PCR Evaluation –
Considering Transition from Manual to Semi-Automated Pavement Distress Collection and Analysis

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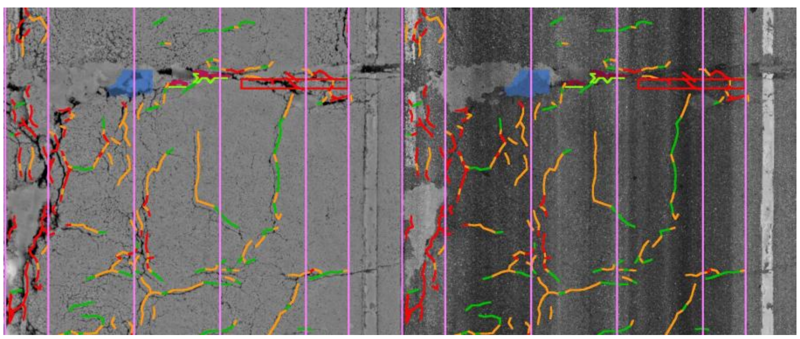

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16. Abstract

This study is designed to assist the Ohio Department of Transportation (ODOT) in determining whether transitioning from manual to state-of-the-practice semi-automated pavement distress data collection is feasible and recommended. Statistical and numerical comparisons are detailed between the pavement distresses, severities, and extents determined for 44 representative test sites by ODOT raters and those provided by three participating vendors. In response to the moderate to low initial distress (72 percent), severity (33 percent) and overall (14 percent) correlations, detailed methods for correlation improvement are provided. These methods are based on extensive interactions with ODOT pavement condition raters and participating vendors. Evaluations of system implementation costs and productivity rates offer supplemental information critical to ODOTs implementation decisions. Surveys of six vendors and 18 State agencies reveal the systems, processes, and experiences of those who provide and use automated methods for pavement distress data collection. Based on this information, recommendations for implementation activities, pavement management adjustments, procurement specifications, and equipment specifications are included.

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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	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

SI* (Modern Metric) Conversion Factors

APPROXIMATE CONVERSIONS FROM 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	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
^oC	Celsius	1.8C+32	Fahrenheit	^oF
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003).

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Disclaimer

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1 INTRODUCTION

Ohio Department of Transportation (ODOT) is evaluating the potential benefits and limitations associated with transitioning from a manual to automated collection and automated, semi-automated, or manual data processing or identification of pavement distresses (including severities and extents). Since 1985, ODOT technicians have traversed the State identifying pavement distresses, severities, and extents (DSEs) and compiling them into Pavement Condition Ratings (PCRs) for ODOT's State and Federal roadway system. The PCR index has been employed as a key performance indicator for the overall performance of the roadway network, for the development of pavement management performance models, and for developing short- and long-term capital and maintenance plans. Because of their experience with and reliance on the PCR index, ODOT desires to continue its use. While ODOT is considering a transition from manual to more automated collection and processing of PCR data, they are concerned that this transition may reduce the compatibility and continuity of their DSE data and the related metrics and systems. This research addresses that concern.

In this report, automated data collection involves gathering digital pavement images and sensor data using vehicles and equipment operated by vendor or agency personnel. Automated, semi-automated, or manual data processing is the approach used to evaluate the digital images and sensor data to identify, rate, and quantify pavement distresses. Automated processing uses software to evaluate the images and sensor data to quantify pavement distresses (severities and extents) without human intervention. In semi-automated processing, software assists the raters to identify and, in some cases, quantify pavement distresses from the images. Finally, manual image processing is accomplished by trained raters who identify, rate, and quantify pavement distresses solely from the pavement images.

Several factors contribute to the impetus for transitioning to more automated methods of collection and processing, including safety, reduced available agency staff, changing reporting requirements, and improved equipment capabilities. A primary issue is the safety of ODOT raters. Although no accidents have been reported to date, increases in traffic on ODOT roadways, increased roadway urbanization, and the potential for rater distraction and fatigue reveal the need to engineer increased safety through automated data collection. Second, automated pavement distress data collection allows the use of vendors, thus reducing staff requirements.

Additionally, the new reporting requirements of the Federal Highway Pavement Management System (HPMS)—including percent cracking and rutting, as well as the accountability requirements of the Moving Ahead for Progress in the 21st Century (MAP-21) legislation—demand a level of distress data reporting not easily attained using manual methods. Moreover, as ODOT calibrates and incorporates the AASHTOWare Pavement ME Design tools and approaches, more accurate levels of pavement distress data reporting will be necessary to calibrate ODOT's performance models.

Finally, tremendous advances have occurred in pavement distress data identification equipment in the last decade. Line-scan cameras can provide 2- and 3-dimensional (2D and 3D) images of pavement surfaces with resolutions of less than 0.08 inches (2 mm). Several manufacturers are developing software for identifying a range of pavement DSEs. If automated collection and semi-automated processing systems can effectively match manually collected PCR data, ODOT's pavement planning and management systems can continue without significant interruption. Without a perfect match to PCR, however, ODOT would be required to modify a portion of their PCR rating procedures, including the distress weighting values, the pavement management system decision trees, and the pavement management performance models.

The research reported herein is intended to evaluate state-of-the-practice pavement distress data collection and processing technologies, evaluating their completeness, repeatability, compatibility with ODOT manual distress data, and cost-effectiveness. Initially, the researchers evaluated the current technology, agency demands, and implementation practices. Based on that information, vendors offering potentially successful systems were selected and interviewed. Forty-four test sites representative of the range of pavement types and distresses common to ODOT roadways were identified and marked for evaluation by ODOT raters and selected vendors. Two ODOT raters individually rated the sites, repeating their evaluations independently a month later. Three vendors collected images of each site, also repeating their measurements on three selected sites. The completion of these activities contributes to the performance comparisons and cost-effectiveness comparisons of this research, along with recommendations regarding transition options.

2 RESEARCH OBJECTIVES

The practical objective of this research is to investigate the current technology for automated and semi-automated collection and processing of PCR data to determine if the systems and rating methods are a suitable replacement for ODOT's manual data collection and processing methods. Primarily, this includes identifying the quality of vendor-collected data and its consistency with ODOT PCR practices and results. An additional goal is to determine the relative benefits of each option—monetary, safety, speed, etc. Finally, should ODOT pursue transitioning to automated image collection and automated, semi-automated, or manual distress data identification from the images, this research is designed to provide recommendations for PCR data collection and processing that meets ODOT's needs.

3 BACKGROUND

Although pavement distress and PCR data have been formally collected in Ohio since 1985, the demand for quality data has never been greater. PCR is a primary performance indicator on the condition of the roadway network and it is used as the key metric in the development of capital and maintenance plans. Coupled with significant changes in the pavement distress data collection environment, the impetus and potential for a successful transition to automated distress data collection and semi-automated or automated distress data identification continues to build.

3.1 DEMAND FOR QUALITY DISTRESS DATA

While increased demands for distress data originate generally from Federal agencies, ODOT's own network-level management increasingly employs pavement distress and associated data in decision-making. As new Federal requirements are implemented, generally State agencies discover additional ways to use their new systems for collecting valuable new information (e.g., inventory data, clearances, shoulder drop off, roadway curvature, surface friction, and smoothness).

3.1.1 ODOT Requirements

ODOT requires the highest quality time series distress data available, as they develop and update reliable pavement deterioration models, measure the impact of maintenance and rehabilitation treatments, and develop work plans to optimize allocation of resources. These data may also be used for research to evaluate the effectiveness of new pavement materials or design features.

Recently, ODOT transitioned to automated collection of pavement smoothness, rutting, and faulting measurements on the interstate highway system and the highway segments required for HPMS reporting. Although it is not currently collected for PCR analysis, the need for such information in multiple ODOT departments points to the benefits of combined automated data collection systems. ODOT's current system also offers inventory collection capabilities, which ODOT has expanded to refine their geographic information system (GIS) pavement site location inventory and their State guardrail inventory. Future expansions available to ODOT include inventories of guardrails, signs, pavement markings, traffic controls, medians, curb and gutter, drop inlets, bridges, and overpasses. Video images from this system may also provide traffic litigation assistance, as noted by the Oregon Department of Transportation (1). Combining these automated collection systems with PCR data collection minimizes duplication of data collection and may reduce overall agency costs.

3.1.2 HPMS Requirements

The HPMS, developed in 1978, supports the 23 U.S.C. 502(h) requirements for collecting "a biennial condition and performance estimate of the future highway investment needs of the nation." It provides information for apportionment, performance measures, highway statistics, and condition reporting (2).

Recent changes in HPMS requirements have increased the responsibility of State agencies for distress data collection. Historically, HPMS required that ride quality data be collected biennially to characterize pavement condition. However, the *HPMS Reassessment 2010+* and the *2012 HPMS Field Manual* now direct the annual full extent collection and reporting of International Roughness Index (IRI) and detailed metadata (2, 3). Additionally, agencies are required to provide detailed distress data for sample panel (SP) sections selected randomly on an annual basis by FHWA. This detailed data includes a Present Serviceability Rating (PSR), fatigue cracking (percent area), transverse cracking (ft/mi), and rutting (0.1-inch resolution) for asphalt concrete (AC) pavements. For Portland cement concrete (PCC) pavements, HPMS requires PSR, faulting (0.1-inch resolution), and percent cracked slabs. Punchouts (percent area), longitudinal cracking, and patches (percent area) must also be reported for continuously reinforced concrete pavements. Finally, agencies must report PSR, rutting, fatigue cracking (percent area), and transverse reflective cracking (ft/mi) for AC/PCC pavements. Reporting of pavement layer thickness and maintenance/rehabilitation activities is also required (2).

These HPMS requirements significantly enlarge the scope and complexity of ODOT's pavement distress data collection for SP sections. Additionally, the random nature of FHWA SP selection provides impetus for ODOT to collect pavement distress data from all HPMS roadways, further increasing the demand for high-quality distress data.

3.1.3 AASHTOWare Pavement ME Design Software Implementation Requirements

State agencies considering the implementation of the AASHTOWare Pavement ME Design software may choose to collect additional pavement distress data to assist them in calibrating the performance prediction models for their pavement, climate, and traffic conditions. This software incorporates state-of-the-art pavement design practices, which represent a leap forward in pavement design and allow prediction of pavement performance based on material mechanics, climate data, axle load spectra, and other factors. Pavement performance measures in Pavement ME Design include slab cracking, faulting, and IRI for PCC pavements; IRI and punchouts for continuously reinforced concrete pavements; and rutting, bottom-up fatigue cracking (alligator cracking), load-related top-down cracking (longitudinal cracking in the wheelpath), thermal cracking (transverse cracking), and IRI for AC pavements. Pavement layer thicknesses and properties also play a critical role in the analysis. Note that these distresses correlate with those now required for HPMS reporting.

If ODOT should implement the Pavement ME Design software, HPMS data collected from the long-term pavement performance program (LTPP) SP sections can be used with other data to calibrate the software models to conditions in Ohio. The scope of these calibrations can be increased if ODOT chooses to collect the full set of HPMS/Pavement ME Design data from all Federal Aid roadways. However, this will increase the demand for high-quality pavement distress data, pointing again to the need for focused, more automated pavement distress data collection and processing.

3.1.4 MAP-21 Requirements

The MAP-21 legislation, signed into law on July 6, 2012, may result in further demands for high-quality pavement surface distress data. This law represents a significant restructuring of the surface transportation programs, instituting a performance management system that will measure the condition and performance of the transportation system and require States and metropolitan planning organizations (MPOs) to set targets and report on progress (1). Details of new FHWA evaluation, reporting, and management requirements are currently being defined through "rulemaking" discussions between FHWA, State agencies, and MPOs. At the conclusion of this process, in December 2013, the ways in which this legislation affects pavement distress data collection will be established (4). Trends indicate that this legislation may further encourage State agencies to collect additional, high-quality, high-resolution pavement distress information.

3.2 CHANGES IN DISTRESS COLLECTION ENVIRONMENT

Significant transformations in the pavement surface distress data collection environment have also contributed to increasing demand for automated and semi-automated systems. These changes stem from progress in equipment technology and concerns for rater safety, and they have led to increased agency transitions to automated systems and improved standardization in data collection, analysis, and reporting.

3.2.1 Progress of Equipment Technology

In recent years, significant improvement has been made in the automated data collection and automated and semi-automated evaluation of pavement distresses (including quantification of distress severity and extent). This is reflected in Federal agency requirements for additional, high-quality pavement distress data. The recent application of illuminated digital line-scan cameras eliminated the problems of shadows and light saturation and, as sampling rates increased, offered reported image resolutions of up to 0.04 in (1 mm). Improvements in equipment technology have led to advances in automated digital image reading crack identification software tools.

In 2009, Pavemetrics introduced a combination of line-scan images and depth images that provided 2D and 3D pavement surface images. These images, illustrated in Figure 1 and Figure 2, have opened the potential for accurately identifying a much larger range of pavement distress data, including quantifying and rating cracks, patches, spalls, surface distress, potholes, and crack seal effectiveness. The intensity image in Figure 1 relies on 2D line scan technology, while the 3D range image in Figure 4 darkens areas below the pavement surface level (e.g., cracks, spalls, and potholes). Currently most vendors can identify surface cracks, but they are developing and refining methods to extract other pavement distress data. As this expansion of technology occurs, demand for such systems is expected to increase.

