automated process. This survey is part of a research project looking at what types of automated data collection equipment is currently available and the feasibility of using this equipment. To date we have only received a few responses.

The survey form is located at the address given below and can be filled out and submitted online. Please take a few minutes to fill out the survey form and/or pass this message on to others who may have an interest. The information you provide will be very valuable in our efforts to evaluate this technology.

Thank you for your assistance.

http://www.odot.state.or.us/tddresearch/auto_data_survey.htm

## Internal Survey on Automated Data Collection

ODOT Research Group is evaluating automated data collection equipment that can collect pavement distress, smoothness and right-of-way video data in a single operation. As part of the study, we are collecting information from the users of the data; Please indicate the types, sources and use of data in your unit's work.

**Completed by:** Enter answer here

**Work Group(s):** Enter answer here

| Road Feature | Use it (✓) | Data Source: ITIS | Data Source: Do you collect? | Data Source: Other ODOT | If you collect data, at what frequency? | What are you using it for? | Use it for federal submittal? (✓) if yes |
|---|---|---|---|---|---|---|---|
| Pavement Type | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Pavement Condition | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Pavement Smoothness | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| # Lanes | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Pavement / Lane Width | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Median Type | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Median Width | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Curb Location | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Striping | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Sidewalk Location | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Bikepath Location | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Sign Inventory | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Vertical Clearance | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Geometric Data | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Signals | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Guardrail (location, type, condition | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| GPS Coordinates | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Other | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Enter answer here | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |
| Enter answer here | ☐ | ☐ | ☐ | ☐ | Enter answer here | Enter answer here | ☐ |

If you use the data above, is the data current enough?

☐ OK as is ☐ OK to collect less frequently ☐ need more current data

If not current enough, how frequently should the data be collected?

How frequently should data be collected?

For data you collect:

Who collects the data? Enter answer here

How often? Enter answer here

How much time and staff is needed? Enter answer here

What training and equipment is required? Enter answer here

Are you aware of others who are using your data? Enter answer here

Automated data collection would by performed with a continuously moving vehicle. With this in mind,

could the data be collected in a combined operation with distress, smoothness, video log?

Enter answer here

Is there data not currently being collected that would benefit ODOT? If so, what?

Enter answer here

Could it be collected with an automated system? Enter answer here

Who would use the data? Enter answer here

If you wish to add other information or to clarify a response you entered, please do so in the space provided below.

Enter information here

Submit Reset

# APPENDIX E: CONTRACT SPECIFICATIONS FOR ADC EQUIPMENT VENDORS

ATTACHMENT "A"

# AUTOMATED DATA COLLECTION EQUIPMENT PRE-QUALIFICATION SPECIFICATIONS

**PRESENTATION**

- Maximum time for presentation should not exceed 1 hour and 30 minutes
- Include a display and tour of equipment
- Provide copies of equipment specifications
- Provide copies and description of any special hardware and software requirements or options
- Discuss any data collection services you provide, including your quality control measures.

**DATA COLLECTION**

- All required information should be collected in a single pass of the test section(s).
- All data should be submitted to ODOT on or before September 15, 2001.

**VIDEO LOG**

- Collect video log information on test section(s).
- Video log images should be indexed by highway and milepoint.
- Provide a rear or left side view, if available.
- Submit 1 copy of the video log information. Video log information can be provided on VHS, CD, or DVD.

**LONGITUDINAL PAVEMENT PROFILE**

- Measure the longitudinal profile in both wheelpaths according the ASTM E950 and AASHTO PP37.
- Report the International Roughness Index (IRI) for each 0.1 mile section in inches per mile(in/mile) to the nearest 0.1 inches. An IRI value should be reported for each wheelpath.
- The data should be submitted in an Excel or delimited text file format to be provided by ODOT.

**PAVEMENT DISTRESS**

- Collect pavement distress data according to the ODOT Distress Identification Guidelines.
- The type, severity and quantity for each distress type should be reported in 0.1 mile increments. The data should be submitted in an Excel or delimited text file format to be provided by ODOT.

## ODOT DISTRESS IDENTIFICATION GUIDELINES

This manual and the SHRP Distress Identification Manual for the Long-Term Pavement Performance Project (SHRP-P-338) outline the procedures for the identification and measurement of pavement distresses used by ODOT. A copy of the SHRP Manual can be obtained at: http://www.nationalacademies.org/trb/bookstore/

## EVALUATION OF ASPHALT CONCRETE PAVEMENTS

The evaluation of asphalt pavements will be completed by rating the distress in the pavement according to the SHRP descriptions and severity levels as summarized below.

### RUTTING

Rutting is a surface depression in the wheel path caused by permanent deformation in any of the pavement layers or sub-grade. The rut depth will be measured in both wheel tracks and an average value for each 0.1 mile will be reported. In addition to the average measured value for each 0.1 mile section, the rut depth will be classified according to the following information:

0” ≤ **O** <1/4”
1/4” ≤ **L** <1/2”
1/2” ≤ **M** <3/4”
**H** ≥ 3/4”

### FATIGUE CRACKING

Fatigue cracking, also known as alligator cracking, is a series of interconnected cracks caused by fatigue failure of the asphalt concrete. Fatigue cracking will begin as one or a series of longitudinal cracks in the wheel paths. Fatigue cracking will be rated as low, moderate, or high based on the criteria set forth in the SHRP Distress Identification Manual (page 8).

The quantity of fatigue cracking will be measured by the lineal feet in each wheel track that suffers from the distress. The amount of cracking in each severity level should be estimated and recorded.

### LONGITUDINAL CRACKING

Longitudinal cracks are cracks that are parallel to the pavement’s centerline. Only longitudinal cracks that are **not** in a wheel path should be recorded as this form of distress. Longitudinal cracks which occur in the wheel path will be rated as fatigue cracking. The cracks will be rated as either low, moderate, or high severity based on the SHRP Distress Identification Manual (page 12). The amount of longitudinal cracking will be determined by estimating the length of the cracks and totaling all crack lengths in the segment.

### TRANSVERSE CRACKING

Transverse cracks are predominantly perpendicular to the pavement centerline, and may extend all or part way across the travel lane. The cracks will be rated low, moderate, or high severity based on the definitions in the SHRP Distress Identification Manual (page 16). The amount of transverse cracking will be measured by counting the actual number of cracks that occur in the travel lane being rated. Cracks must extend at least half way across the travel lane before being counted.

### BLOCK CRACKING

Block cracking is a distress where cracks divide the pavement surface into rectangular pieces. These pieces are typically one to 100 square feet. Block cracking, unlike fatigue cracking, will typically occur throughout the pavement width, not just in the wheel tracks. Block cracking will be rated as low, moderate, or high based on the SHRP Distress Identification Manual (page 10). The amount of block cracking will be determined by the square feet of the travel lane that suffers this distress. Block cracking occurring in the wheelpath is also counted as fatigue cracking.

**<u>POTHOLES AND PATCHES</u>**

Potholes and patches will be rated together. Potholes and Patches will be rated as low, moderate, or high based on the SHRP Distress Identification Manual (pages 20 & 22). The amount of potholes and patching in any one segment will be determined by the square feet of the travel lane experiencing this distress.

**<u>RAVELING</u>**

Raveling is the wearing away of the pavement surface caused by the dislodging of aggregate particles. Raveling will be rated as low, moderate, or high severity based on the SHRP Distress Identification Manual (page 32). The quantity of raveling in a section will be estimated as to the square feet of the travel lane that suffers this distress

**<u>BLEEDING</u>**

Bleeding is indicated by the excess bituminous material on the pavement surface, which creates a shiny, glass-like reflective surface which usually becomes sticky in hot temperatures. Bleeding is not rated by severity level, but should be recorded when it is severe enough to cause a reduction in skid resistance. A segment is considered to have measurable bleeding if it has multiple areas of 25 square feet or larger patches of bleeding. Bleeding will simply be recorded as either existing or not existing for each 0.1-mile segment.

## EVALUATION OF JOINTED & JOINTED REINFORCED PORTLAND CEMENT CONCRETE PAVEMENTS

The evaluation of Jointed and Jointed Reinforced Portland Cement Concrete pavements will be completed by rating the distress in the pavement according to the SHRP descriptions and severity levels as summarized below.

### RUTTING/WEAR

Rutting is a surface depression in the wheel path caused by permanent deformation in any of the pavement layers or sub-grade. The rut depth will be measured in both wheel tracks and an average value for each 0.1 mile will be reported. In addition to the average measured value for each 0.1 mile section, the rut depth will be classified according to the following information:

0” ≤ **O** <1/4”
1/4” ≤ **L** <1/2”
1/2” ≤ **M** <3/4”
**H** ≥ 3/4”

### CORNER CRACKING

Corner cracks are short cracks that begin at transverse joints and are predominantly parallel to the pavement centerline. These cracks are generally located anywhere from the edge of the PCC to and including the wheel path. Corner cracks will be rated based on the criteria for longitudinal cracks as described in the SHRP Distress Identification Manual (page 42). The amount of corner cracking will be measured by counting the number of cracks that occur in each segment. Corner cracks that intersect transverse cracks will be rated as shattered slab and not as corner cracks.