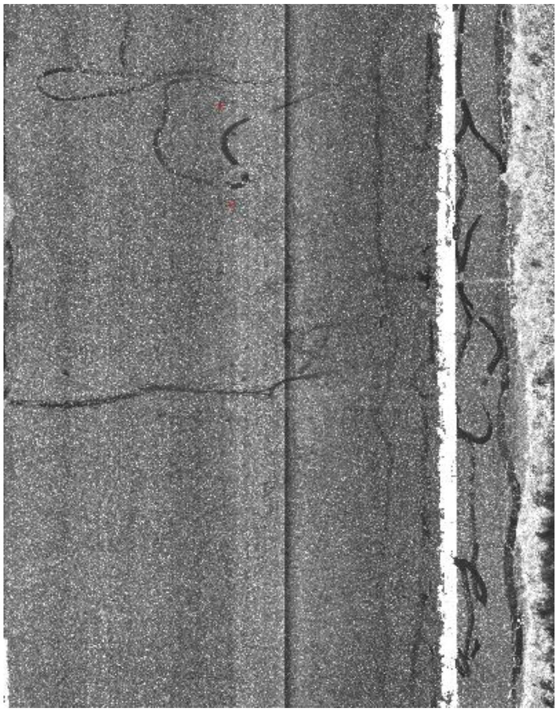


Figure 1. Pavement surface intensity image.

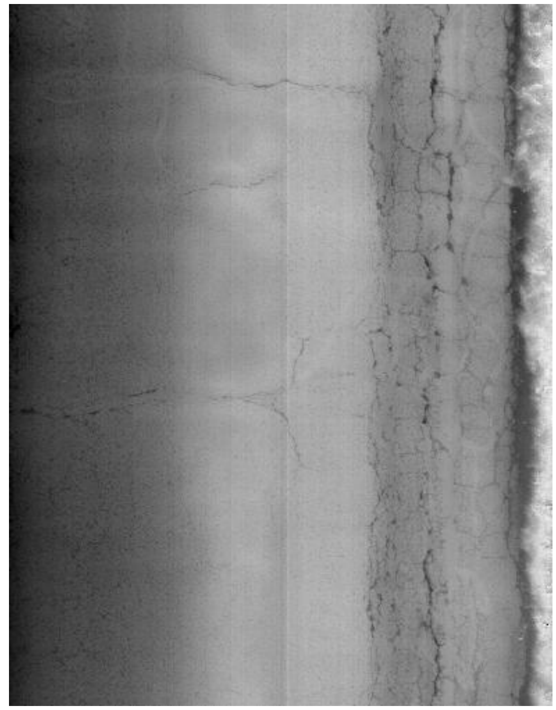


Figure 2. Pavement surface 3D image.

D-Vision, an Israeli company represented in New York, is developing unique computer vision distress identification software that detects and classifies pavement distress with resolution twice that of a single recorded pixel. The software employs single moving downward, forward, and backward images to convert 2D images into 3D models, using a series of complex algorithms. Equipment costs for this system are low, since only 2D camera images are required. If this system performs as promised, it will provide a simple tool for pavement distress rating and quantification.

3.2.2 Increasing Safety Concerns for Raters

Several agencies continue to use manual raters for identifying pavement distresses. Concern for their safety has increased over the years as traffic levels increase, urbanization and congestion expand, and raters are asked to collect even more distress data. ODOT's process of collecting roadway PCRs involves a single rater traversing a site and pulling onto and off the shoulder, while focusing on identifying and quantifying pavement distress ratings. Although no accidents are reported to date, the potential for distraction and fatigue highlight the need for engineering increased safety. Eliminating driver distraction through automated collection at highway speeds is one method for improving safety.

3.2.3 Mounting Transitions by State Agencies

In 2008, some 29 State agencies were collecting network-level pavement surface images and sensor data for semi-automated and manual surface distress data identification (5). That number has grown significantly within the last few years. Discussions with vendors indicate that number exceeds 35. Among the agencies recently transitioning to automated data collection are North Carolina, New Jersey, and Massachusetts.

Within the last decade, agencies have increasingly relied on data collected by service providers to collect network- and project-level pavement condition data. Three factors reportedly have fueled this trend: increased demand by agency management for timely, high-quality data; reduced available agency staff; and availability of expensive equipment that can quickly and efficiently collect large quantities of data. As a result, much of today's pavement distress data is collected for State agencies by service providers. A 2009 survey indicated that more than 98 percent of agencies collect network pavement surface distress data and 60 percent collect project level distress data. At least 38 percent of this work outsourced to single or multiple contractors, as shown in Figure 3 (5). It is noted that not all agencies responded to this survey question:

Question: How does your agency currently collect pavement condition data?

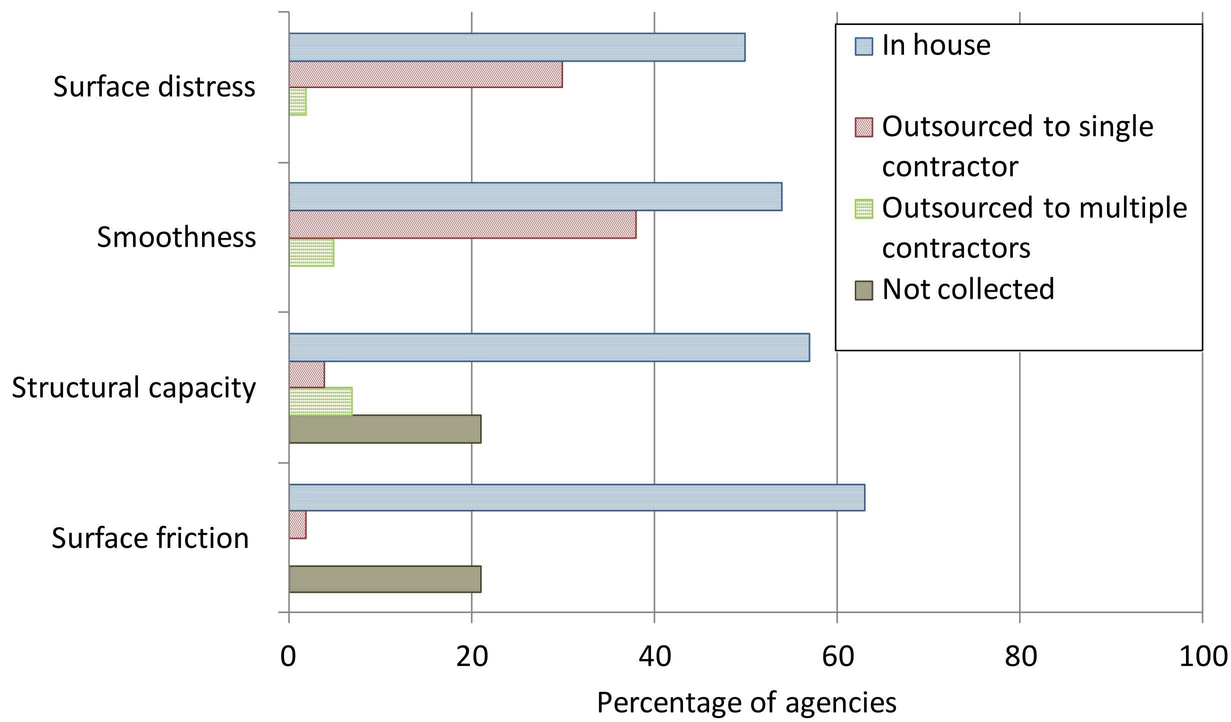


Figure 3. In-house versus contracted pavement condition data collection (5).

3.2.4 Standardization of Agency and Federal Requirements

According to NCHRP Synthesis 401 (pg. 15), "Although there have been efforts to standardize the definitions and measuring procedures for the various distresses by ASTM International and AASHTO [American Association of State Highway and Transportation Officials], the use of national (or international) standards for distress data collection is still not a common practice"

(5). Several recently developed standards regarding pavement distress data collection have addressed this shortcoming, reducing the complexity associated with transitioning to automated data collection and providing increased consistency within and between agencies. These standards support the accurate measurement of HPMS data.

Primary among these are ASTM E 1656-11, AASHTO R 55-10, AASHTO PP 67-10, and AASHTO PP 68-10, each developed, in part, to standardize the new HPMS data collection. ASTM E 1656, Standard Guide for Classification of Automated Pavement Condition Survey Equipment, assists agencies in classifying pavement condition survey equipment that measures longitudinal and transverse profile and surface cracking. Systems are categorized according to stationary measurement repeatability, longitudinal and transverse sampling interval, and transverse coverage.

AASHTO R 55-10, Quantifying Cracks in Asphalt Pavement Surfaces, recommends surveying the same lanes for each repeated survey in one direction for undivided highways and the outside lane in both directions for divided highways. This standard identifies the cracking per unit area for each wheelpath and between the wheelpaths, using three severity levels ranging from ≤ 0.125 inch (≤ 3 mm) to >0.25 inch (>6.4 mm).

AASHTO provisional standard PP 67-10, Quantifying Cracks in Asphalt Pavement Surfaces from Collected Images Utilizing Automated Methods, offers guidelines for acceptable levels of automated crack identification. Five measurement zones are identified, including the two wheelpaths and the areas adjacent to and between the wheelpaths. Measurement methods for summarizing pattern, longitudinal, and transverse cracks are provided, along with brief system validation procedures. ODOT's current PCR distress identification method provides more detailed DSE reporting. By enhancing compatibility with these standards, ODOT could benefit HPMS and other Federal reporting requirements.

AASHTO standard PP 68-10, Collecting Images of Pavement Surfaces for Distress Detection, recommends 14-ft (4.25-m) wide downward images and provides estimates of allowable crack identification and width detection error.

New rut measurement standards have been provided in AASHTO R 48-10, Determining Rut Depth in Pavements, including algorithms, offset, and accuracy for five-point and expanded rut depth measurements. Similarly, AASHTO R 36-04, Evaluating Faulting of Concrete Pavements, standardizes fault measurement locations, algorithms, accuracy levels, and reporting requirements.

4 PROJECT RESEARCH ACTIVITIES

ODOT's primary intent for this project is to evaluate the capabilities of vendors' systems and methods to identify the pavement DSEs recorded by trained and experienced ODOT PCR raters. This will allow ODOT to determine how well vendor distress severities and quantities mirror ODOT PCR distress ratings. Additional aspects include evaluation of the cost, productivity, and manpower requirements associated with ODOT and vendor collection and processing options. As such, the research activities include review of current ODOT data, selection of field evaluation sites, evaluation of vendor technology, selection of vendors, and collection and summarization of field evaluation data. Supplemental survey results are also provided.

4.1 DATA REVIEW AND SITE SELECTION

To select sites representative of the primary DSEs present on ODOT pavements, ODOT's 2011 PCR survey database was examined. The results led to selection of 44 test sites in northeast Ohio. A list of ODOT's currently evaluated distresses is provided in Table 1. Summaries of the numbers of sites containing each distress-severity-extent combination are shown for AC pavements in Table 2 with information for other pavement types included in Appendix A. Rows In the rows of Table 2 distresses are listed while severity ranking (low, medium, and high), and extent levels (occasional, frequent, and extensive) are shown in the columns. ODOT's distress rating system includes 339 possible DSE combinations. However, the 2011 survey did not identify all possibilities. Instead, it noted sites containing 247 DSEs, with 58 of these DSEs identified in less than 5 sections.

Table 1. ODOT pavement condition distresses.

Code	AC	PCC	AC/PCC
1	Raveling	Surface Deterioration	Raveling
2	Bleeding		Bleeding
3	Patching	Patching	Patching
4	Debonding	Pumping	Disintegration, debonding
5	Crack seal deficiency	Faulting	Rutting
6	Rutting	Settlement	Pumping
7	Settlement	Transverse joint spalling	Shattered slab
8	Corrugation		Settlement
9	Wheel track cracking	Pressure damage	Tvs. Cracking – unjointed
10	Block/transverse cracking	Transverse cracking. slabs > 20 ft	Tvs. Cracking – joint reflection
11	Longitudinal cracking	Longitudinal cracking	Tvs. Cracking – intermediate
12	Edge cracking	Corner breaks	Longitudinal cracking
13	Random cracking	Longitudinal joint spalling	Pressure damage – upheaval
14	Thermal cracking	Transverse cracking. slabs <= 20 ft	Crack sealing deficiency
15	Potholes		Corrugation
16			Corner breaks – jointed base
17			Punchouts – unjointed base

Note: 1 ft = 0.3 m

Optimization methods and software were developed to select the final set of test sites. The software identified 50 PCC pavement segments that contained two replicates of all PCC DSE combinations in the 2011 database. Based on this, the scope of site selection was reduced from two replicates of all DSEs to meet a reasonable 2-day, 30- to 40-site data collection limit. Initially, the scope was narrowed to include at least one replicate for each DSE combination that is considered critical or adjacent to the major and minor rehabilitation criteria designated in Table 3 and Table 4 and charted in ODOT's Decision Support Tree, and noted in Appendix B. This resulted in 199 DSE combinations to be collected from 101 sites (43 composite, 32 jointed concrete, and 26 flexible). Further reduction was achieved by combining overlapping distresses from the AC and AC/PCC sites and focusing on selecting critical DSE combinations.

After confirming their status, 44 test sites were selected for inclusion in the study (11 PCC, 14 AC, and 19 AC/PCC). Locations of the PCC (green), AC (blue), and AC/PCC (red) sites are shown in Figure 4 and details about these sites are included in Appendix C. Site 2 was later eliminated from the survey because of variations in the vendor data collection paths. Travel routes required of participating vendors traversed approximately 500 miles within central and northeastern Ohio, requiring about 17 hours of travel time.

Table 2. ODOT 2011 reported flexible pavement DSE combinations.

Code	Distress	LO	LF	LE	MO	MF	ME	HO	HF	HE	O	F	E
1	Raveling	1498	1436	1625	1047	311	97	21	15	1			
2	Bleeding	5	1	2	143	30	15	4	3	4			
3	Patching	558	2	2	444	34	14	435	20	5			
4	Debonding	329	13	4	69	7				1			
5	Seal damage										1069	616	2396
6	Rutting	1431	951	572	386	165	17	27	3				
7	Settlement	617	8	3	120	8	3	11	1				
8	Corrugation												
9	Wheelpath cks.	1222	339	12	850	217	32	325	106	1			
10	Block cks.	1897	696	125	501	251	90	489	286	156			
11	Longit cracks	1122	891	105	1136	1006	127	204	381	49			
12	Edge cracks	833	227	87	939	300	119	424	119	21			
13	Random cks.												
14	Thermal cks.	627	107	42	578	316	90	51	45	18			
15	Potholes	4			5								

Table 3. Major rehabilitation criteria for ODOT Decision Tree.

Jointed Concrete	Composite Pavement	Flexible Pavement
Structural deduct $\geq$ 20	Joint reflective cracking, HF, HE	Rutting: MF, ME, HF, HE
Longit. cracking: HF, HE	Tvs. cracking - jointed: LE, ME, HE	Wheel track cracking: ME, HF, HE
	Tvs. cracking - unjointed: ME, HF, HE	

Table 4. Minor rehabilitation criteria for ODOT Decision Tree.

Jointed Concrete	Composite Pavement	Flexible Pavement
Patching: ME, HE	Raveling: MF, ME, HF, HE	Raveling: MF, ME, HF, HE
Faulting: ME, ME, HF, HE	Bleeding: HF, HE	Bleeding: HF, HE
Joint spalling: HE, ME	Patching: LF, LE, MF, ME, HF, HE	Patching: LF, LE, MF, ME, HF, HE
Tvs. cracking (plain): LE, MF, ME, HF, HE	Surface debonding: LF, LE, MO, MF, ME, HO, HF, HE	Surface debonding: LF, LE, MO, MF, ME, HO, HF, HE
Tvs. cracking (reinf.): ME, HF, HE	Rutting: MF, ME, HF, HE	Rutting: MF, ME, HF, HE
Corner breaks: ME, HE	Pumping: F, E	Potholes: LE, MF, ME, HF, HE
	Shattered slab: ME, HF, HE	Wheel track cracking: MF, ME, HF, HE
	Joint reflective cracking, MF, ME, HF, HE	Block/trans. cracking: ME, HF, HE
	Tvs. cracking (jointed): LF, LE, MF, ME, HF, HE	Longit. cracking: ME, HE
	Tvs. cracking (unjointed): MF, ME, HF, HE	Edge cracking: LE, MF, ME, HF, HE
	Corner breaks (jointed): MO, MF, ME, HO, HF, HE	Thermal cracking: MF, ME, HF, HE
	Punchouts: MO, MF, ME, HO, HF, HE	

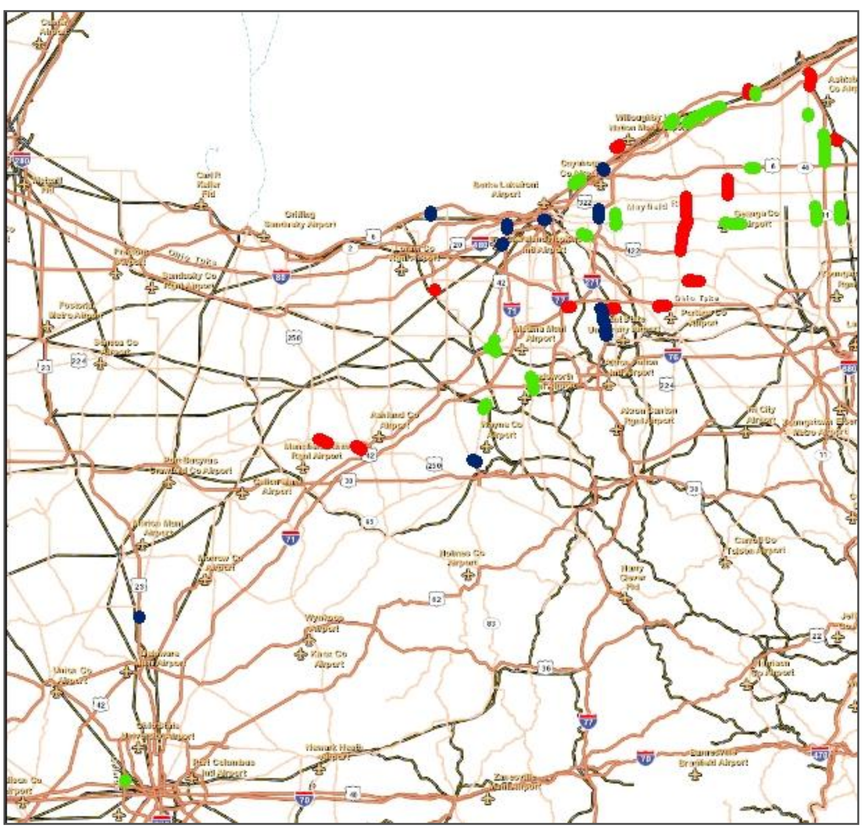


Figure 4. ODOT test site locations.

Although full-scale replication of vendor data collection was not within the scope of the project, vendors were asked to conduct repeat runs and separate evaluations on PCC site 19, AC site 20, and AC/PCC site 35. Their locations are shown in Figure 5.

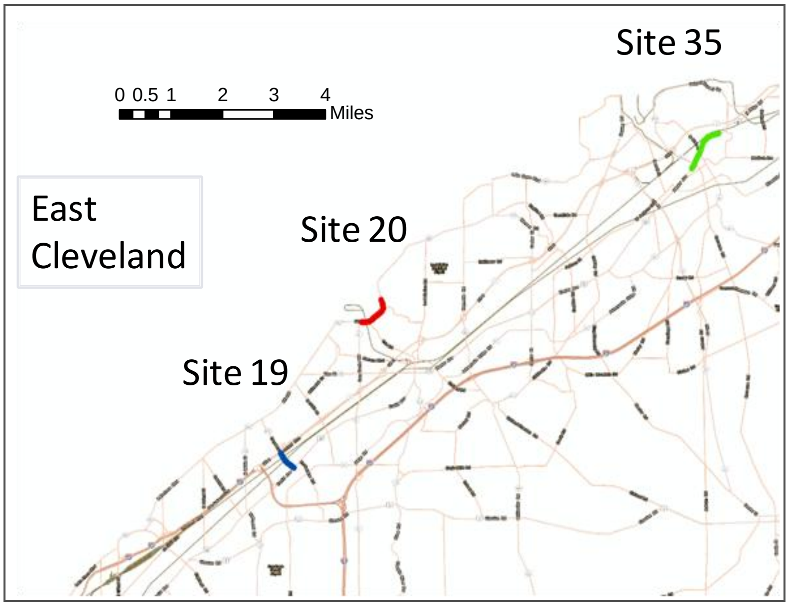


Figure 5. Replicate site locations.

4.2 EVALUATION OF TECHNOLOGIES AND VENDOR SELECTION

Recent advances in technology have resulted in several vendors expressing confidence in their system's ability to accurately collect and process pavement distress data necessary for identifying PCR and ODOT's critical DSEs. The technologies described below represent systems boasting these new capabilities. Unique vendor properties are provided, along with production rates, anticipated costs, and service options.

4.2.1 Vendor Technology Options

Over the years, vendors have offered State agencies several alternatives to manual pavement distress data collection. This progression is charted in Figure 6. Primarily, these options have been based on 2D image-based systems that collect downward images of the pavement surface, allowing manual or semi-automated identification of pavement distress data. Initially, these were collected using videotape and photographic images. In the early 2000s, high-quality digital area images began to be collected and stored electronically. However, these systems were plagued by inconsistent image illumination. The advent of 2D and 3D line-scan pavement images has greatly expanded the potential for manually and electronically identifying pavement distress data. These 2D and 3D systems carry increasing potential for adequately identifying ODOT's pavement DSEs, and are described below.

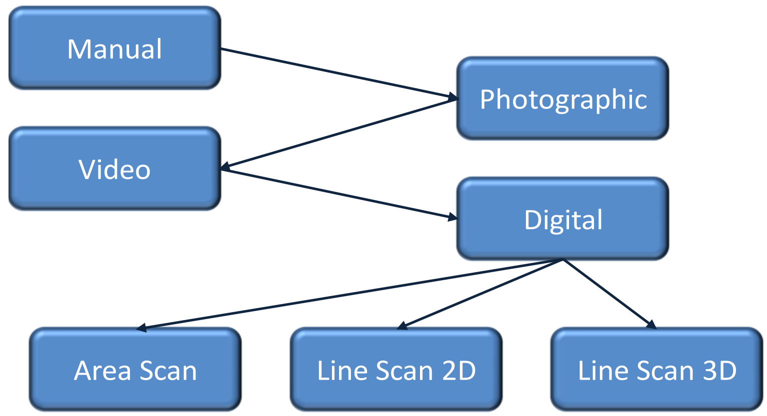


Figure 6. Progression of DSE collection technology advances.

4.2.1.1 2D Line-scan

In 2007, Pavemetrics began marketing a breakthrough system, incorporating current line-scan technology into pavement image collection. This system collects a single line of images, similar to a fax machine or digital scanner. When “stitched” together longitudinally, they provide a continuous 2D digital image of the roadway surface. Images are captured full pavement width, typically using line-scan camera with image fields highlighted in orange and employing infrared laser illumination (shown in yellow), as Figure 7 illustrates. Collecting line-scan camera images at an angle toward the opposite side of the lane with vertical infrared laser illumination increases the ability of the 2D images to reveal pavement cracks and distortions. These laser emitters, when combined with wavelength filters, remove the influence of sunlight on 2D line-scan images, allowing them to provide high-quality images in both day and night testing operations. Other vendors developed similar and expanded systems in the following years.

Using these images, gray shade levels and patterns could be employed to electronically estimate the location and width of cracks and other distresses. Combined with high-frequency (1,000 samples per lane width) laser-based rut measurement systems, many pavement distresses could easily be visually identified, and several could be recognized using advanced software imaging algorithms.

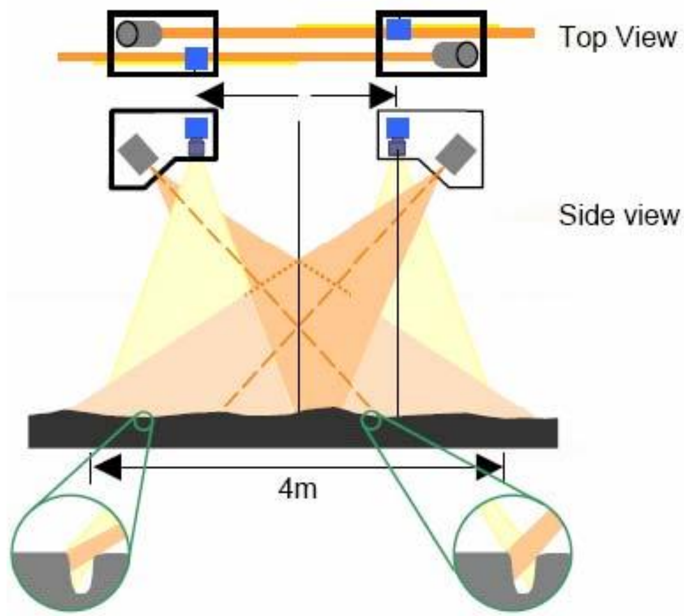


Figure 7. Line-scan 2D sensors (6).

4.2.1.2 3D Line-scan

On the heels of the advancement of the 2D line-scan technology came another breakthrough—3D imagery to provide a full-width trace of the pavement surface's vertical profile. This advance in pavement surface imagery occurred through a series of refinements. The NCHRP-88 research raised new hope of using the stereo-photogrammetric principle to collect full pavement surface macro- and mega-texture images. However, its inability to provide consistent lighting limited the system's effectiveness. Similarly, light detecting and ranging (LIDAR) methods using a polygon scanner fell short of expectations, due to spread of the laser beam and the resultant resolution limitations (6).

Concurrent with these innovations, the most promising advance in 3D pavement surface imaging was brought to market using techniques commonly employed to inspect objects on conveyor belts (see Figure 8). In this process, infrared laser lines are projected onto the pavement surface, typically 14 ft (4m) wide, as shown in Figure 9. Two high-resolution line-scan cameras, mounted at an angle to the laser line, then collect images that include the pavement surface and line laser side profiles. Because of the angle between the camera and laser line, the contrast and visibility of both longitudinal and lateral cracks are increased. High-powered laser protectors and specialized collection optics eliminate the effects of ambient lighting and shadows from bridges, tunnels, and trees on the roadway surface image. The resulting consecutive images, collected along the roadway, provide a digital 3D image of the pavement's features and distresses. Such image resolution in three dimensions provides significantly greater information to better allow for semi-automated and automated pavement DSE identification.