### CORNER BREAKS

A corner break is the separation of a corner portion of concrete from the rest of the PCC slab. Corner breaks occur when a corner crack is intersected by a transverse crack or when a diagonal crack extends across the corner of a slab. Corner breaks will be rated as low, moderate, or high severity based on the SHRP Distress Identification Manual (page 40). The amount of corner breaks will be measured by counting the number of breaks that occur in each segment.

### LONGITUDINAL CRACKING

Longitudinal cracks are cracks that are predominantly parallel to the pavement centerline. Only longitudinal cracks that are **not** classified as corner cracks should be recorded as this form of distress (see description of corner cracks). The cracks will be rated as low, moderate, or high severity based on the criteria in the SHRP Distress Identification Manual (page 42). The amount of longitudinal cracking will be determined by the length of the cracks and totaling all lengths in the segment.

### TRANSVERSE CRACKING

Transverse cracks are cracks that are predominantly perpendicular to the pavement centerline. These cracks extend all or part way across the travel lane. Transverse cracks will be rated according to the severity levels established in the SHRP Distress Identification Manual (page 44). The amount of transverse cracking will be measured by counting the actual number of cracks that occur in the travel lane being rated. Cracks should extend at least half way across the travel lane before being counted.

### SHATTERED SLABS

A jointed concrete slab section that is broken into three or more pieces. Do not include corner breaks when counting broken slabs. Also does not include slab sections that are divided by one or more transverse or longitudinal cracks. Shattered slabs will be rated as low, moderate, or high severity based on the following severity levels.

Low Severity:

A slab is broken into 3 pieces. The cracks describing the broken slab are spalled for < 10% of the length of the crack: no measurable faulting.

Moderate Severity:

A slab is divided into 4 pieces OR the cracks are spalled at low severity ( < 3 inches) for > 10% of the length; or faulting is < 0.5 inches.

High Severity:

A slab is broken into 5 or more pieces OR the cracks describing the broken slab are spalled > 3inches for > 10% of the length; or faulting is > 0.5 inches.

Measure shattered slabs by recording the number of slabs at each severity level.

**PATCH CONDITION**

A patch is an area where the original pavement has been removed and replaced with a **permanent** type of material. The patch condition will be rated as low, moderate, or high based on the SHRP Distress Identification Manual (page 60). Asphalt patches should be rated as a high severity patch. The amount of patching will be measured by estimating the square feet of the outside lane that is patched. The amount of patching of each severity level should be estimated for each segment.

**JOINT CONDITION**

The condition of joints will be rated based on a combination of the joint condition and the seal condition. The condition of the joint will be based on the following criteria:

- **L**- Joint is in good condition and seal is in good condition.
- **M**- Joint is slightly spalled with seal in good condition or joint is in good condition with seal in poor condition.
- **H**- Joint is badly spalled or joint is slightly spalled with seal in poor condition.

The condition of the transverse, lane, and shoulder joints will be rated separately based on the average condition of the joints in each segment.

## EVALUATION OF CONTINUOUSLY REINFORCED PORTLAND CEMENT CONCRETE PAVEMENTS

The evaluation of Continuously Reinforced Portland Cement Concrete pavements will be completed by rating the distress in the pavements according to the SHRP description and severity as summarized below.

### RUTTING

Rutting is a surface depression in the wheel path caused by permanent deformation in any of the pavement layers or sub-grade. The rut depth will be measured in both wheel tracks and an average value for each 0.1 mile will be reported. In addition to the average measured value for each 0.1 mile section, the rut depth will be classified according to the following information:

0” ≤ **O** <1/4”
1/4” ≤ **L** <1/2”
1/2” ≤ **M** <3/4”
**H** ≥ 3/4”

### LONGITUDINAL CRACKING

Longitudinal cracks are cracks that are predominantly parallel to the pavement centerline. The cracks will be rated as low, moderate, or high severity based on the SHRP Distress Identification Manual (page 67). The amount of longitudinal cracking will be determined by estimating the length of the crack and totaling all crack lengths in the segment at each severity level.

### TRANSVERSE CRACKING

Transverse cracking of continuously reinforced concrete pavement is normal and is not considered a form of distress. However, if the cracks open up, major deterioration may result. The transverse crack severity will be rated based on the crack condition according to the levels established in the SHRP Distress Identification Manual (page 68). Record the number of transverse cracks at each severity level within the section.

### PUNCHOUTS

A punchout is the separation of a block of concrete from the rest of the CRCP formed by two closely spaced transverse cracks, a short longitudinal crack, and the edge of the pavement or longitudinal joint. As the cracks deteriorate, the steel ruptures and the block of concrete punches downward into the base and sub-base. Punchouts will be rated as low, moderate, or high based on the SHRP Distress Identification Manual (page 82). The quantity of punchouts will be measured by counting the number that occurs in each segment. If a punchout has been patched with asphalt, it should be rated as a high-severity punchout and not a patch, as the patch is only a temporary repair.

### PATCH CONDITION

A patch is an area where the original pavement has been removed and replaced with a **permanent** type of material. The patch condition will be rated as low, moderate, or high based on the SHRP Distress Identification Manual (page 80). Asphalt patches should be rated as high severity for the type of distress in which they are intended to repair. Typically either a punchout or a transverse or longitudinal crack. The amount of patching will be measured by estimating the square feet of the outside lane that is patched. The amount of patching in each severity level should be estimated for each segment.

### JOINT CONDITION

The condition of joints will be rated based on a combination of the joint condition and the seal condition. The condition of the joint will be based on the following criteria:

- **L**- Joint is in good condition and seal is in good condition.
- **M**- Joint is slightly spalled with seal in good condition or joint is in good condition with seal in poor condition.
- **H**- Joint is badly spalled or joint is slightly spalled with seal in poor condition.

The condition of the lane joint and shoulder joint will be rated separately based on the average condition of the joints in each segment.

# APPENDIX F: ODOT VIDEO LOGGING HARDWARE SPECIFICATIONS

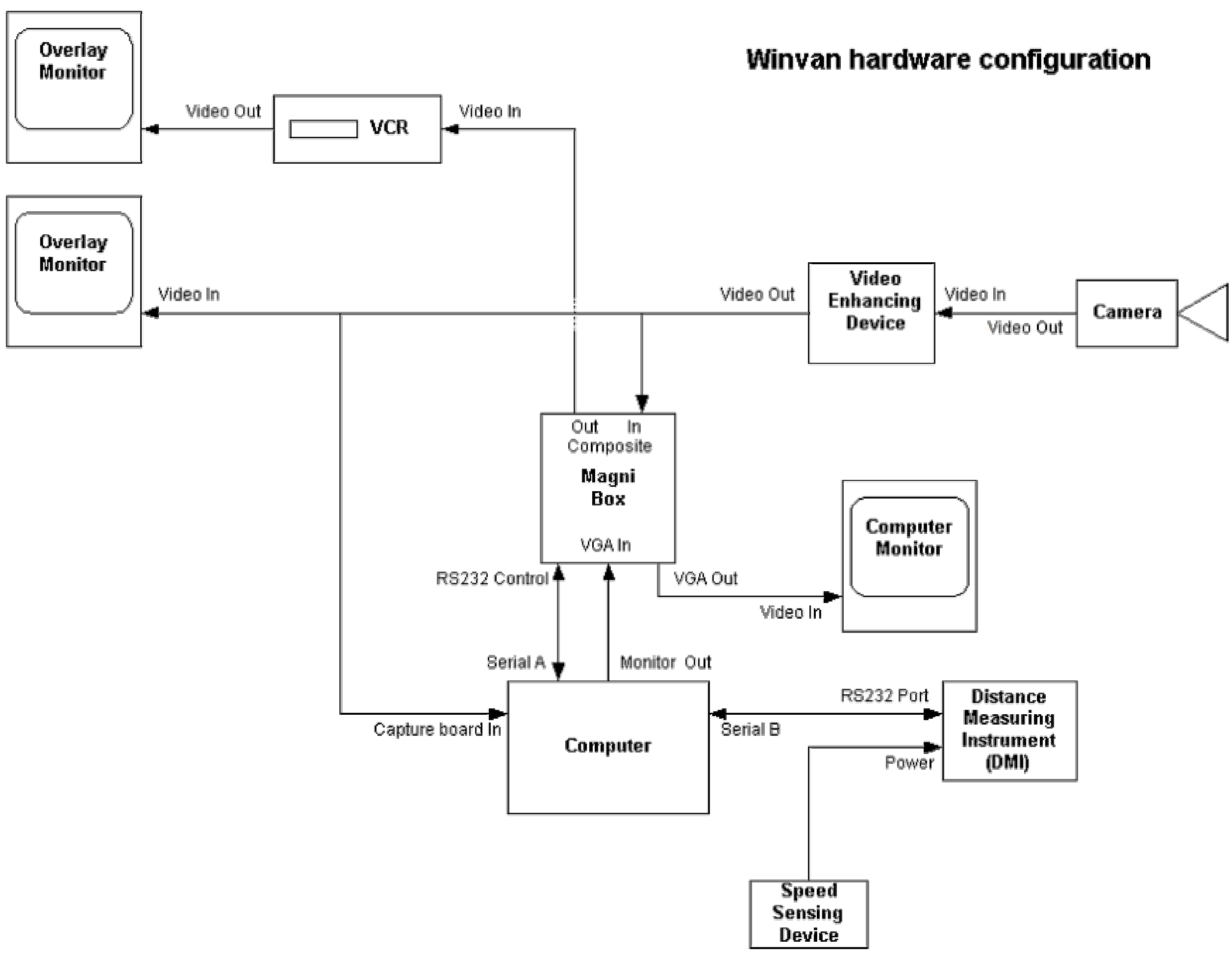
# WinVan
# 370 Physical Configuration

Original Author: Jeff Spalding
File Name: 490-520_Winvan.doc
Created Date:
Saved Date: 6/1/2005 12:58 PM

## Winvan Hardware Configuration

| Component | Connection | Description |
|---|---|---|
| | | |
| **Camera** | | Video source |
| | Monitor Out | Connects to input of Video Enhancement device |
| **Video Enhancement device** | | Device to enhance quality of camera image before sending to program |
| | input | Takes input from Camera |
| | output | To MagniBox In, Monitor 1 & Capture Board |
| **Camera Monitor**<br><br>**Composite input** | | Display enhanced image stream from camera without the overlay |
| | Video In | From Video Enhancement device |
| **MagniPro Box** | | Combines camera image stream with overlay text from Computer and outputs to VCR |
| | In | Enhanced Camera Image |
| | Out | Overlayed Camera image to VCR |
| | VGA In | Text overlay from Computer program |
| | VGA Out | To Computer Monitor |
| | RS232 Control | Receives overlay parameters from MagniApp program on Computer |
| **Computer Monitor**<br><br>**Any standard monitor compatible with Computer** | | Displays running program and Enhanced Camera image stream |
| | VGA In | From Magni box |
| **Computer**<br><br>**Min requirements:**<br>**800 MH 128K RAM**<br>**NT Operating System**<br>**20 GB Hard drive**<br>**CD ROM** | | Runs MagniApp and Winvan programs and provides storage for captured images |
| | Serial A | Sends overlay parameters to Magni box via MagniApp program. |
| | Serial B | Connects with RS232 port on DMI |
| | Monitor Out | To Magni box |
| **Flash Bus MV Pro image capture card** | | Uses FlashBus MV VIDCAP 32 Driver version 0.3.0.2. See FlashBus installation instructions. |
| | Capture Board Input | Receives enhanced camera image stream. |

| | | |
|---|---|---|
| **Distance Measuring Instrument(DMI)**<br><br>**Numetrics Nitestar NS-60 or equivalent.** | | Displays Accumulated Relative Mileage |
| | RS232 | Serial port for reading from and writing to DMI by the computer |
| | Power | Provided by vehicle |
| **Speed Sensing Device (comes with DMI)** | | Sends speed/distance data to DMI |
| | Output | To Power port on DMI |
| **VCR** | | Records archive video. |
| | Video In | Merged camera image stream and text overlay. |
| | Video Out | To Monitor 2 |
| **Overlay Monitor**<br><br>**Composite input** | | Displays video from VCR. |
| | Video In | From VCR Video Out |



# APPENDIX G: NON-NHS HIGHWAY CONDITION RATING PROCEDURE

# PAVEMENT CONDITION SURVEY PROCEDURE
# for
# NON-NATIONAL HIGHWAY SYSTEM PAVEMENTS

All Non-NHS condition surveys will be conducted by two-person teams trained in pavement surface distress identification and rating procedures. The survey teams will be comprised of Pavement Services Unit personnel trained by Pavement Management staff. Training will include proper distress identification and the associated Good-Fair-Poor (GFP) condition rating using actual sections of the State Highway System. These sections will include representative samples of the distress types that affect the GFP condition ratings.

The Pavements Unit will provide each rating team with a list of Sections to be rated, sorted by *State Highway Number*. Condition ratings will be accomplished via a "windshield" survey from a moving vehicle. Raters may slow or stop the vehicle as often as necessary to correctly identify and quantify distress and properly rate each section of pavement. **The operator of the motor vehicle should always ensure that he or she operates the vehicle in a manner that does not endanger the rating team or the public. Safety shall always take precedence over the requirement to collect accurate data.**

Standard practice is to drive the section, mostly at highway speeds, and note the general condition of the entire section. A GFP rating is then assigned based on the overall average condition of the section and recorded on the appropriate rating forms provided by the Pavement Management Unit. If conditions vary significantly between lanes, the rating shall be based upon the condition of the worst lane. The condition survey teams will only rate pavements that are dry. Ratings shall not be done while it is raining or while the pavement is still wet following a rain event.

The two people in a rating team have different roles. Both people conduct visual surveys of the section being rated. The Driver does so while operating the vehicle in a safe and responsible manner. In addition to the visual survey, the Navigator also provides the Driver with relevant section information (BMP, EMP, age, surface type, etc.), records both people's section ratings, documents any comments the raters have on the section, and determines the location of the next section to be rated.

Sections are identified from ODOT's Pavement Management System by the Pavement Management Unit and are based on section names, surface types and the previous two years pavement condition. Ideally raters should rate sections of like name as having the same condition where appropriate. Conditions may vary within the sections. When appropriate, the rater may identify new sections by splitting existing sections into subsections. These new sections should be of sufficient length to reasonably be programmed as a single construction project (i.e. the new sections should be no less than half a mile). If the rater(s) split(s) an existing section into subsections, they shall record the milepoints which define the new subsections and rate the subsections individually. Where sections are split because of previous condition history, we would like the raters to make suggestions for recombination of the sections where appropriate.

**GFP CONDITION RATING DEFINITIONS**
For Non-National Highway System
**Asphalt Concrete Pavement (AC)**

| Score | Definition |
|---|---|
| Very Good (1.0 - 1.9) | Stable, no cracking, no patching, and no deformation. Excellent riding qualities. Nothing would improve the roadway at this time. |
| Good (2.0 - 2.9) | Stable, minor cracking, generally hairline and hard to detect. Minor patching and possibly some minor deformation evident. Dry or light colored appearance. Very good riding qualities. Rutting may be present but is less than ½". |
| Fair (3.0 - 3.9) | Generally stable, minor areas of structural weakness evident. Cracking is easier to detect, patched but not excessively. Deformation more pronounced and easily noticed. Ride qualities are good to acceptable. Rutting may be present but is less than ¾". |
| Poor (4.0 - 4.9) | Areas of instability, marked evidence of structural deficiency, large crack patterns (alligatoring), heavy and numerous patches, deformation very noticeable. Riding qualities range from acceptable to poor. When rutting is present, rut depth is greater than ¾". |
| Very Poor (5.0) | Pavement in extremely deteriorated condition. Numerous areas of instability. Majority of section showing structural deficiency. Ride quality is unacceptable (probably should slow down). |

**Special Circumstances:**

| Score | Used When: |
|---|---|
| "8" | Section is on a bridge |
| "9" | Section is under construction |
| "0" | Pavement was not rated |

## GFP CONDITION RATING DEFINITIONS

For Non-National Highway System

**Portland Cement Concrete Pavement (JCP and CRCP)**

| Score | Definition |
|---|---|
| Very Good (1.0 - 1.9) | Ride qualities are good. Original surface texture evident. Jointed reinforced--have no mid-slab cracks. Continuously reinforced--may have tight transverse cracks with no evidence of spalling. No faulting is evident. |
| Good (2.0 - 2.9) | Ride qualities are good. Original surface texture is worn in wheel tracks exposing coarse aggregate. Jointed reinforced--may have tight mid-slab transverse crack. Continuously reinforced--transverse cracks may show evidence of minor spalling. Pavement may have an occasional short longitudinal crack. No faulting is evident. Rutting may be present but is less than ½". |
| Fair (3.0 - 3.9) | Ride qualities are good. Jointed reinforced--may have some spalling at cracks and joint edges with longitudinal cracks appearing at less than 20% of the joints. A few areas may require minor level of repair by maintenance forces. Continuously reinforced--may show evidence of spalling with longitudinal cracks occurring in the wheel paths on less than 20% of the section. Shoulder joints may show evidence of deterioration and loss of slab support; faulting may be evident. Rutting may be present but is less than ¾". |
| Poor (4.0 - 4.9) | Ride may continue to be acceptable. On both jointed and continuously reinforced, cracking patterns are evident with longitudinal cracks connecting joints and transverse cracks occurring more frequently. Occasional punchout repair evident. Some joints and cracks show loss of base support. When rutting is present, rut depth is greater than ¾". |
| Very Poor (5.0) | Rate of deterioration rapidly accelerating. |

**Special Circumstances:**

| Score | Used When: |
|---|---|
| "8" | Pavement section is on a bridge |
| "9" | Pavement section is under construction |
| "0" | Pavement section was not rated |

# APPENDIX H: NHS HIGHWAY CONDITION RATING PROCEDURE

# OREGON DEPARTMENT OF TRANSPORTATION

## Distress Survey Manual

### INTRODUCTION

- This manual in conjunction with the SHRP Distress Identification Manual for the Long-Term Pavement Performance Project (SHRP-P-338) outlines the procedure for conducting distress surveys. The purpose of the distress surveys is to identify and quantify the amount and severity of surface distress in a given segment of pavement. The results of the distress survey are used along with other measured pavement characteristics to establish a condition rating for the roadway segment.
- The Oregon State Highway System is currently composed of three primary surface types; Asphalt Concrete (AC), Jointed Portland Cement Concrete Pavement (JCP), and Continuously Reinforced Portland Cement Concrete Pavement (CRCP). The distress types and procedures for rating each of these pavement types are presented in this manual.