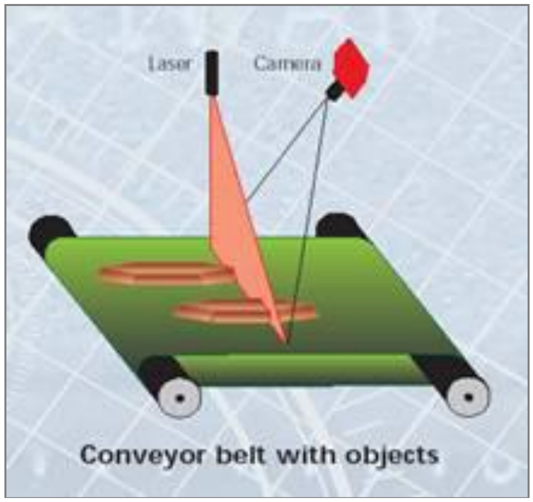


Figure 8. Automated survey overview (7).

Other systems include up to eight separate line-scan cameras to provide increased sampling rates. Most current systems collect up to 14-ft (4.3-m) wide images and transverse elevations at intervals of 0.04 to 0.125 inch (1 to 3 mm). These systems are described in a subsequent section in further detail.

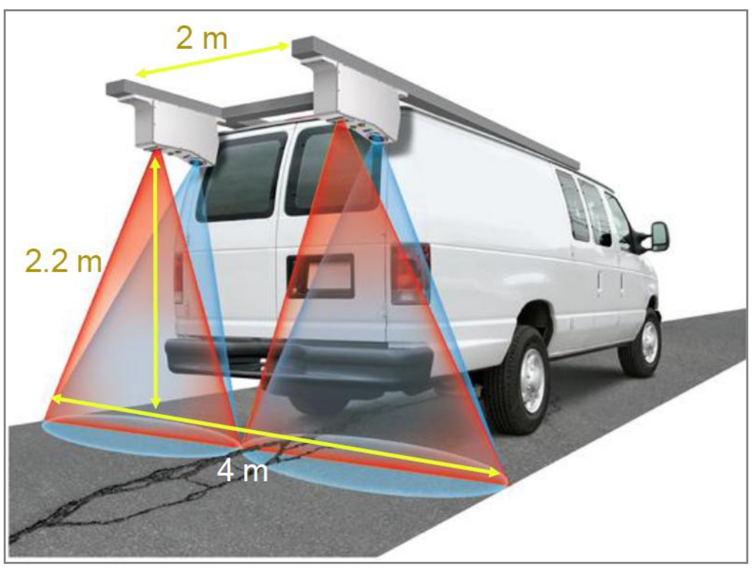


Figure 9. Line-scan 3D system (8).

4.2.1.3 Distress Identification Software

While modern line-scan systems provide high resolution pavement surface intensity (2D) and range or elevation (3D) images from which workstation viewers can manually identify and quantify pavement DSEs, advances in image processing and pattern recognition are significantly improving automated distress classification and summarization. Two-dimensional intensity images record the intensity of light reflected from the various pavement surface features (e.g., stripes, cracks, asphalt, aggregates) and can now be pre-processed to enhance the identification of surface cracking (Figure 10). A process of enhancing (b), threshold imaging (c), dilation (d), and erosion (e) of the image can be used to isolate crack sealant (f), as Figure 11 illustrates. This example notes a method for identifying surface crack seal materials.

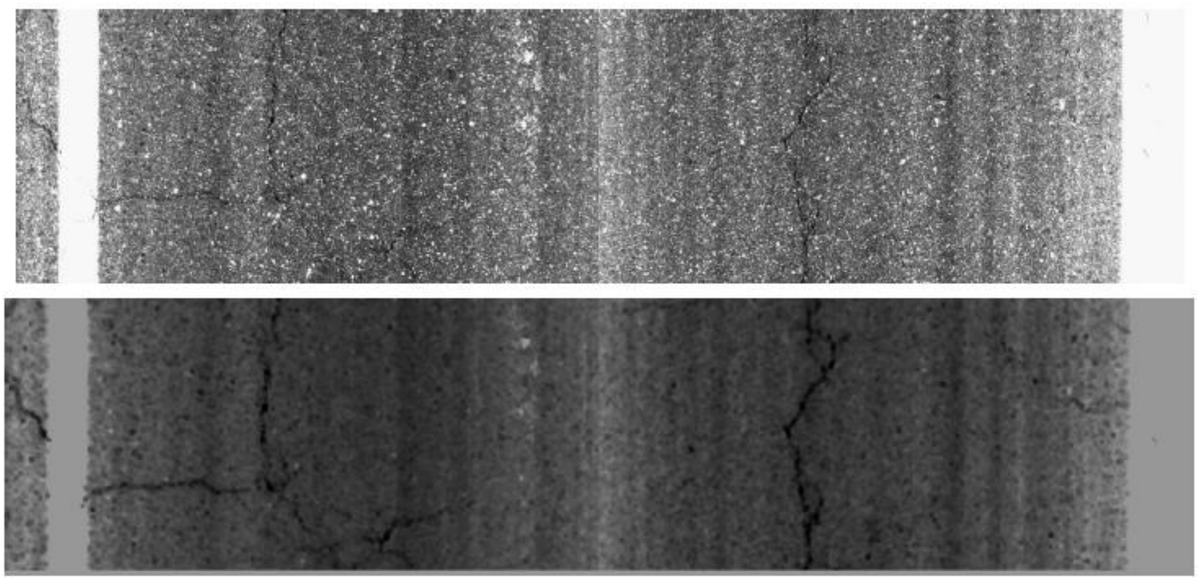


Figure 10. Unprocessed (upper) and pre-processed (lower) crack images (9).

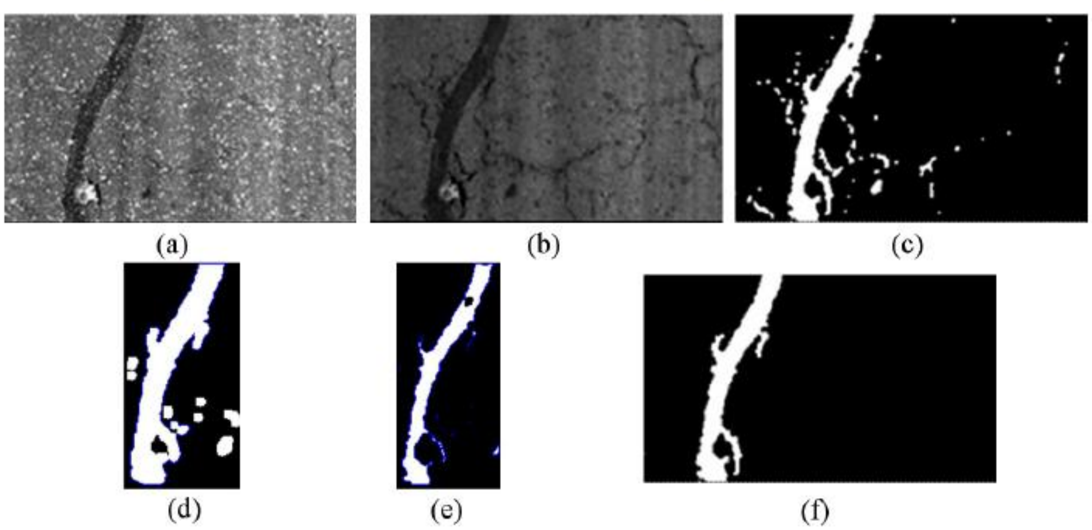


Figure 11. Crack seal isolation (9).

Paint stripes can also be isolated for use in lane identification and to avoid misidentification of other distresses. Figure 12 illustrates the isolated stripes (lower image) compared with the original (upper) image. Also, narrow joints in PCC pavements can be more easily identified through a process of imaging with vertical and horizontal segments and using a series of transform algorithms, as illustrated in Figure 13. All of these 2D processes are being further enhanced using 3D images.

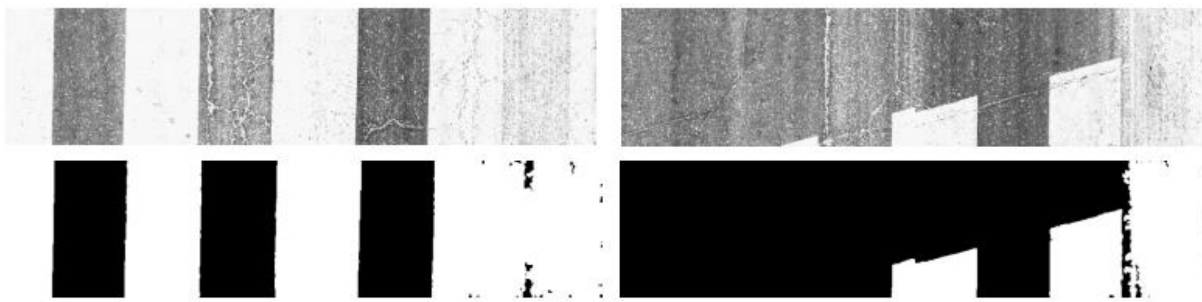


Figure 12. Surface stripe isolation (9).

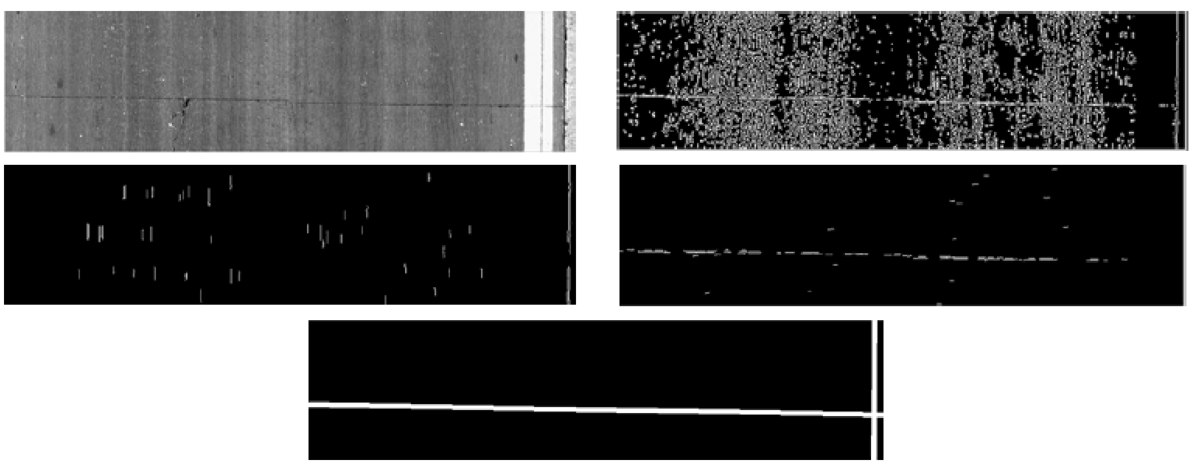


Figure 13. Narrow joint enhancement (9).

Three-dimensional surface profile data, when combined with information from 2D image analysis, further enhance the ability to assist with or completely identify pavement DSEs. Because 3D technology is fairly new, vendors have not fully tapped the potential for this technology to assist with or completely identify pavement DSEs. Manufacturers report the capability of their systems to detect and analyze cracks, ruts, lane markings, potholes, and macrotexture. They also indicate that patches, raveling, and sealed cracks can be detected using these systems. Joints can be identified on PCC pavements, along with the presence of surface tining. Pavement roughness indices, including the IRI, can also reportedly be collected. One manufacturer indicates, according to Figure 14, a predominant use of 3D data for distress and severity recognition, with more limited use of 2D data. The figure describes the uses of 3D and 2D laser crack measurement system (LCMS) technology. Three-dimensional range and 2D intensity images can also be merged for visual and electronic evaluation, as shown in Figure 15.