### SURVEY PROCEDURE

- Two-person crews trained in distress identification procedures will conduct condition surveys. Training will include proper distress identification using standardized sections of the State Highway System. These standardized sections will include examples of each of the four pavement types. For a given pavement type, the standardized sections will include typical examples of each type of distress.
- The condition survey will be accomplished via a ”side window” survey from a slow-moving vehicle operating on the adjacent shoulder. If conditions do not permit the safe operation of a vehicle along the shoulder, then the crew will either skip the segment or conduct the survey on foot being careful to not endanger themselves or the motoring public.
- The highway will be rated in 0.1-mile increments. The distresses will be recorded for each segment rated. The distress will be identified according to the descriptions provided in this manual.

The following is a brief summary of the distress survey procedure:

- Begin at the appropriate milepoint marker.
- Select the appropriate data entry screen or survey form (AC, JCP, or CRC).
- Complete the section description information.
- Survey the 0.1-mile segment.
- Record information on the computer or survey form.
- Return to step one and repeat the process.

When recording the survey data, note any unusual conditions in the comment section. Also note, but do not rate, long bridge decks, which fall within the section. Frequently, only partial miles will be rated because of construction activity, a bridge deck, or for safety reasons. In the event one or more 0.1-mile segments are not rated within a given mile, place an "N" in the appropriate field to indicate that the segment was not rated. Also note in the remarks field the reason why the segment was not rated.

# DISTRESS SURVEY MANUAL

# SECTION 1
# ASPHALT CONCRETE (AC) PAVEMENTS

The evaluation of asphalt pavements will be completed by rating the distress in the pavement according to the SHRP descriptions and severity levels as summarized below.

## *DISTRESS TYPES*

Rutting
Fatigue Cracking
Longitudinal Cracking
Transverse Cracking
Block Cracking
Potholes and Patches
Raveling
Bleeding

# RUTTING

## AC - JCP - CRCP

Rutting is a longitudinal surface depression in the wheel path caused by permanent deformation (AC only) or  the wearing away of the pavement surface. Rut depth is measured in both wheel tracks by a 5-point laser system mounted on the profilometer. This measurement is performed separate from the manual distress survey.

The rut depth will be categorized as zero, low, moderate, or high according to the following criteria:

### *Identification*

Longitudinal surface depression in wheel path

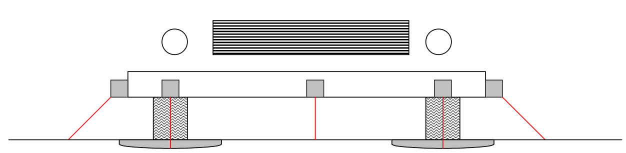
### *Severity Level*

**Zero** =  0” < 1/4”
**Low** = 1/4” < 1/2”
**Mod** = 1/2” < 3/4”
**High** ≥ 3/4”

### *How to Measure*

#### 5-Point Laser System

Ruts are measured with a 5 point laser system mounted on the front bumper of a Class 1 high speed Profilometer. The data is collected every 6-inches and then aggregated for every 10th mile. The average rut depth plus one standard deviation for each wheeltrack is evaluated and the greater of the two measurements determines the rut severity.



# FATIGUE CRACKING

Fatigue cracking, also known as alligator cracking, is a single crack or series of interconnected cracks caused by fatigue failure of the asphalt concrete. Longitudinal cracks in the wheel path are rated as fatigue cracks.

## *Identification*

Occurs in areas subjected to repeated traffic loading (wheel paths). Can be a series of interconnected cracks in early stages of development. Develops into many-sided, sharp-angled pieces, usually less than 0.3 meters longest side. Characteristically has chicken wire/alligator pattern in later stages.

## *Severity Levels*

**Low** - An area of cracks with no or only a few connecting cracks
Cracks must not be spalled
No pumping is evident.

**Moderate** - An area of interconnected cracks forming a complete pattern
Cracks may be slightly spalled
No pumping is evident.

**High** - An area of moderately or severely spalled interconnected cracks forming a complete pattern
Cracks may be sealed
Pieces may move when subjected to traffic
Pumping may be evident

## *How to Measure*

Visually estimate the **linear feet** of the wheel track affected. Record the linear feet at each severity level. Maximum quantity - **1,000** ft per 0.1-mile. If different severity levels exist within an area that cannot easily be distinguished, use highest severity level

# LONGITUDINAL CRACKING

Longitudinal cracks are cracks that are parallel to the pavement's centerline. Only longitudinal cracks that are **not** in a wheel path should be recorded as this form of distress. Longitudinal cracks which occur in the wheel path should be rated as fatigue cracking.

## *Identification*

Cracks predominantly parallel to pavement centerline. Location within the lane (non-wheel path) is significant.

## *Severity Levels*

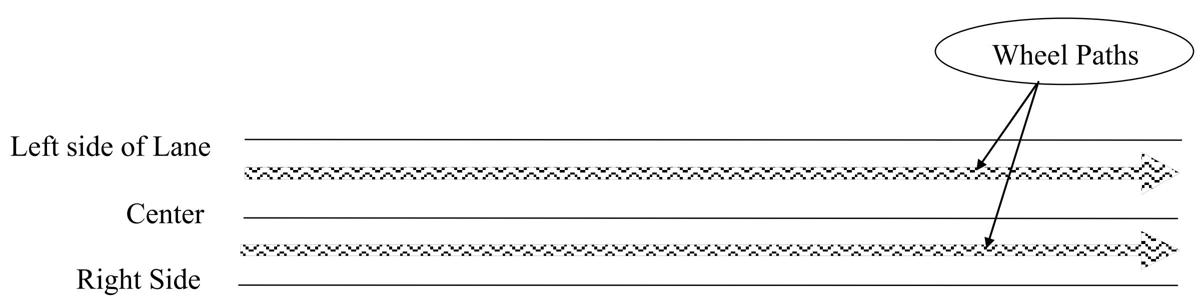
**Low** - A crack with a mean width of < 0.25"; or a sealed crack with sealant material in good condition and a width that cannot be determined.

**Moderate** - Any crack with a mean width ≥ 0.25" and < 0.75"; or any crack with a mean width < 0.75 in and adjacent low severity random cracking.

**High** - Any crack with a mean width ≥ 0.75"; or any crack with a mean width < 0.75" and adjacent moderate to high severity random cracking.

## *How to measure*

Record **linear feet** at each severity level. Maximum of **1,500** linear feet per 0.1-mile. If questionable whether longitudinal or fatigue cracking, record as fatigue.



# TRANSVERSE CRACKING

Transverse cracks are predominantly perpendicular to the pavement centerline, and may extend all or part way across the travel lane. The amount of transverse cracking will be measured by counting the actual number of cracks that occur in the travel lane being rated.

Cracks must extend at least half way across the travel lane before being counted.

## *Identification*

Cracks predominantly perpendicular to pavement centerline.

## *Severity Levels*

**Low** - An unsealed crack with a mean width of < 0.25; or a sealed crack with sealant material in good condition and the width cannot be determined.

**Moderate** - Any crack with a mean width ≥ 0.25" and < 0.75"; or any crack with a mean width < 0.75 in and adjacent low severity random cracking.

**High** - Any crack with a mean width ≥ 0.75"; or any crack with a mean width < 0.75" and adjacent moderate to high severity random cracking.

## *How to Measure*

**Count number** of transverse cracks at each severity level. Rate entire transverse crack at the highest severity level present (must be present over 10% of crack). Maximum number of Transverse Cracks per 0.10-mile is **44.**

# BLOCK CRACKING

Block cracking is a distress where cracks divide the pavement surface into approximately rectangular pieces. These pieces are typically one to 100 square feet. Block cracking, unlike fatigue cracking, will typically occur throughout the pavement width, not just in the wheel tracks. The amount of block cracking will be visually estimated as to the square feet of the travel lane that suffers this distress.

## *Identification*

A pattern of cracks that divide the pavement into approximately rectangular pieces or blocks. Blocks range in size from approximately 1 $ft^2$. to 100 $ft^2$.

## *Severity Levels*

**Low** - Cracks with a mean width of < 0.25; or sealed cracks with sealant material in good condition and the width cannot be determined.

**Moderate** - Cracks with a mean width ≥ 0.25" and < 0.75"; or any crack with a mean width < 0.75 in and adjacent low severity random cracking.

**High** - Cracks with a mean width ≥ 0.75"; or any crack with a mean width < 0.75" and adjacent moderate to high severity random cracking.

## *How to Measure*

Record **square feet** of affected area at each severity level. The maximum area of Block cracking is **6,000** $ft^2$ per 0.10-mile.

# PATCH

Potholes and patches will be rated together. The amount of potholes and patching in any one segment will be visually estimated as to the square feet of the travel lane experiencing this distress.

## *Identification (Patch)*

Portion of pavement surface, greater than 1-$ft^2$ that has been removed and replaced or additional material applied to the pavement after original construction.

## *Severity Levels*

**Low** - Patch has at most low severity distress of any type.

**Moderate** - Patch has moderate severity distress of any type.

**High** - Patch has high severity distress of any type.

## *How to Measure*

Square feet of affected area at each severity level. The maximum area of Patching is **6,000** $ft^2$ per 0.10-mile.

Note 1: Any distress in the boundary of the patch is included in rating the patch.

Note 2: Do not include utility patches. Only include patches caused by distresses.

# POTHOLE

Potholes and patches will be rated together. The amount of potholes and patching in any one segment will be visually estimated as to the square feet of the travel lane experiencing this distress.

## *Identification (Pothole)*

Bowl-shaped holes of various sizes in the pavement surface. Minimum plan dimension is **6**”.

## *Severity Levels*

**Low** < 1”
**Mod** ≥ 1 < 2”
**High** ≥ 2”

## *How to Measure*

Square feet of affected area at each severity level.

# RAVELING

Raveling is the wearing away of the pavement surface caused by the dislodging of coarse aggregate particles. It is a progressive disintegration from the surface downward, usually as the result of traffic action. The severity of raveling is based on the estimated percentage of aggregate loss in a 1' wide longitudinal strip of pavement surface as described below. The quantity of raveling will be estimated based on the linear feet of raveling occurring in the inside wheel path, outside wheel path, and between the wheelpaths.

## *Identification*

Raveling can be identified by a roughened or pitted texture on the pavement surface. Mechanical abrasion from tire chains, studs, snowplows, or dragging equipment which significantly roughens up the texture should be rated as raveling. Studded tire rutting which does not roughen up the texture significantly should not be rated as raveling. Raveling tends to be most often found in the wheel paths, but can be elsewhere on the pavement surface.

## *Severity Level*

For all surface types, raveling is not rated if less than 25% of the surface in a given 1' wide strip is affected. NOTE Chip Seals are normally rough textured - only rate as low severity raveling if there is ≥25% aggregate loss present in a 1' wide strip.

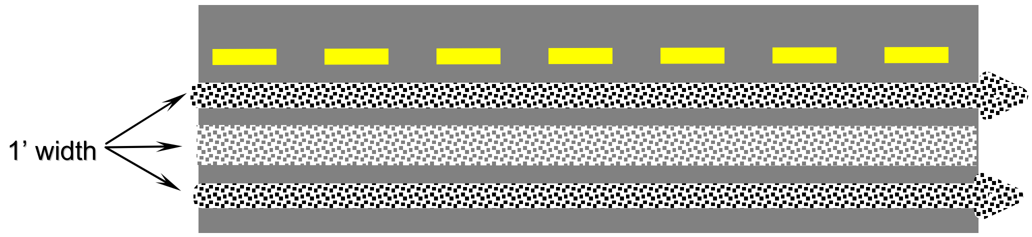
**Low** - The **coarse** aggregate has worn away resulting in ≥25% to <50% aggregate loss in a 1' wide longitudinal strip of pavement surface. Loss of chip seal rock should be rated as raveling, but this is the maximum severity for chip sealed surfaces.

**Moderate** - Surface texture is noticeably rough and/or pitted with ≥50% to <75 % aggregate loss in a 1' wide longitudinal strip of pavement surface. A nearly continuous strip of aggregate loss 3" – 6" wide may be present. Loose particles may be present outside the traffic area.

**High** - Surface texture is very rough and/or pitted with ≥75% aggregate loss in a 1' wide longitudinal strip of pavement surface. Flat bottom potholes may be present where complete loss of aggregate has occurred.

## *How to Measure*

Record **linear feet** of each severity level for each path - inside, outside, and between wheel paths. Maximum of **500** ft per path and **1,500** ft per 0.1 mile. If raveling covers entire area count as if there were 3 adjacent paths.



# BLEEDING

Bleeding is indicated by the excess bituminous material on the pavement surface, which creates a shiny, glass-like reflective surface which usually becomes sticky in hot temperatures. Bleeding is not rated by severity level, but should be recorded when it is severe enough to cause a reduction in skid resistance. A segment is considered to have measurable bleeding if it has multiple areas ≥ 25 square feet of bleeding. Bleeding will simply be recorded as either existing or not existing for each 0.1-mile segment.

## *Identification*

Excess bituminous binder on pavement surface. May create a shiny, glass-like, reflective surface that may be tacky to the touch. Usually found in the wheelpaths.

## *Severity Levels*

Bleeding is present if multiple areas of **25 $ft^2$** or larger patches**.**

## *How to Measure*

Recorded as either existing or not existing (**Yes/No**)

# DISTRESS SURVEY MANUAL

# SECTION 2
# JOINTED CONCRETE PAVEMENTS
# (JCP)

The evaluation of jointed concrete pavements will be completed by rating the distress in the pavement according to the SHRP descriptions and severity levels as summarized below.

## *DISTRESS TYPES*

Rutting (See AC Pavement Section)
Corner Crack
Corner Break
Longitudinal Cracking
Transverse Cracking
Shattered Slab
Patch Condition
Joint Condition

# CORNER CRACKING

Corner cracks are cracks of any length that begin at transverse joints and are predominantly parallel to the pavement centerline. These cracks are located anywhere from the edge of the PCC up to and including the wheel path. Corner crack severity is based on crack width, spalling or faulting. The amount of corner cracking will be measured by counting the number of cracks that occur in each tenth-mile segment. Corner cracks that intersect transverse cracks will be rated as corner breaks and not as corner cracks.

## *Identification*

A crack which begins at a transverse joint and radiates outward predominantly parallel to the pavement centerline. Located anywhere from the PCC edge to and including the wheel path.

## *Severity Levels*

**Low** – Crack widths < 0.125”, no spalling, and no measurable faulting; or well sealed and with a width that cannot be determined.

**Moderate** – Crack widths $\geq$ 0.125” and < 0.5”; or with spalling < 3”; or faulting up to 0.5”.

**High** – Crack widths $\geq$ 0.5”; or with spalling $\geq$ 3”; or faulting $\geq$ 0.5”.

## *How to Measure*

Record the **number** of corner cracks at each severity level (Total **32** max)

# CORNER BREAK

A corner break is the separation of a corner portion of concrete from the rest of the PCC slab. Corner breaks occur when a corner crack is intersected by a transverse crack <u>or</u> when a diagonal crack extends across the corner of a slab. Corner break severity is based on spalling, faulting, or number of broken pieces, <u>not</u> crack width. The amount of corner breaks will be measured by counting the number of breaks that occur in each segment.

## *Identification*

A crack which separates the slab and intersects the adjacent transverse and longitudinal joints, describing an approximate 45 degree angle with the direction of traffic. Not included are cracks that are within one foot of the edge and less than 1 foot long.

## *Severity Levels*

**Low** – Crack is not spalled or is spalled for <10 % of the length of the crack; no measurable faulting; and corner piece is not broken into two or more pieces.

**Moderate** – Crack is spalled at low severity (< 3”) for >10% of its total length; or faulting of crack or joint is < 0.5”; and the corner piece is not broken.

**High** – Crack is spalled at moderate (≥ 3” and < 6”) to high severity ≥ 6” for >10 % of its total length; or faulting is ≥ 0.5”; or the corner piece is broken into two or more pieces.

## *How to Measure*

Record the **number** of corner cracks at each severity level (Total **32** max)

# LONGITUDINAL CRACKS

Longitudinal cracks are cracks that are predominantly parallel to the pavement centerline. Only longitudinal cracks that are **not** classified as corner cracks should be recorded as this form of distress (see description of corner cracks). Longitudinal cracks do not start at the joint, or if they start at the joint they are in the center of the lane between wheel paths. The crack severity is based on width, spalling, and faulting.

## *Identification*

Cracks that are predominately parallel to the pavement centerline. Only cracks that are not corner cracks (intersecting transverse joints) should be recorded

## *Severity Levels*

**Low** – Crack widths < 0.125”, no spalling, and no measurable faulting; or well sealed and with a width that cannot be determined.

**Moderate** – Crack widths ≥ 0.125” and < 0.5”; or with spalling < 3”; or faulting up to 0.5”.

**High** – Crack widths ≥ 0.5”; or with spalling ≥ 3”; or faulting ≥ 0.5”.

## *How to Measure*

Record the linear feet in each severity level (**1500** ft Maximum)

# TRANSVERSE CRACK

Transverse cracks are cracks that are predominantly perpendicular to the pavement centerline. These cracks extend all or part way across the travel lane. Transverse crack severity is based on crack width, spalling and faulting. The amount of transverse cracking will be measured by counting the actual number of cracks that occur in the travel lane being rated.

## *Identification*

Cracks that are perpendicular to the pavement centerline.

## *Severity Levels*

**Low** – Crack width < 0.125 inches, and no spalling, and no measurable faulting; or well-sealed and width cannot be determined.

**Moderate** – Crack widths ≥ 0.125 inches and < 0.25 inches; or with spalling < 3 inches; or faulting up to 0.25 inches.

**High** – Crack widths ≥ 0.25 inches; or with spalling ≥ 3 inches; or faulting ≥ 0.25 inches.

## *How to Measure*

Record the number of cracks at each severity (Total **44** maximum). Rate the entire transverse crack at the highest severity level present for at least 10% of the total length of the crack. Cracks should extend at least half way across the travel lane before being counted.