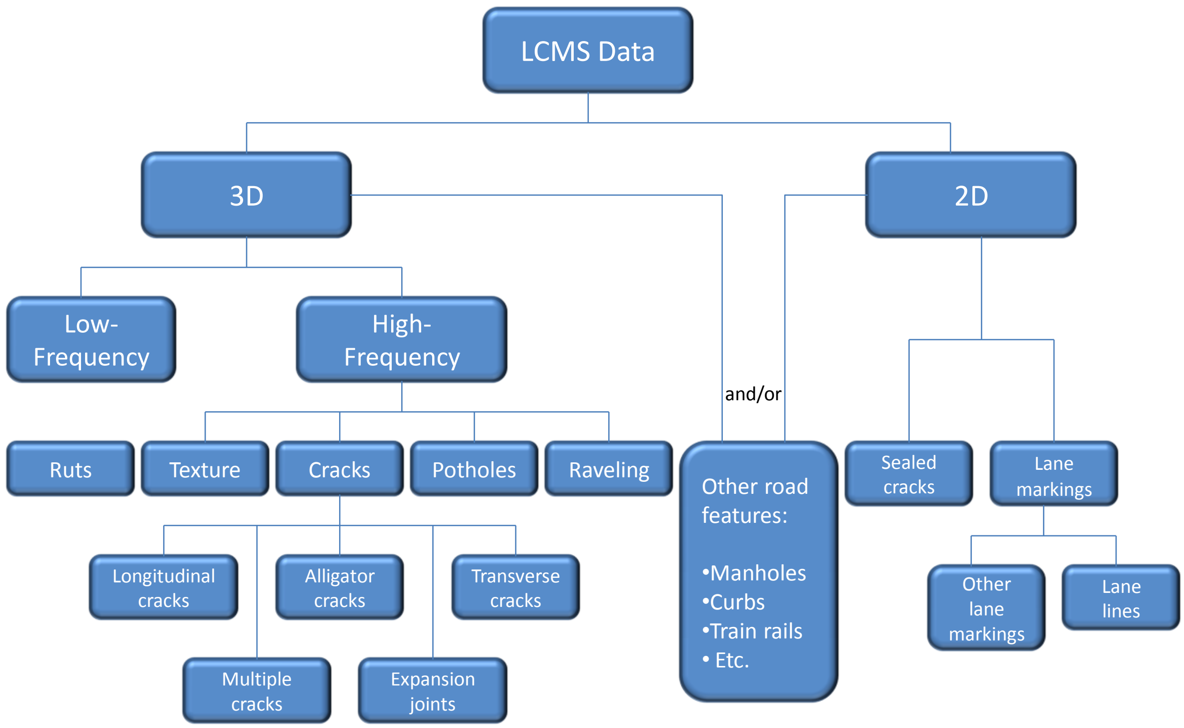


Figure 14. Images used in automated distress identification (10).

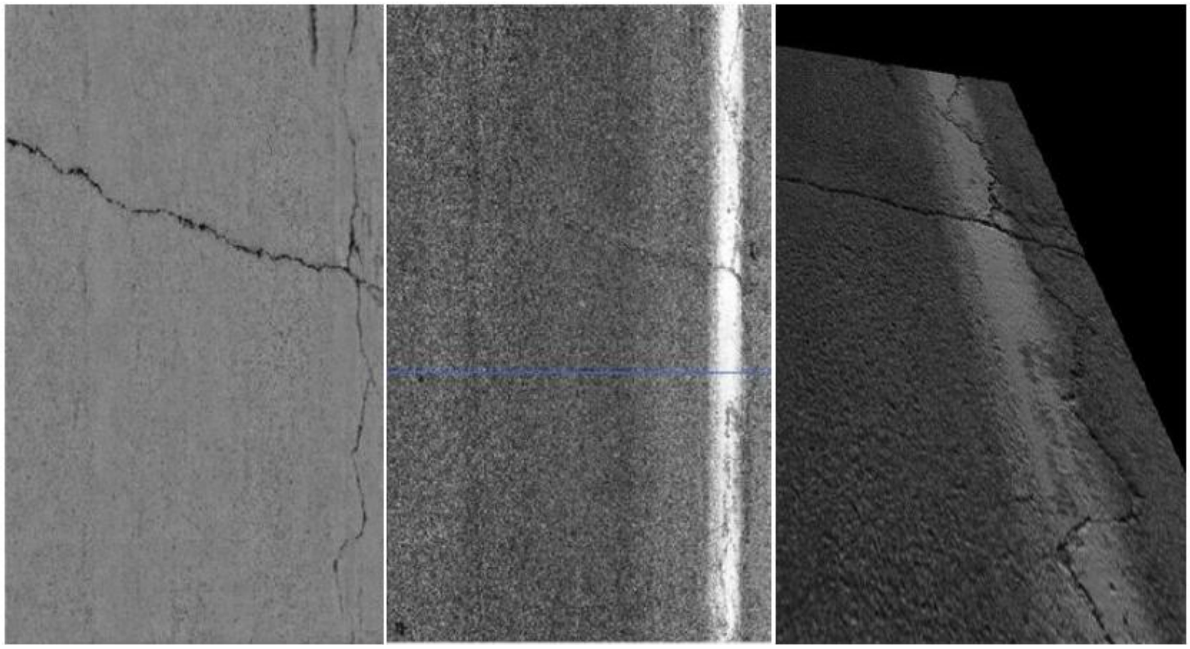


Figure 15. From left to right: range, intensity, and 3D merged images (9).

4.2.2 Major Line-Scan Distress Identification Vendors

Four major vendors in the United States provide 3D line-scan automated distress rating systems: Dynatest Consulting, Inc., Fugro-Roadware Inc., Mandli Communications, Inc., and Pathway Services, Inc. These vendors also offer a range of 2D systems; however, because of reported limitations of the 2D line-scan systems, only their 3D line-scan systems are described below. WayLink, Inc. has also been included in these descriptions due to the advanced nature of their technology. Dynatest, Fugro, and Mandli incorporate Pavemetrics LCMS 3D sensors, while Pathway and WayLink have developed unique 3D sensors in addition to offering LCMS sensors. Because Dynatest uses the same LCMS sensors as Fugro and Mandli, and they did not significantly participate in this research, their system is not discussed below.

4.2.2.1 Fugro-Roadware Pave3D System

Fugro began offering the Pave3D System in 2010, incorporating the Pavemetrics INO LCMS sensors. Currently, the system can include 2D and 3D downward pavement imagery, combined with Fugro's forward cameras, global positioning sensors, an inertial measurement suite, ground penetrating radar, and LIDAR equipment. They provide two platform options: the ARAN 9000 (see Figure 16), built on a Mercedes Benz Sprinter chassis, and the ARAN 8000, built on an agency-selected utility vehicle. Fugro offers both system sales and distress data collection services.

Figure 16. Fugro ARAN 9000 collection vehicle.

The ARAN 9000 survey vehicle can be configured with a maximum of six right-of-way (ROW) Sony high-definition cameras using charge-coupled device (CCD) broadcast-quality image sensors. Each camera is housed in a weatherproof housing that includes an extended visor to shield the lens from the direct sun above. Furthermore, forward-facing cameras are mounted on a platform located in the front of the vehicle (thus reducing the risk of images being obstructed by the vehicle). Three HD charged coupled device (CCD) broadcast-quality cameras provide extremely high-quality images over a range of lighting conditions, as the 60 fps (18.2 m/s) free-running frame rate is able to adapt to the local environmental lighting conditions better than trigger-based cameras. Additionally, these ROW images are calibrated and can be used to determine the offset and dimensions of roadway assets. Figure 17 illustrates image quality on ODOT test site 20. Image capture is linked to the ARAN distance measuring instrument (DMI), with images typically captured at a rate of 200 frames per mile (124 frames per km). Although images can be captured more frequently (maximum of 500 frames per mile), it has been Fugro's experience that 200 frames per mile works best to optimize the ability to clearly see all of the roadside images without unnecessary image storage requirements. Images are stored in JPEG format at typical compression ratios of 10:1 with virtually no image quality loss.

Figure 17. Fugro ROW image for ODOT site 20.

The system can be configured to collect global positioning system (GPS) coordinates with a stand-alone accuracy of 16 ft (5 m) or better. When real-time differential corrections are received from satellite (such as Omni-Star) or FM transmitters, typical accuracy falls below 3.2 ft (1 m), and if these data are post-processed using auxiliary base stations, accuracy is further improved. Should satellite lock be interrupted, Fugro uses its DMI and inertial reference system (Smart Geometrics or POS LV^{TM}) to maintain accuracy. The inertial reference system also employs gyroscopes, accelerometers, software, and algorithms to measure pavement cross fall, transverse profile, vertical alignment (grade), and horizontal alignment (curve radius) of the roadway. To assist operators with routing, Fugro provides GPS coordinates and pre-established routing information loaded into the Fugro's ARAN data collection software.

Fugro's Laser SDP (South Dakota Profiler) longitudinal profiling subsystem employs Selcom 16- and 32-kHz laser sensors and high-quality accelerometers to collect longitudinal profiles at

0.08-inch (2-mm) and 0.04-inch (1-mm) intervals at 70 mi/hr (110 km/hr). This system meets FHWA specifications for Class II HPMS profilers, ASTM E 950 Class 1 requirements, and ASTM E 1656-11 L111 ratings—collecting IRI and other roughness indices in real time. An additional macrotexture module employs one or more 64 kHz lasers to collect texture profiles at 0.02 inch (0.5 mm) up to (70 mi/hr (110 km/hr), computing mean profile depth (MPD) and other texture indices. Additionally, Fugro offers LIDAR services using Optech or Dynascan, along with ground penetrating radar, employing the Geophysical Survey System, Inc. system.

Standard 2D and 3D pavement view digital images are collected simultaneously by Fugro using two INO LCMS sensors, as shown in Figure 18. The Pave3D system collects 4,096 transverse profile points (about (13.1 ft) [4-m]) giving 0.04-inch (1-mm) transverse resolution at 5,600 profiles per second down the road, allowing nominal sampling rate at 70 mph (110 km/h) of about 0.20 inch (5.5 mm). This Pave3D sensing system reportedly meets ASTM E 1656-11 C3331 crack measurement requirements. The existing sensors can collect up to 11,200 profiles per second, with the nominal sampling rate reduced to about 0.1 inch (2.5 mm) at 50 mph (80 km/h). The reported sensor height resolution approaches 0.02 inch (0.5 mm). Power consumption is minimal: 150 W for standard sensors and 250 W for upgraded sensors. Sensors are mounted about 6.2 ft (1.9 m) from the road surface. Storage of the resultant compressed JPEG files requires about 20 MB/sec or 1,159 MB/mi (720 MB/km) at 70 mi/hr (110 km/hr).

Figure 18. Fugro standard 3D pavement image collection system.

Distress rating software is available and is continuing to be expanded by Fugro and Pavemetrics to develop and incorporate the 3D capabilities of the LCMS sensors. Currently, they report the ability to automatically detect crack type (transverse, longitudinal, and alligator) and severity, raveling, potholes, rutting, and faulting. Their semi-automated approach reportedly identifies corner cracks and block cracking. Distresses such as debonding, pumping, bleeding, patching, crack sealant distress, and punchouts require manual identification.

Fugro reports currently providing 3D services to the California Department of Transportation (Caltrans) and 2D systems or services to 16 State agencies. Additionally, Fugro has supplied 3D-equipped ARAN pavement survey vehicles to the Ministry of Transportation of Ontario (MTO), Nova Scotia Department of Transportation, and the City of Tucson. Fugro has offices in Mississauga, Ontario; and Richmond, Virginia; incorporating more than 100 employees, with about 200 trained manual distress identification raters residing outside the United States.

At the initiation of this research, Fugro was asked to estimate their confidence in their ability (high, moderate, and low) to accurately identify the presence, severity, and extent of each distress ODOT uses for PCR computation. They also estimated the processing method required to achieve the noted level of accuracy (automated, semi-automated, or manual). Values of 3 (high, automated), 2 (moderate, semi-automated), and 1 (low, manual) were assigned to their responses and summed for each distress. With a maximum of 3, Fugro estimated their average confidence rating at 2.7 and their average process rating at 2.6. They expressed the greatest confidence in their ability to accurately identify flexible pavement DSEs using automated means.

4.2.2.2 Mandli Communications LCMS

Mandli offers a 3D distress collection and identification system that includes the Pavemetrics LCMS and associated subsystems. Typically, these subsystems are mounted on a full-sized van, selected by the purchasing agency (see Figure 19).

They typically provide up to three (3,296 x 2,472 pixels) industrial ROW cameras, mounted above the rear view mirror. This camera requires little operator adjustment. Exposure is controlled automatically, while gain can be user-adjusted through the collection software. Focus and aperture settings are fixed during collection but can be manually adjusted during setup. A typical image from ODOT site 3 is shown in Figure 20. Image capture is linked to Mandli's DMI, and collection intervals can be controlled by the operator. ROW camera images are stored digitally in JPEG format and typically stored at a 5:1 to 15:1 compression ratio. This results in storage rates between 48 MB/mi (29.8 MB/km) and 126 MB/mi (78.3 MB/km).

Figure 19. Mandli LCMS distress collection vehicle (front).

Figure 20. Mandli ROW image for ODOT site 20.

The Mandli Applanix POS LV 220 collects real-time differential GPS coordinates using satellite positions and ground station or satellite-based augmentation systems to provide sub-meter X-Y-Z accuracy. If post-processing is employed, the reported X-Y accuracy is about 0.8 ft (0.25 m). To maintain precision when satellite lock is lost, Mandli's DMI and POS LV inertial measurement unit are employed. These same instruments can provide pavement crossfall, vertical alignment (grade), and horizontal alignment (curve radius).

Mandli provides pavement profiles at 0.07-inch (1.7-mm) intervals (60 mi/hr [98 km/hr]) using Dynatest's rear-mounted Mark IV Portable Road Surface Profiler (RSP), shown in Figure 21. Two Selcom 16-kHz laser sensors and high-quality accelerometers are mounted in this system and positioned in selected wheelpath locations. Optionally, 16-kHz Roline lasers are available to resolve longitudinal texturing variability. The RSP system reportedly meets ASTM E 950-09 Class 1 specifications, providing a vertical displacement resolution of 0.002 inch (0.05 mm). It is rated with an ASTM E1556-11 Code of L111. Mandli can optionally replace the RSP sensors with 64 kHz sensors for collection of pavement texture properties. Mandli also offers supplemental LIDAR 360-degree imaging for high-level asset identification.

Figure 21. Mandli LCMS distress collection vehicle (rear).