# SHATTERED SLAB

A shattered slab is a concrete slab that is broken into three or more pieces. Slabs that are divided solely by transverse cracks are not included. Corner breaks are also not included. The severity of a shattered slab is determined by the number of pieces the slab is broken into combined with the severity of spalling and faulting exhibited. The quantity of shattered slabs will be measured by counting the number that occurs in each 0.1-mile segment.

## *Identification*

A concrete slab that is broken into three or more pieces. Do not include corner breaks when counting broken slab sections. Also do not include slab sections that are divided by one or more transverse cracks.

## *Severity Levels*

**Low** – Slab is broken into 3 pieces. The cracks describing the broken sections are not spalled or are spalled for <10 % of the length of the crack; no measurable faulting.

**Moderate** – Slab is broken into 4 pieces; or the cracks describing the broken sections are spalled at low severity (< 3”) for >10% of its total length; or faulting is < 0.5”.

**High** – Slab is broken into 5 or more pieces; or the cracks describing the broken sections are spalled $\geq$ 3” for >10 % of its total length; or faulting is $\geq$ 0.5”.

## *How to Measure*

Record the number of shattered slabs at each severity level
(Total **32** max)

# PATCH CONDITION

A patch is an area where the original pavement has been removed and replaced, or additional material applied to the pavement after original construction. *If patch material is non-concrete, the patch will be rated as high severity*. The patch severity is based on distresses present in the patch or faulting. The amount of patching will be measured by estimating the square feet of the outside lane that is patched.

## *Identification*

A portion or all of the original concrete slab that has been removed and replaced, or additional material applied to the pavement after original construction.

## *Severity Levels*

**Low** – Patch has at most low severity distress of any type; and no measurable faulting or settlement; pumping is not evident.

**Moderate** – Patch has moderate severity distress of any type; or faulting or settlement to 0.25 inches; pumping is not evident.

**High** – Patch has a high severity distress of any type; or faulting or settlement $\geq$ 0.25 inches; pumping may be evident. Also includes patches that are not made with concrete materials.

## *How to Measure*

Record the square feet at each severity level (**6,000** square feet maximum).

# JOINT CONDITION

## *Rating*

Rating is based on a combination of the joint and joint seal condition. The condition of the transverse, lane, and shoulder joints will be rated separately based on the average condition of the joints in each segment, as follows:

## *Severity Level*

**Low** - Joint is in good condition and seal is in good condition.

**Mod** - Joint is slightly spalled with seal in good condition or joint is in good condition with seal in poor condition.

**High** - Joint is badly spalled or joint is slightly spalled with seal in poor condition.

## DISTRESS SURVEY MANUAL

# SECTION 3
# CONTINUIOUSLY REINFORCED CONCRETE PAVEMENT (CRCP)

The evaluation of continuously reinforced concrete pavements will be completed by rating the distress in the pavement according to the SHRP descriptions and severity levels as summarized below.

## *DISTRESS TYPES*

Rutting (See AC Pavement Section)

Longitudinal Cracking

Transverse Cracking

Punchouts

Potholes and Patches

Joint Condition

# LONGITUDINAL CRACK

Longitudinal cracks are cracks that are predominantly parallel to the pavement centerline. The crack severity is based on width, spalling, and faulting, and is adjusted for load related cracking.

## *Identification*

Cracks that are predominately parallel to the pavement centerline. For CRCP, the severity level is "bumped" up to the next level if the crack is load related, in accordance with the definition below.

**Non-Load Related -** Majority of crack *out of wheeltrack*

Within 1' of the lane or shoulder joint, or Within 1' of the middle of the lane

Note - Crack may meander into wheeltrack but generally stays out of the wheeltrack

**Load Related -** Majority of crack *in the wheeltrack* (area excluded in above definition)

Shape is typically linear and parallel to lane, although may be diagonal or crescent shaped. All load related cracks are rated as either moderate or high severity

## *Severity Levels*

**Low** – Non-load related cracks with a width < 0.125”, no spalling, and no measurable faulting; <u>or</u> well sealed and with a width that cannot be determined. Low load-related cracks are bumped to moderate.

**Moderate** – Crack widths ≥ 0.125” and < 0.5”; <u>or</u> with spalling < 3”; or faulting up to 0.5”. Also includes low severity load related cracks. Moderate load-related cracks are bumped to high.

**High** – Crack widths ≥ 0.5”; <u>or</u> with spalling ≥ 3”; or faulting ≥ 0.5”. Also includes moderate severity load related cracks.

## *How to Measure*

Record the **linear feet** in each severity level. (**1,500** feet maximum)

# TRANSVERSE CRACK

Transverse cracking of continuously reinforced concrete pavement is normal and is not considered a form of distress. However, if the cracks open up, major deterioration may result. Transverse crack severity is rated based on the average crack condition in the 0.1-mile segment Also, at each milepoint marker, the average crack spacing is determined in a 100-foot section by dividing 100 by the number of cracks counted in the section.

## *Identification*

Cracks that are perpendicular to the pavement centerline.

## *Severity Levels*

**Low** – Cracks that are not spalled or are spalled < 10% of the crack length.
**Moderate** – Cracks that are spalled along ≥ 10% and < 50% of the crack length.
**High** – Cracks that are spalled along ≥ 50% of the crack length.

## *How to Measure*

Measure **once per mile at the mile point marker** by counting the number of cracks within a 100-foot section. Record as a crack spacing (100/number of cracks). Severity is based upon average crack condition. All transverse cracks that intersect an imaginary longitudinal line at midlane, and propagate from the pavement edges, shall be counted as individual cracks. Cracks that do not cross midlane are not counted.

**EXAMPLE # 1**

The DMI indicates a group is at MP 240. The group counts the number and severity of the cracks for 100 feet. After travelling the 100 feet the group has gathered the following information:

17 Low severity cracks, of which 5 are "Y" cracks
20 Moderate severity cracks, of which 8 are "Y" cracks
3 High severity cracks, of which 1 is a "Y" crack.

There are a total of 40 cracks (17 + 20 + 3 = 40). Recall that "Y" cracks are recorded as a single crack. The crack spacing is calculated as 100/40 = 3 (Nearest whole number). The average severity is moderate. Three is entered under the moderate spacing column for transverse crack severity.

**EXAMPLE #2**

The DMI indicates a group is at MP 241. The following information is recorded in the 100-foot measurement interval.
1 Low severity cracks
4 Moderate severity cracks
15 High severity cracks
The crack spacing is 100/20 = 5. The severity is high.

# PUNCHOUT

A punchout is the separation of a block of concrete from the rest of the CRCP formed by two closely spaced transverse cracks, a short longitudinal crack, and the edge of the pavement or longitudinal joint. As the cracks deteriorate, the steel ruptures and the block of concrete punches downward into the base and subbase. Punchouts will be rated as low, moderate, or high based on spalling or faulting. The quantity of punchouts will be measured by counting the number that occurs in each segment. If a punchout has been patched with asphalt, it should be rated as a high-severity punchout and not a patch, as the patch is only a temporary repair.

### *Description*

A localized separation of a block of concrete from the rest of the PCC slab. Also includes "Y" cracks that exhibit spalling, breakup, and faulting. Longitudinal crack defining the block may be any length. Adjacent transverse cracks may be more than 2' apart.
Branch portion of "Y" crack must be less than 1/2 lane.

### *Severity Levels*

**Low** – Longitudinal or transverse crack are spalling < 3” or faulting < 0.25”. At least two cracks defining the block must be spalled. Does not include "Y" cracks.

**Moderate** – Spalling ≥ 3” and < 6” or faulting ≥ 0.25 inches. Includes "Y" cracks that exhibit spalling, breakup and faulting in the branch portion of the "Y" along >10% (1' minimum) and <50% of crack length.

**High** – Spalling ≥ 6” or concrete within the punchout is punched down by ≥ 0.5” or is loose and moves under traffic. Includes "Y" cracks that exhibit high severity spalling, breakup and faulting in the branches of the "Y" along >50% of the crack length.

### *How to Measure*

Record the **number** of punchouts at each severity level (Total **5** maximum). A group of punchouts on a single longitudinal crack is counted as only one punchout (rate highest severity of group). The cracks which outline the punchout are also recorded under longitudinal and transverse cracking when appropriate.

# PATCH CONDITION

A patch is an area where the original pavement has been removed and replaced with non-asphalt type of material. An asphalt patch should be rated as a high-severity punchout instead of a patch. The patch severity is based on distress in the patch, faulting or pumping. The amount of patching will be measured by estimating the square feet of the outside lane that is patched.

## *Description*

A portion or all of the original concrete slab that has been removed and replaced with a permanent (concrete) type of material. An asphalt patch should be rated as a high-severity punchout instead of a patch.

## *Severity Levels*

**Low** – Patch has at most low severity distress of any type; and no measurable faulting or settlement at the perimeter of the patch.

**Moderate** – Patch has moderate severity distress of any type; or faulting or settlement < 0.25 inches at the perimeter of the patch.

**High** – Patch has a high severity distress of any type; or faulting or settlement ≥ 0.25 inches at the perimeter of the patch.