To assist operators in safe, complete, and accurate data collection, Mandli includes onboard tracking software and support employing their internal GPS. Operators can plan the next day's routing using Google Earth. During collection, Mandli's Moving Map display shows the vehicle's location, marking routes that have been collected. Operators must trigger collection at the beginning and end of each segment.

Mandli employs the Pavemetrics LCMS 2D and 3D pavement imaging system, sampling at 5,600 (alternately 11,200) transverse profiles per second. This subsystem reportedly meets the requirements of ASTM E 1656-11 C 2321. Distresses automatically reported by this system include block/transverse, longitudinal, and wheel track cracking, rutting, faulting, crack sealing deficiency, and potholes. Manually supplemented semi-automated reviews reportedly would allow Mandli to collect transverse cracking (unjointed, joint reflection, intermediate), thermal cracking, raveling, and corner breaks. Currently, Mandli identifies punchouts, bleeding, patching, debonding, edge cracking, shattered slab, pumping, pressure damage, surface deterioration, longitudinal joint spalling, and transverse joint spalling manually, although they are working to upgrade these to semi-automated identification. At the initiation of the project, on a scale from 1 to 3, Mandli expressed a confidence in their average ability to accurately identify distresses of 2.4. Similarly, they estimated their average level of automation at 2.1 (primarily semi-automated).

Mandli maintains both an engineering and system assembly office in Madison, Wisconsin, employing about 128 people, building equipment, collecting and processing data, developing software, and supporting agency needs. Currently they report providing 3D services and/or equipment to eight State agencies and 2D assistance to one additional agency.

4.2.2.3 Pathway Systems 3D Data Acquisition System

Pathway, out of Tulsa, Oklahoma, offers the PathRunner XP collection vehicle, shown in Figure 22, with an expanded top to allow for higher ROW camera angles while protecting cameras from the elements. This system includes high-resolution forward cameras, supplemented with GPS capabilities and pavement roughness and texture measurement. They offer a wide range of pavement 3D imaging subsystems based on industry standards and their proprietary Pathway 3D Data Acquisition System. Supplemental collections systems such as LIDAR and ground penetrating radar are also available.

Pathway offers both forward ROW and 360-degree imaging. Up to three industrial forward cameras (3,296 x 2,472 pixels) can be mounted in the high-top extension, with optional side and rear view cameras as well. Wide-angle lenses can be used to collect more panoramic images. ROW cameras are automatically adjusted for brightness, contrast, and gain, subject to vendor thresholds. The quality of images from the three adjacent (2,000 x 1,200 pixels) Pathway ROW cameras used for the ODOT survey is displayed in Figure 23. These images can also be used to determine offset and dimensions of roadway assets, including guardrail, signs, and edge of roadway. The intervals of image capture can be adjusted by the operator and are automatically linked to the Pathway DMI output. Compression ratios used in storing the JPEG images average 20:1, with typical recording rates of 40MB/mi (24.9 MB/km) per camera.

Figure 22. PathRunner XP collection vehicle (front).

Figure 23. Pathway ROW image for ODOT site 20.

The PathRunner XP typically includes an enhanced GPS that uses real-time differential corrections from base stations, satellites, or transmitters to achieve true sub-meter accuracy. Post-processing using auxiliary input and onboard inertial measurement unit (IMU) data is also available to further improve the accuracy. Pathway uses an inertial measurement unit (including military grade or optical gyroscopes) and its DMI to retain accuracy when satellite lock is limited or lost. This system is also capable of accurately providing pavement crossfall, curve radius, and roadway grade.

Pathway's longitudinal profiling system typically collects pavement profiles at 0.067-, 0.031-, and 0.16-inch (1.7-, 0.8- or 0.4-mm) intervals at 60 mi/hr (97 km/hr) using Selcom 16-, 32-, or 64-kHz spot lasers. They can also provide Selcom Roline lasers for agencies with significant longitudinal texturing or grooving. All spot sensors meet the ASTM E-950-11 Class 1 measurement sampling and resolution requirements and achieve an ASTM 1656-11 rating of L122, reporting such roughness indices as IRI (quarter- and half-car), Ride Quality Index (RQI), and Ride Number. Additionally, Pathway can collect 0.016-inch (0.4-mm) samples and report mean profile depth at highway speeds, with one or more 64 kHz spot lasers. To assist agencies with asset management and identifying lane shoulder drop-off, Pathway currently offers a Velodyne LIDAR subsystem. Their ground-penetrating radar option includes both high- and lower-frequency antennas to collect pavement layer information at a range of depths.

Pathway offers 2D and 3D downward pavement image collection systems. Their primary 2D and 3D pavement view digital image collection system is an internally developed, single-camera Pathway 3D Data Acquisition System, shown in Figure 24. This standard system records transverse profiles of 1,500 elevations in a 13.5-ft (4.1-m) wide range, at a typical collection rate of 3,000 profiles per second. At 60 mi/hr (97 km/hr), this corresponds to a sampling rate of about 0.35 inch (9 mm). The Pathway 3D system allows the operator to choose the speed at which the camera collects, offering ranges from 3,000 to 9,000 cycles per second. Height sensor resolution and accuracy for this system are 0.01 inch (0.25 mm) and 0.02 inch (0.50 mm), respectively, and their vertical depth range extends to about 4 inches (100 mm). Their advanced system collects up to 6,000 transverse profile points at more than 9,000 cycles per second, recording longitudinal elevations at 0.125-inch (3-mm) intervals while traveling at 60 mi/hr (97 km/hr). Pathway reports their ASTM E 1656-11 crack measurement capabilities as C3331. Sensors draw minimal power and can be supplied from the vehicle electrical generation system. On the fly, compressed JPEG files produced by this subsystem generate about 700 MB/mile (435 MB/km) at 60 mi/hr (97 km/hr). These files can be compressed through post-processing to about 70 MB/mi (43 MB/km).

Pathway continues to expand and refine their pavement distress identification software to incorporate the 3D capabilities of their new sensors. With an 80 percent accuracy level, they anticipate the ability to automatically detect cracking (wheel track, longitudinal, edge, thermal, and intermediate transverse cracking), rutting, potholes, crack sealing deficiency, punchouts, shattered slabs, and joint spalls. Reportedly, minimal quality control (QC) is required to identify raveling, bleeding, patching, reflective cracks, surface deterioration, and patching. Identification of debonding requires both manual and automated processing, and pressure damage cannot be easily discerned using automated data collection.

Pathway began providing 3D services in 2010, and since then they have collected more than 100,000 miles (160,900 km) of 3D cracking data. They currently supply 3D services and/or equipment to at least eight State agencies, including Idaho and Montana. Additionally, they provide 2D services and/or equipment to more than 10 agencies. Their headquarters employs about 75 people, including about 45 trained raters.

Figure 24. PathRunner XP collection vehicle (rear).

Prior to data collection, Pathway estimated their average ability to accurately identify ODOT PCR distress ratings as 2.4 out of 3.0 (moderate to high). Similarly, they estimated their typical collection process as semi-automated to automated (2.3), expressing the most confidence in their ability to automatically collect primary distress types (longitudinal, transverse, alligator, block, load/misc.) on both rigid and flexible pavement types.

Pathway provides real-time onboard routing to assist operators in selecting optimum routes. Agency-supplied shape files for each route are tracked and color-coded to indicate the location and completion status of routes scheduled for collection. Their computer system differentiates and automatically records each pavement segment, warning of the approach and end of segments scheduled for collection. The system also generates voice descriptions of road information and routing details, along with warnings of subsystem outages or out-of-limit readings.

4.2.2.4 WayLink PaveVision3D System

WayLink has developed the PaveVision3D System for identifying pavement distresses and other measurements, mounting it on a standard full-sized digital highway data vehicle (DHDV), as shown in Figure 25. This system reportedly offers the highest 2D and 3D imaging resolution on the market. Currently, WayLink is developing algorithms for semi-automated and automated identification of pavement surface DSEs. Although they are not primarily a services company, their potential data quality benefits warrant their inclusion in this study.

WayLink's ROW camera is mounted in the vehicle cabin, collecting images through the windshield. This camera provides 1,920 x 1,080 pixel images, recording them either continuously or using triggered intervals, and storing JPEG files (or other standard formats) with a typical compression ratio of 10:1. This camera reportedly falls within both the industrial and cinema categories and allows image brightness and gain to be adjusted both automatically and manually. An example of the ROW camera output is shown in Figure 26.

Figure 25. WayLink PaveVision3D DHDV.

Figure 26. WayLink ROW image.

To ensure accurate positioning, the WayLink system includes a standard 10 Hz industrial GPS that provides 3.3-ft (1-m) accuracy. When combined in real time with augmented satellite or ground station positioning input, the accuracy can be within 4 inches (10 cm). Additional post-processing of the data can further improve their locational accuracy. WayLink supplements their GPS with an Applanix IMU to ensure coordinate accuracy when satellite signals are lost or limited. Presently, WayLink offers crossfall, grade, and curve radius collection services using IMU output.

WayLink is in the process of confirming the precision and accuracy of longitudinal profiles collected by their Ultra 3D image height sensors and their correlation to the industry standard Selcom spot laser road profiling systems. They report that the PaveVision3D Ultra sensors exhibit substantially less electronic “noise” than the standard spot lasers, making them a viable option for longitudinal profiling and even for texture measurements typically collected with 64 kHz spot lasers, as the Ultra 3D sensors operate at 30 KHz data rate for the entire pavement surface.

WayLink, in their PaveVision3D Ultra System, has two sensor cases mounted in the back of their DHDV van. Each sensor case has two subsystems for data acquisition: 2D and 3D. The 2D subsystem reportedly provides laser imaging at 0.04-inch (1-mm) resolution in both the X and Y directions using one 2D camera, one laser assembly, and required optics. WayLink’s 3D subsystem reportedly includes laser imaging at 0.04-inch (1-mm) resolution in the X and Y directions (0.01-inch [0.3-mm] resolution in the vertical direction), employing four 3D cameras, one laser assembly, and required optics (see Figure 27). The use of multiple 3D cameras in a single PaveVision3D Ultra 3D sensor allows the four cameras to collect synchronously, operating at 30 KHz collection rate over the entire pavement surface. In other words, when 3D line profile data from the four cameras are stitched transversely and combined longitudinally, the longitudinal sampling interval reportedly falls below 0.04 inch (1 mm), with a system collection rate of about 4,160 transverse profile points recorded at 30,000 samples each second. Combined, ten 2D and 3D cameras are included in a pair of PaveVision3D Ultra sensors. This configuration reportedly meets ASTM E 1656-11 Code C1111. When compressed, the 2D and 3D image data require storage space less than 2,000 MB/mi (1,243 MB/km) at 60 mi/hr (97 km/hr).

In January 2013, WayLink demonstrated their Beta version software for identification of pavement distresses. However, they do not anticipate completing the development of this software until the second half of 2013. Anticipating the capabilities of this software, WayLink estimated the average ability of the system to accurately identify ODOT DSEs at 3.0 (high), and with an average automation level of 2.2 (semi-automated). The Federal Aviation Administration (FAA), South Africa National Road Agency, and a private company in Brazil are currently operating WayLink's PaveVision3D Ultra system. Waylink also holds a pending order for a complete vehicle system of PaveVision3D Ultra from a State DOT.

Figure 27. WayLink PaveVision3D Ultra Sensor System.

4.2.3 Vendor Production Rates

Depending on the scope of ODOT testing and the capabilities of each vendor, production rates can vary. As ODOT plans for the possibility of automated vendor data collection and processing, the following aggregate vendor estimates will assist in developing and refining a schedule. The first year of semi-automated collection and processing by any vendor requires greater time and effort than in subsequent years. ODOT and the vendor must coordinate test site location details, conduct initial and supplemental fine tuning of distress rating, develop and implement quality assurance (QA) procedures, and resolve any locational, collection, processing, and reporting discrepancies. Average first-year full-scale production estimates are included in Table 5 for each of the major activities.

Table 5. Average first year's full-scale production estimates (vendor collection and processing).

Activity	Time, weeks
Time required after award for mobilization	3
Time required for data collection (two vehicles)	20
Time required for initial data processing and QC	16
Time required for initial fine tuning of distress rating procedures	5
Total time from mobilization to completed project delivery	30

In subsequent years, vendors estimate a 7 percent reduction in the time required for collection and processing, as Table 6 indicates. The 28-week average total estimated time for vendor project completion allows for completion of data collection without the delays and troubles associated with early spring and winter collection.

Table 6. Average subsequent year's full-scale production estimates (vendor collection and processing).

Activity	Time, weeks
Time required for vendor data collection	20
Time required for vendor data processing and QC	15
Total time from mobilization to completed project delivery	28

4.2.4 Selected Vendors

Based on the available vendor information, five vendors were selected for inclusion in the planned field system evaluation. Fugro, Dynatest, Mandli, and Pathway displayed the potential for successfully collecting pavement distress data at a level adequate for ODOT acceptance. WayLink's analysis software status and service capability limited their potential, but their significant likelihood of collecting extremely high-quality data warranted their inclusion. Dynatest was not able to participate due to concurrent commitments. A small stipend was provided to participating vendors in appreciation of their participation.