## *How to Measure*

Record the **square feet** at each severity level (**6,000** square feet maximum).

# JOINT CONDITION

### *Rating*

Rating is based on a combination of the joint and joint seal condition. The condition of the lane joint and shoulder joint will be rated separately based on the average condition of the joints in each segment, as follows:

**Low** - Joint is in good condition and seal is in good condition.

**Mod** - Joint is slightly spalled with seal in good condition or joint is in good condition with seal in poor condition.

**High** - Joint is badly spalled or joint is slightly spalled with seal in poor condition.

# APPENDIX I: PAVEMENT CONDITION INDICES

# COMPUTATION OF CONDITION INDICES

The detailed distress data from the Distress Survey procedure is summarized into index values that represent the range of pavement conditions observed in the field. The condition index values are a function of distress type, distress severity, and distress quantity present in the pavement surface. The index values have been established to range from zero (0) to 100. Larger index values indicate better pavement conditions. For example, a new pavement with no distress is assigned an index value of 100.

The distance of a tenth-mile has been selected as the length of a standard increment for which distress data are collected for calculation of condition index values. Once tenth-mile condition index values are determined, condition index values are calculated for relatively homogeneous pavement management sections. These sections vary in length depending on the factors such as construction history.

To calculate indices for a pavement management section, each tenth-mile increment within a given section is surveyed via the Distress Survey procedure. Using the distress data, a rut index, raveling index, patching index, fatigue index, and no load index are computed for each tenth-mile increment. For a given pavement management section, the tenth-mile rut indices are then averaged to produce a pavement management section rut index value. Similarly, the other indices for a given pavement management section are calculated by averaging the tenth-mile indices.

To determine an overall condition index of a pavement management section, each tenth-mile raveling index, patching index, fatigue index, and no load index are combined into one tenth-mile index value. This tenth-mile index value is compared to the tenth-mile rut index value. The lower of the index values is determined to be the "tenth-mile overall condition" index value. Next, to determine the overall pavement management section condition index, the "tenth-mile overall condition" indices are averaged.

For calculation of an index value for a given tenth-mile section, the distress(es) found in the pavement surface is categorized by type (fatigue cracking, transverse cracking, longitudinal cracking, etc.) and severity (low, moderate, or high) and then quantified. For each distress severity for each distress type, an index value is computed using Equation (1) as follows:

$$Index(typeX)_{(severityX)} = 1.0 - A * (Measured\ Distress/Maximum\ Distress)^{B} \qquad \text{Equation (1)}$$

The coefficient **A** and exponent **B** represent the relative importance of the type and severity of each distress. These values control the sensitivity of the index to the quantities of a given distress. Dividing the "Measured Distress" quantity by the "Maximum Distress" quantity possible generates a dimensionless value which ranges from zero (no distress measured) to one (measured distress is maximum possible). The "Maximum Distress" quantities which could occur in a standard tenth-mile section have been established for each of the distress type measured (e.g., 1,000 LF max. per tenth-mile section for fatigue cracking).

The values of coefficient **A** and exponent **B** have been established by determining the quantity and severity of each distress type allowed in each condition category. The coefficient **A** can range in value from 0 to 1.0 and establishes the importance of a particular severity level and distress type relative to all the other severity levels and distress types. The exponent **B** also ranges in value from 0 to 1.0 and sets the curvature of the equation, which controls the relative effect of small quantities for a particular distress type. When **B = 1.0**, the equation generates a straight line with slope **A**, and the index calculated is directly proportional to the quantity of measured distress. As **B** approaches **0** the equation becomes highly non-linear and very small quantities of distress generate increasingly larger percentage deducts.

After computing index values based on distress severity and distress type using Equation (1), a composite index value is calculated for each distress type by using Equation (2). This equation calculates the weighed average of the severity indices within a given distress type based on measured quantities for each category. Determination of this weighted average is a modification made to the 1993 condition index calculation procedure.

$$Index(typeX)=[(index\ (typeX)_{(sev.1)}*measured\ distress_{(sev.1)})+...(index(typeX)_{(sev.3)}*measured\ distress_{(sev.3)})] /(measured\ distress_{(sev.1)}+...measured\ distress_{(sev.3)}) \qquad \text{Equation (2)}$$

Once an index value is calculated for each distress type, a tenth-mile condition index is determined by multiplying each tenth-mile raveling index, patching index, fatigue index, and no load index together into one tenth-mile index value. This tenth-mile index value is compared to tenth-mile rut index value. The lower of the index values, multiplied by the constant 100, is determined to be the "tenth-mile overall condition" index value.

The index calculating algorithm utilizing Equations (1) and (2) provides a very flexible model for converting multiple distress types with quantities into a single dimensionless index value. The coefficients, exponents, and maximum values for the various distress types are presented in Tables D-1 through D-3. Most of the distress types have three levels of severity: low, moderate, and high. The total measured quantity of all three severity levels for a particular distress type cannot exceed the maximum value listed in Tables D-1, D-2, and D-3. (e.g., Fatigue(low) + Fatigue (mod) + Fatigue(high) <=1000 LF).

The distresses used to calculate the overall index are determined by the pavement surface type. For flexible (AC) pavements, the overall index is dependent on the following:

- Raveling index - moderate and high severity raveling (no deduct for low severity)
- Patch index - patches and potholes
- Fatigue index - fatigue cracks (no deduct for low severity fatigue cracking <= 25 feet)
- No load index - (environmental distresses including transverse and block cracks)
- Bleed index – bleeding
- Rut index – rutting

For Continuously Reinforced Concrete pavements, the overall index is dependent on the following:

- Lane joint index - moderate and high severity lane joint (no deduct for low severity)
- Shoulder joint index - moderate and high severity shoulder joint (no deduct for low severity)
- Fatigue index – longitudinal cracking, transverse cracking (moderate and high severity transverse crack severity with no deduct for low severity), and punchouts
- Patch index - patching
- Rut index – rutting

For Jointed Portland Cement Concrete pavements, the overall index is dependent on the following:

- Transverse joint index - moderate and high severity transverse joint (no deduct for low sev.)
- Lane joint index - moderate and high severity lane joint (no deduct for low severity)
- Shoulder joint index - moderate and high severity shoulder joint (no deduct for low severity)
- Fatigue index – longitudinal cracking, transverse cracking, corner breaks, corner cracks, and shattered slabs
- Patch index – patching
- Rut index – rutting

Regardless of pavement surface type, the rut index is based solely on the severity of rutting in the
pavement surface.

The following example demonstrates the calculation of the overall condition index for a given tenth-mile section:

**Example 1:** The field data for an asphalt concrete section from MP 37.8 to MP 37.9 indicates the following distress: 300 linear feet of low severity fatigue cracking, 500 linear feet of moderate severity fatigue cracking, and eight (8) low severity transverse cracks. The rutting is measured as low (¼"< ½"). Using Equations (1) and (2) and the appropriate coefficients and exponents from Table D-1, the overall index is computed for the given tenth-mile section as follows:

First, using Equation (1), calculate the index for each severity level for each distress type reported in the standard section:

$$Index\ (fatigue)_{(low)} = 1.0 - 0.6*(300/1{,}000)^{0.1} = 0.468$$
$$Index\ (fatigue)_{(moderate)} = 1.0 - 0.8*(500/1{,}000)^{0.1} = 0.254$$
$$Index\ (no\ load)_{(low)} = 1.0 - 0.33*(8/44)^{0.5} = 0.859$$
$$Index\ (rutting)_{(low)} = 1.0 - 0.05*(1/1)^{1} = 0.950$$

*Since no other detrimental conditions exist, the value for all other indices will be equal to 1.00 as shown in the following example:*

$\text{Index (patching)}_{(low)} = 1.0-0.55*(0/6000)^{0.1} = 1.0-0.55*0.0 = 1.000$

Second, with two severity levels measured for fatigue cracking, calculate the weighted average for the overall "index (fatigue)" using Equation (2):

$\text{Index (fatigue)} = [(0.47*300)+(0.25*500)]/(300+500) = 0.333$

$\text{Note: index (no load)} = \text{index (transverse)}_{(low)} = 0.859$

Third, multiply each tenth-mile index, excluding the tenth-mile rut index, into a single tenth-mile index value. This tenth-mile index value is compared to tenth-mile rut index value. The lower of the index values, multiplied by the constant 100, is determined to be the "tenth-mile overall condition" index value.