4.3 FIELD DATA COLLECTION

For a full-scale comparison of the capabilities of vendor systems to identify and rate the distresses classified by ODOT raters, 44 test sites were selected. Based on 2011 and 2012 surveys, these sites, described in Appendix C, provided representations of all ODOT distresses. These test sites represented 66 AC DSE combinations, 35 PCC DSE combinations, and 57 AC/PCC DSE combinations, resulting in 354 DSE replicates. Site locations range from Columbus to the northeast corner of Ohio. In August and September of 2012, Ohio University and ODOT personnel set up and marked the test sites, and ODOT raters conducted four PCR surveys of the sites. Three vendors completed surveys of all sites, and one vendor collected images from several sites.

4.3.1 Site Setup and Marking

In mid-August 2012, each of the 11 PCC, 14 AC, and 19 AC/PCC test sites was visually inspected, shortened as necessary, marked at the beginning and end, and located using GPS coordinates. Testing lanes were also selected. To maintain a reasonable project scope, 20 sites were reduced in length from the ODOT designated segment length to about 1 mi (1.61 km). Marking was placed on the pavement surface and edge, as shown in Figure 28, to assist vendors in identifying site boundaries.

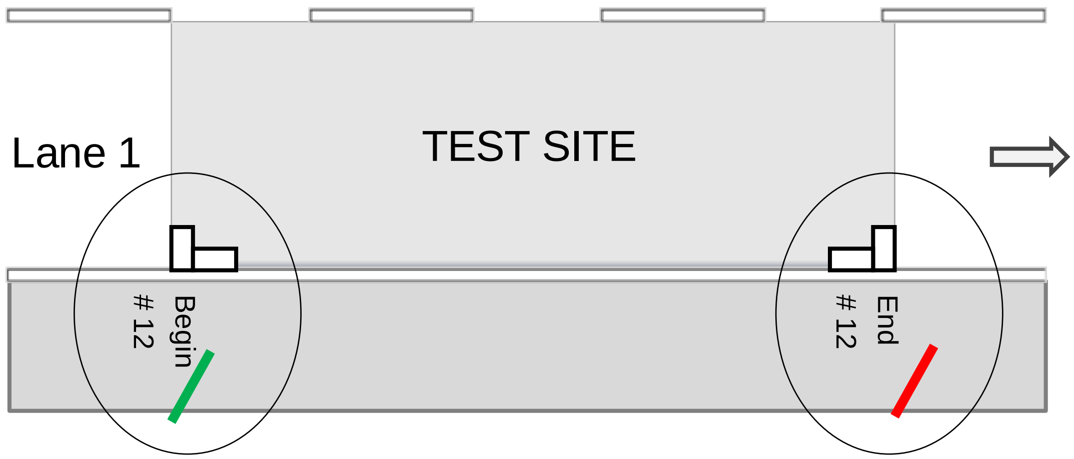


Figure 28. Test site markings.

4.3.2 ODOT Baseline Site Evaluations

Two ODOT raters completed site evaluations the weeks of August 15 and October 1, 2012, bookending the vendor surveys. As is typical of ODOT manual PCR survey methods, the raters carried with them DSE ratings from the 2011 ODOT surveys of each site.

ODOT raters drove slowly through each section to identify the extent of distresses present at the site. They commonly stopped several times, when safe to do so, to determine the severity of each distress. Once they defined the severity and extent combinations present for each distress, they selected and recorded the combination that produced the highest deduct value. Distresses exhibiting severities other than those producing the highest deduct level were not noted or included in the final rating.

4.3.3 Vendor Site Evaluations

Three vendors collected distress images and data from all sites: Pathway (September 9-12), Mandli (September 15-18), and Fugro (September 21, 23, 25, 28-30). Each vendor collected ROW images, range and intensity images, surface profile, GPS coordinates, and DMI distances from all sites.

Pathway ran the 3,000 Hz system, while Mandli and Fugro employed their 5,600 Hz systems. Initial results were provided for review by two vendors within 30 days and the third within 110 days.

Two vendors conducted semi-automated distress identification, visually reviewing all images. One vendor initially developed, calibrated, and ran fully automated DSE identification algorithms for all sites. Current limitations of automated identification led the vendor to reanalyze the images in a limited semi-automated analysis.

Feedback regarding obvious errors was provided to the vendors, and they were allowed to resubmit their data following adjustment. This feedback included situations where the beginning or end of the vendor's test site needed to be adjusted to meet that used by the ODOT raters. Additionally, vendors were experiencing difficulty distinguishing between AC overlays of jointed and unjointed pavement, due to distresses representative of both structures. To resolve this, they were provided with ODOT's designation for the underlying PCC type for composite test sites. Finally, missing data, such as the number of slabs and transverse joints, were requested.

Some vendors were not able to provide a full set of DSE data. After expending significant effort on solely automated analysis, Pathway chose not to rate intermediate transverse cracks on AC/PCC pavements. Other constraints led Mandli to not completely evaluate crack seal deficiency.

5 RESEARCH RESULTS

Results of the ODOT and vendor field testing are summarized below. The primary focus of this comparison is with distinct distresses, severities, and extents noted by participating parties. This focus helps to identify particular areas of successful distress identification and those needing improvement.

5.1 DISTRESS/SEVERITY/EXTENT ANALYSIS

Vendors were able to consistently match the existence of the distresses identified by ODOT raters for all pavement types, resulting in 72 (Pathway and Fugro) to 73 (Mandli) percent of the ODOT-marked distresses identified by vendors. However, extent and severity ratings, both critical to ODOT pavement management operations, proved more difficult for vendors to replicate consistently. The levels at which Fugro, Mandli, and Pathway matched ODOT's distress/severity ratings for all pavements dropped to 32, 35, and 33 percent, respectively. Combined distress, severity, and extent correlations further fell to 13, 19, and 14 percent. Listed below are success rates for each pavement type and areas for focused attention. Reasons for some discrepancies are also discussed, along with the anticipated potential for improvement and distresses (severities and extents) for which vendors should not be expected to accurately match ODOT ratings. Appendix D includes the complete distress, severity, and extent results.

The significantly different approaches employed by each vendor contributed to differences in their reported results. Pathway has developed, employs, and continues to improve and train their fully automated distress identification tools. Nearly every distress was searched for automatically, after which semi-automated, manual reviews served to check the automated ratings and identify such distresses as bleeding and pumping. Fugro and Mandli completed their distress reviews manually, assisted by automated crack detection software. Both Mandli and Fugro currently employ Pavemetrics software for automated distress identification.

5.1.1 AC Pavements

All vendors showed good ability to identify the existence of ODOT-rated distresses on AC pavements, but low success at matching ODOT's severity and extent. Fugro matched 78 percent of ODOT distresses. Mandli and Pathway noted 85 and 94 percent, respectively. The best AC pavement distress correlations occurred with standard crack types (block, transverse, and longitudinal). Vendor severities matched ODOT's for 35.9 percent of distresses, and severity and extent matched ODOT for 19.3 percent of distresses. Figures 29, 30, and 31 illustrate the vendors' abilities to match the DSEs noted by the ODOT raters. Numbers in parenthesis indicate the number of sites in which ODOT identified the distress. Where ODOT raters varied, the most selected DSE served as the baseline, and if raters were evenly divided, the rating closest to the vendor's call or the highest severity was selected. Table 7 quantifies and summarizes these AC pavement correlation ratings. The average at the bottom of the table is based on the DSEs matching ODOT raters, as a percentage of the total number of distresses.

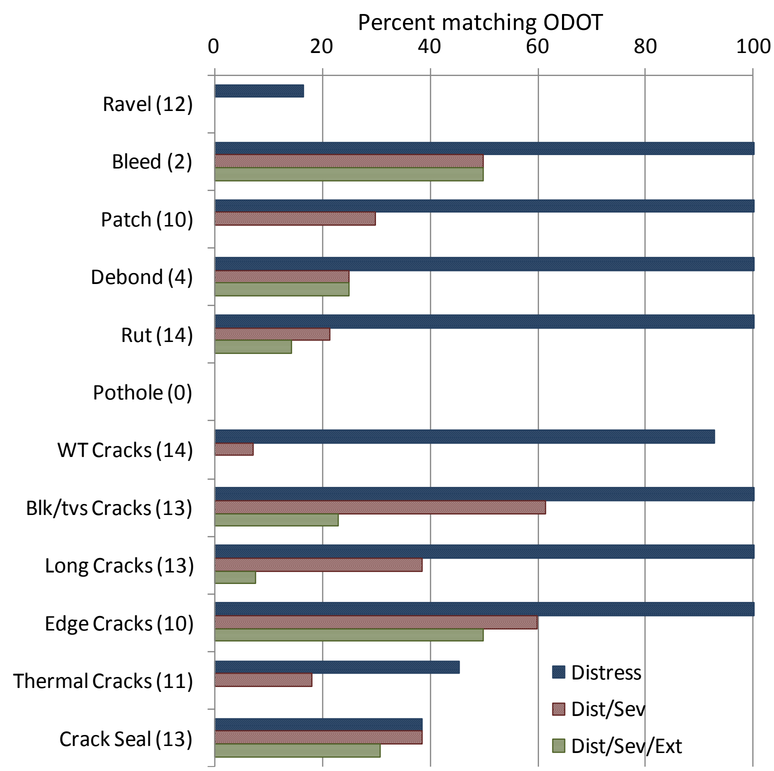


Figure 29. Fugro DSE rating match with ODOT for AC pavements.

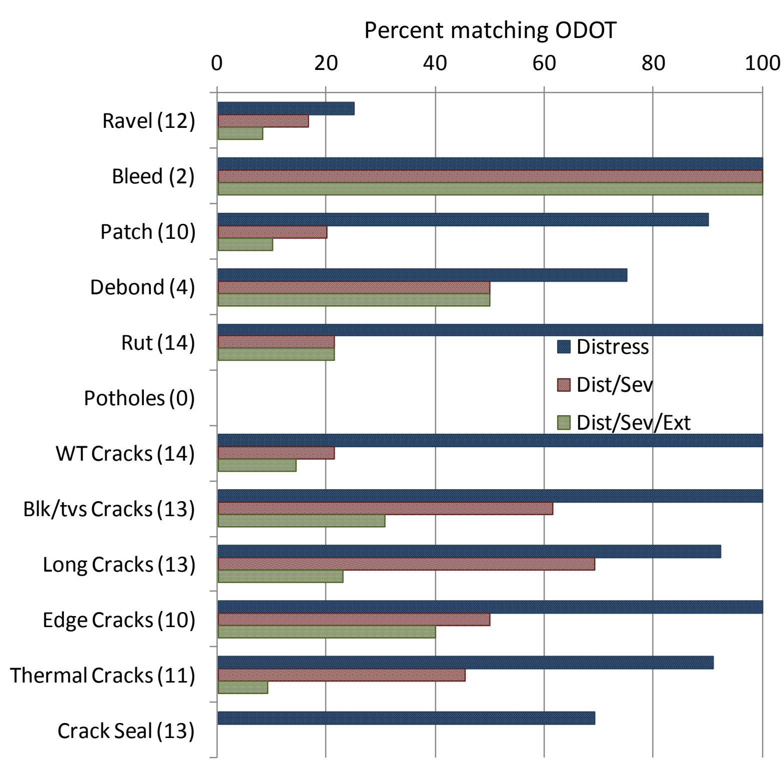


Figure 30. Mandli DSE rating match with ODOT for AC pavements.

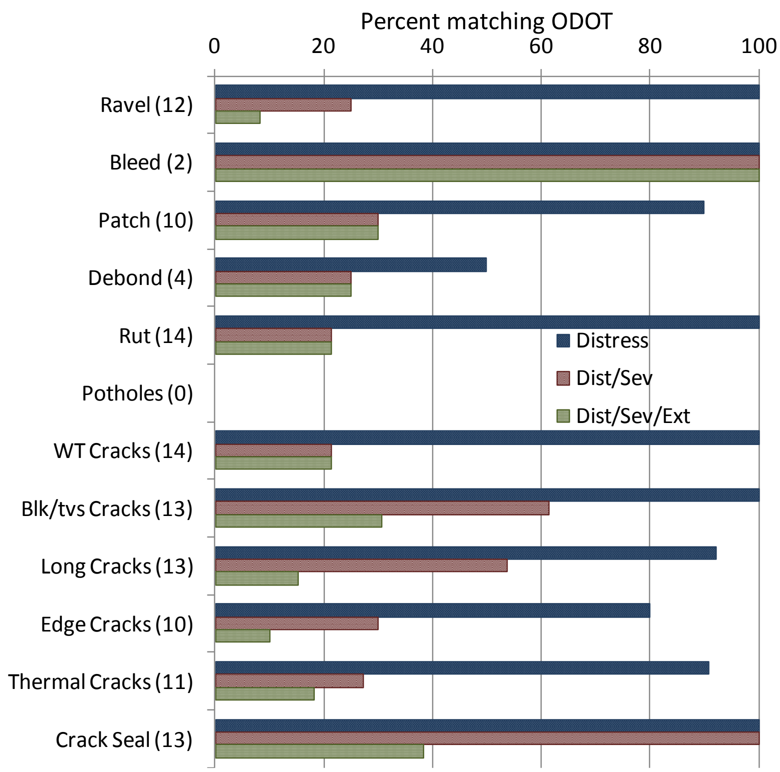


Figure 31. Pathway DSE rating match with ODOT for AC pavements.

Table 7. Summary of vendor match with ODOT DSE ratings for AC pavements.