$\text{Non-rut index value} = \text{index(fatigue)}*\text{index(transverse)} = 0.333*0.859 = 0.286$
$\text{Rut index value} = 1.0-0.05 = 0.950$

*Therefore:*

$\text{Overall Index} = 100*\text{Non-rut index} = 100 * 0.286 = 28.6$

**Example 2:** The field data for an asphalt concrete section from MP 37.9 to MP 38.0 indicates the following distress: 100 linear feet of low severity fatigue cracking, 50 linear feet of moderate severity fatigue cracking, and six (6) low severity transverse cracks. The rutting is measured as high (≥ ¾"). Using Equations (1) and (2) and the appropriate coefficients and exponents from Table D-1, the overall index is computed for the given tenth-mile section as follows:

First, using Equation (1), calculate the index for each severity level for each distress type reported in the standard section:

$\text{Index (fatigue)}_{(low)} = 1.0-0.6*(100/1,000)^{0.1} = 0.523$
$\text{Index (fatigue)}_{(moderate)} = 1.0-0.8*(50/1,000)^{0.1} = 0.407$
$\text{Index (no load)}_{(low)} = 1.0-0.333*(6/44)^{0.5} = 0.877$
$\text{Index (rutting)}_{(high)} = 1.0-0.70*(1/1)^{1} = 0.300$

*Since no other detrimental conditions exist, the value for all other indices will be equal to 1.00 as shown in the following example:*

$\text{Index (patching)}_{(low)} = 1.0-0.55*(0/6000)^{0.1} = 1.0-0.55*0.0 = 1.000$

Second, with two severity levels measured for fatigue cracking, calculate the weighted average for the overall "index (fatigue)" using Equation (2):

$\text{Index (fatigue)} = [(0.523*100)+(0.407*50)]/(100+50) = 0.484$

$\text{Note: index (no load)} = \text{index (transverse)}_{(low)} = 0.877$

Third, multiply each tenth-mile index, excluding the tenth-mile rut index, into a single tenth-mile index value. This tenth-mile index value is compared to tenth-mile rut index value. The lower of the index values, multiplied by the constant 100, is determined to be the "tenth-mile overall condition" index value.

*Non-rut index value = index(fatigue)*index(transverse) = 0.484*0.877 = 0.424*
*Rut index value =1.0-0.70 = 0.300*

*Therefore:*
*Overall Index = 100*rut index = 100 * 0.300 = 30.0*

The individual index value for the Pavement Management Section is the average value of all of the tenth-mile sections within the length of the Pavement Management Section. The following example demonstrates the calculation of the overall index for a given Pavement Management Section.

**Example 3**: The two tenth-mile sections from the above examples are contained in a Pavement Management Section from MP 37.5 to MP 38.0. There are no distresses for the other tenth-mile sections contained in the Pavement Management Section. Therefore the overall index for the Pavement Management Section would be calculated as follows:

*Overall Index for Pavement Management Section = (Overall Index first 0.1 mile section + Overall Index second 0.1 mile section + …Overall Index nth 0.1 mile section)/n.*

*With*
*MP37.5 – MP 37.6 Overall Index = 100 (No distress)*
*MP37.6 – MP 37.7 Overall Index = 100 (No distress)*
*MP37.7 – MP 37.8 Overall Index = 100 (No distress)*
*MP37.8 – MP 37.9 Overall Index = 28.6 (Distress from example 1)*
*MP37.9 – MP 38.0 Overall Index = 30.0 (Distress from example 2)*

*Then the Overall Index for this Pavement Management Section is calculated as follows:*

*(100 + 100 + 100 + 28.6 + 30.0)/5 = 71.7 (This Pavement Management Section would be rated as fair)*

Typically it is unusual to find a Pavement Management Section with such a severe difference between tenth-mile sections.

**Table D-1. Flexible (AC) Pavement Deduct Coefficients**

| DISTRESS | A | B | MAXIMUM |
|---|---|---|---|
| RUTTING (LOW) | 0.050 | 1.00 | N/A |
| RUTTING (MOD) | 0.450 | 1.00 | |
| RUTTING (HIGH) | 0.700 | 1.00 | |
| FATIGUE (LOW) | 0.600 | 0.10 | 1,000 LF |
| FATIGUE (MOD) | 0.800 | 0.10 | |
| FATIGUE (HIGH) | 1.000 | 0.10 | |
| LONGITUDINAL (LOW) | 0.000 | 1.00 | 1,500 LF |
| LONGITUDINAL (MOD) | 0.000 | 1.00 | |
| LONGITUDINAL (HIGH) | 0.000 | 1.00 | |
| TRANSVERSE (LOW) | 0.333 | 0.50 | 44 EA |
| TRANSVERSE (MOD) | 0.667 | 0.50 | |
| TRANSVERSE (HIGH) | 1.000 | 0.50 | |
| BLOCK CRACK (LOW) | 0.333 | 0.50 | 6,000 SF |
| BLOCK CRACK (MOD) | 0.667 | 0.40 | |
| BLOCK CRACK (HIGH) | 1.000 | 0.30 | |
| PATCH/POTHOLE (LOW) | 0.550 | 0.10 | 6,000 SF |
| PATCH/POTHOLE (MOD) | 0.800 | 0.10 | |
| PATCH/POTHOLE (HIGH) | 1.000 | 0.10 | |
| RAVELING (LOW) | 0.500 | 0.50 | 1,500 SF |
| RAVELING (MOD) | 0.750 | 0.50 | |
| RAVELING (HIGH) | 1.000 | 0.50 | |
| BLEEDING (NO) | 0.000 | 1.00 | N/A |
| BLEEDING (YES) | 0.050 | 1.00 | N/A |

Highlighted sections indicate a change from previous reports.

## Table D-2 Jointed Concrete Deduct Coefficients

| DISTRESS | A | B | MAXIMUM |
|---|---|---|---|
| RUTTING (LOW) | 0.050 | 1.00 | N/A |
| RUTTING (MOD) | 0.450 | 1.00 | |
| RUTTING (HIGH) | 0.850 | 1.00 | |
| TRANSVERSE JOINT (LOW) | 0.000 | 1.00 | N/A |
| TRANSVERSE JOINT (MOD) | 0.060 | 1.00 | |
| TRANSVERSE JOINT (HIGH) | 0.090 | 1.00 | |
| LANE JOINT (LOW) | 0.000 | 1.00 | N/A |
| LANE JOINT (MOD) | 0.040 | 1.00 | |
| LANE JOINT (HIGH) | 0.060 | 1.00 | |
| SHOULDER JOINT (LOW) | 0.000 | 1.00 | N/A |
| SHOULDER JOINT (MOD) | 0.040 | 1.00 | |
| SHOULDER JOINT (HIGH) | 0.060 | 1.00 | |
| CORNER CRACK (LOW) | 0.333 | 0.50 | 32 EA |
| CORNER CRACK (MOD) | 0.667 | 0.50 | |
| CORNER CRACK (HIGH) | 1.000 | 0.50 | |
| PATCHES (LOW) | 0.500 | 0.10 | 6,000 SF |
| PATCHES (MOD) | 0.750 | 0.10 | |
| PATCHES (HIGH) | 1.000 | 0.10 | |
| CORNER BREAK (LOW) | 0.333 | 0.50 | 32 EA |
| CORNER BREAK (MOD) | 0.667 | 0.50 | |
| CORNER BREAK (HIGH) | 1.000 | 0.50 | |
| TRANSVERSE (LOW) | 0.333 | 0.10 | 44 EA |
| TRANSVERSE (MOD) | 0.667 | 0.10 | |
| TRANSVERSE (HIGH) | 1.000 | 0.10 | |
| LONGITUDINAL (LOW) | 0.333 | 0.20 | 1,500 LF |
| LONGITUDINAL (MOD) | 0.667 | 0.20 | |
| LONGITUDINAL (HIGH) | 1.000 | 0.20 | |
| SHATTERED SLAB (LOW) | 0.333 | 0.50 | 32 EA |
| SHATTERED SLAB (MOD) | 0.667 | 0.50 | |
| SHATTERED SLAB (HIGH) | 1.000 | 0.50 | |

## Table D-3. Continuously Reinforced Concrete Deduct Coefficients

| DISTRESS | A | B | MAXIMUM |
|---|---|---|---|
| RUTTING (LOW) | 0.050 | 1.00 | N/A |
| RUTTING (MOD) | 0.450 | 1.00 | |
| RUTTING (HIGH) | 0.850 | 1.00 | |
| TRANSVERSE CRACK SEVERITY (LOW) | 0.000 | 1.00 | N/A |
| TRANSVERSE CRACK SEVERITY (MOD) | 0.500 | 1.00 | |
| TRANSVERSE CRACK SEVERITY (HIGH) | 0.800 | 1.00 | |
| LANE JOINT (LOW) | 0.000 | 1.00 | N/A |
| LANE JOINT (MOD) | 0.040 | 1.00 | |
| LANE JOINT (HIGH) | 0.060 | 1.00 | |
| SHOULDER JOINT (LOW) | 0.000 | 1.00 | N/A |
| SHOULDER JOINT (MOD) | 0.040 | 1.00 | |
| SHOULDER JOINT (HIGH) | 0.060 | 1.00 | |
| PATCHES (LOW) | 0.500 | 0.10 | 6,000 SF |
| PATCHES (MOD) | 0.750 | 0.10 | |
| PATCHES (HIGH) | 1.000 | 0.10 | |
| TRANSVERSE (LOW) | 0.000 | 1.00 | N/A |
| TRANSVERSE (MOD) | 0.000 | 1.00 | |
| TRANSVERSE (HIGH) | 0.000 | 1.00 | |
| LONGITUDINAL (LOW) | 0.333 | 0.10 | 1500 LF |
| LONGITUDINAL (MOD) | 0.667 | 0.10 | |
| LONGITUDINAL (HIGH) | 1.000 | 0.10 | |
| PUNCHOUT (LOW) | 0.650 | 0.04 | 5 EA |
| PUNCHOUT (MOD) | 0.820 | 0.04 | |
| PUNCHOUT (HIGH) | 1.000 | 0.04 | |