		Distress/severity match, %				DSE match, %			
Distress	**Sites**	**Fugro**	**Mandli**	**Pathway**	**Avg.**	**Fugro**	**Mandli**	**Pathway**	**Avg.**
Ravel	12	0	17	25	14.0	0	8	8	5.3
Bleed	2	50	100	100	83.3	50	100	100	83.3
Patch	10	30	20	30	26.7	0	10	30	13.3
Debonding	4	25	50	25	33.3	25	50	25	33.3
Rut	14	21	21	21	21.0	14	21	21	18.7
Pothole	0	0	0	0	0.0	0	0	0	0.0
Wheeltrack cracks	14	7	21	21	16.3	0	14	21	11.7
Block/trans cracks	13	62	62	62	62.0	23	31	31	28.3
Long cracks	13	38	69	54	53.7	8	23	15	15.3
Edge cracks	10	60	50	30	46.7	50	40	10	33.3
Thermal cracks	11	18	45	27	30.0	0	9	18	9.0
Crack seal damage	13	-	-	-	-	31	0	38	23.0
Weighted Avg:		**30.2**	**35.3**	**42.2**	**35.9**	**14.7**	**19.8**	**23.3**	**19.3**

Raveling: Identification of raveling remains elusive to vendors, with the existence of the distress being noted on an average of 42 percent of raveled sites. Severity and extent matches expectedly fell lower as well. Some of this variation resulted from the vendors not increasing their noted raveling severity when block cracking was present. This resulted in lower deducts and higher PCR values. Pathway exhibited the greatest success, noting raveling on 100 percent of twelve raveled sites identified by ODOT raters. This may be the result of their advanced automated approach to detecting raveling. Mandli and Fugro currently identify raveling manually, although they collect macrotexture information. In addition, the rough texture of chip seals makes it difficult for vendors to automatically identify raveling; however, at least one vendor indicates the ability to automatically identify chip seals. Although improvements can be made, matching ODOT raveling ratings using digital image systems with greater than 75 percent success is not anticipated at this time. Better correlations are expected for medium and high severity raveling.

Bleeding: Vendors showed little trouble identifying the presence, severity, and extent of the bleeding (high extensive and medium extensive) noted on two sites by ODOT raters. Although vendors fared well in identifying the project site bleeding, they express apprehension about their ability to consistently and accurately identify bleeding. This presence of bleeding is typically identified visually using ROW and downward images, although Pathway reports using semi-automated recognition methods. Vendors using 3D systems with manual, semi-automated, or automated analysis methods are not expected to perfectly match ODOT raters above the 75 percent level.

Patching: Most vendors identified all sections for which ODOT noted patching; however, Fugro noted patches on three additional sites (30, 31, and 39). Further review revealed single small patches on sites 30 and 31, which ODOT would not typically rate. Patches noted on site 39 resulted from seals being incorrectly rated as patching material. Severity and extent were difficult for vendors to match with ODOT rater values. Contributing to this difficulty on sites 3, 12, 33, and 37 were patches greater than 15 yd^2 (12.5 m^2) that were recorded by Pathway, contrary to defined ODOT practice. Additionally, patch counts recorded by Mandli (233) and Fugro (358) more closely approximate patches present at the sites, whereas Pathway showed difficulty identifying patches, noting only 45 patches on all AC sites. This resulted from Pathway not including spray patches in their distress rating. Additionally, vendor-rated severities fell consistently higher than ODOT ratings, in part due to the vendors not following the unwritten ODOT practice of excluding patches near manholes and drain inlets. Significant improvement in patch identification correlation (estimated above 75 percent) with ODOT ratings is expected as vendors incorporate ODOT written and unwritten data collection protocols.

Debonding: Vendors again were only able to partially identify and rate debonding. This primarily resulted from their unfamiliarity with reporting this type of distress. Mandli most closely replicated ODOT, identifying debonding at three sites and replicating ODOT ratings for two. Fugro noted all four sites, matching one severity and all ODOT extent ratings. Pathway identified two sites, matching the extent on both. However, Mandli incorrectly noted debonding on two additional sites. Follow-up conversations with vendors indicated that Pathway would have noted the debonding on sites 3 and 20 if they had expanded their search to include the centerline stripe area. Mandli rated a large, deteriorated patch as debonding, resulting in high severity and extent values, and Fugro mislabeled debonding as patching on sites 3 and 4. With further training, vendors indicate potential to improve their debonding DSE match with ODOT raters to between 50 and 75 percent.

Rutting: Vendor ratings for rutting displayed more consistency with each other than with ODOT raters, as Table 8 indicates. The difference in vendor-reported average inches of rutting for each site (noted in parentheses in the table) averaged less than 0.05 inch (1.3 mm). This consistency may be expected, given the reported repeatability and accuracy of current high-speed systems, and provides an indication of the ability of automated systems to collect rutting data. Although automated system rutting values may not match ODOT ratings at high levels, they may offer a higher level of representation and accuracy.

Table 8. Rutting ratings for AC test sites.

Test Site	ODOT	Fugro	Mandli	Pathway
3	LF	HO (0.18)	HO (0.14)	HO (0.13)
4	HO	HO (0.18)	HO (0.12)	HO (0.16)
12	MO	MO (0.33)	MO (0.15)	MO (0.30)
20	LF	HO (0.21)	HO (0.22)	HO (0.20)
24	LO	HO (0.16)	HO (0.11)	MO (0.12)
27	LF	HO (0.29)	HO (0.21)	HO (0.24)
28	MO	HO (0.34)	MO (0.31)	MO (0.29)
29	LE	MO (0.32)	HO (0.26)	MO (0.3)
30	LF	LE (0.14)	MO (0.09)	MO (0.13)
31	LF	MO (0.17)	HO (0.17)	HO (0.17)
33	LF	HO (0.17)	MO (0.12)	MO (0.15)
37	LF	HO (0.17)	HO (0.13)	HO (0.13)
39	MF	HO (0.09)	HO (0.06)	HO (0.05)

Note: 1 inch = 25.4 mm

Potholes: While potholes were reported on sites selected for the study, apparently maintenance operations had repaired them prior to the field surveys. As a result, ODOT found no potholes on the selected AC test sites. Similarly, Fugro noted only one in site 3. Digital image review indicated that Fugro had mistakenly marked a deteriorated patch as a pothole. Mandli, however, identified 42 potholes on 10 sites, incorrectly reporting as potholes, cracks that had widened to more than 3 inches (76 mm). Pathway did not report potholes at sites 4 and 29 because they mistakenly assumed that potholes would not be counted when block cracking or wheel track cracking is present. However, without this exclusion, they would have reported potholes at these sites as well. Vendors also reported some confusion regarding whether a depression should be rated as a pothole or debonded area, given the overlap of the two distress descriptions. Further clarification and vendor refinement may increase the match of vendor DSE ratings with ODOT results to between 50 and 75 percent.

Wheel Track Cracking: Vendors proved capable of identifying nearly all AC sites containing wheel track, block/transverse, longitudinal, edge, and thermal cracking, yet their ability to match ODOT's severity and extent ratings proved only moderate. All vendors typically rated the severity of wheel track cracking one or two levels higher than ODOT. Several factors may have contributed to this trend. First, sites 3, 29, 30, and 31 had been widened such that the longitudinal construction joint fell in the wheelpath. Although ODOT does not rate this lane-widening crack as wheel track cracking, the vendors did. Participating vendors indicate that identifying and removing lane widening cracks in AC pavements would be difficult for vendors to achieve using automated methods and may require forewarning with respect to the ODOT asset database or significant manual image review. Additionally, vendors rated what ODOT would call "gear box" cracking (asphalt paver-induced longitudinal segregation/cracking) as wheel track cracking on site 31. Fugro and Pathway assumed that block cracking overrides all other distresses and did not report wheel track cracks and other distresses when block cracking was noted. Moreover, some vendors rated edge cracking that extended into the wheelpath as wheel track cracking, diverging from ODOT's approach. Finally, vendors appeared to not be combining crack widths according to ODOT practice to determine crack severity levels. Vendor training, detailed manual review, and possibly a database of widened lanes is anticipated to increase wheel track and edge cracking correlations to above 75 percent.

Block/Transverse Cracking: Block/transverse cracking was readily identified by vendors at the sites noted by ODOT raters. Vendors matched severity levels with ODOT on 60 percent of the sites and replicated ODOT DSE rating levels for about 30 percent of sites. These variations may result from the difficulty vendors reported in identifying dimensions of blocks from downward images. Additional vendor training by ODOT personnel is likely to improve this correlation. Vendors rated the extent of all 13 sites as "occasional," whereas ODOT only rated 7 sites in that category. Extent variations between vendors were also evidenced by their reported average low-severity block/transverse cracking lengths ranging from 430 ft [131 m] (Pathway), to 1,303 ft [397 m] (Fugro) to 1,713 ft [522 m] (Mandli)—all less than 20 percent of the site length. The difficulties vendors encountered with differentiating thermal and transverse cracking resulted in their underreporting block cracking. Additional refinement of vendor methods through vendor training and supplemental field correlations is anticipated to increase vendor block/transverse cracking correlations with ODOT ratings to between 50 and 75 percent or higher.

Longitudinal Cracking: Vendors noted longitudinal cracking on nearly all sites identified by ODOT raters, matching ODOT severity on about 60 percent of sites and extent on about 15 percent. Typically, vendors' extents fell significantly below ODOT ratings. All vendors mistakenly reported longitudinal cracking on site 37. Their reasons vary, with Mandli including the longitudinal joints of patches, Pathway not rating the centerline joint, and Fugro and Pathway not rating longitudinal cracking when block cracking was noted. After vendor training and additional field calibration, the potential for most vendors to match ODOT DSE ratings at a level greater than 75 percent appears high.

Edge Cracking: Mandli and Fugro noted all 10 sites identified by ODOT as containing edge cracking. Pathway recognized edge cracking on eight sites, missing the distress on sites 12 and 29 and incorrectly adding edge cracking to sites 4 and 20. Mandli mistakenly noted edge cracking at sites 4, 20, and 27, and Fugro improperly designated edge cracking on site 4. Confusion which led to this variability can be resolved through better communication, training, and supplemental field calibration. For instance, ODOT did not record the edge cracking on the narrow shoulders of site 4, because curbs were present for a majority of the site. Similarly, ODOT declined to report the edge cracking on sites 20 and 27 because the bike lane shoulder was greater than 4 ft (1.2 m) wide. Most vendors, however, recorded the shoulder edge cracking for these sites. Additionally, Pathway reported cracks along the centerline joint as edge cracking, which occasionally increased their extent ratings. After training and calibration, it is anticipated that vendor DSE correlations will increase to between 50 and 75 percent or greater.

Thermal Cracking: Thermal cracking, by ODOT's definition, includes only transverse cracks that extend from edge to edge of the pavement. Vendors are limited in their view of the entire pavement, commonly rating transverse cracks that extend the full width of the measured lane. As a result, at least one vendor demonstrated limited ability to identify the thermal cracking noted by ODOT raters. Mandli and Pathway noted thermal cracking in most ODOT-rated sections, matching severities and extent at a level similar to other cracking distresses. Fugro did not achieve this level, identifying thermal cracking in only 45 percent of sites noted by ODOT. This discrepancy, in part, is related to Fugro's (and Pathway's) assumption that block cracking overrides thermal cracking. ODOT's unreported practice of recording thermal cracking only when five or more thermal cracks are present may also have contributed to the vendor variations. As noted, ODOT raters only record thermal cracking if the cracks extend across the entire pavement width. This criterion will be difficult (and time consuming) for vendors to judge, because forward cameras must be used and sun angles may not allow for accurate assessment. If ODOT were to allow vendors to designate as thermal cracks those that extend across the measured lane width and exhibit a minimum width, vendors are expected to provide greater than 75 percent DSE accuracy, with extended training and field calibrations.

Crack Seal Deficiency: Using automated software to identify the presence of crack seal material failed seals, Pathway identified crack seal deficiency on all AC sites noted by ODOT raters, matching DSE ratings on 38 percent of the ODOT-identified sites. Fugro experienced difficulty identifying crack seal deficiency for 62 percent of the sites in which ODOT raters noted crack seal deficiency, although their overall DSE match held at 31 percent. Not expecting high return on their efforts, Mandli did not complete a formal rating, instead noting only that the deficiency was present on some sites. Since completing their evaluation, they report receiving a crack seal identification upgrade to their Pavemetrics software, which may improve their correlations. Pathway and Fugro did not count as unsealed, the unsealed cracks that were wider than 0.125 inch (3 mm). Pathway also assumed that if any portion of a seal was failed, the entire segment length was failed. This resulted in over-reporting the extent of crack seal deficiency. Further clarification of vendor expectations, software improvements, and refined field calibrations are expected to increase crack seal correlations with ODOT DSE ratings for some vendors to above the 75 percent level.

Table 7 and the above discussion indicate the ability of vendors to match ODOT DSE ratings. Figure 32 indicates whether vendor ratings typically fell lower or higher than those noted by ODOT. This figure displays the average difference between vendor and ODOT deduct values for each AC pavement distress type. As can be seen, vendors' deduct values for patching, debonding, rutting, potholes, wheel track cracking, edge cracking, and thermal cracking typically exceeded those of ODOT, while their raveling, block/transverse, longitudinal cracking, and crack seal deficiency typically fell below ODOT ratings.

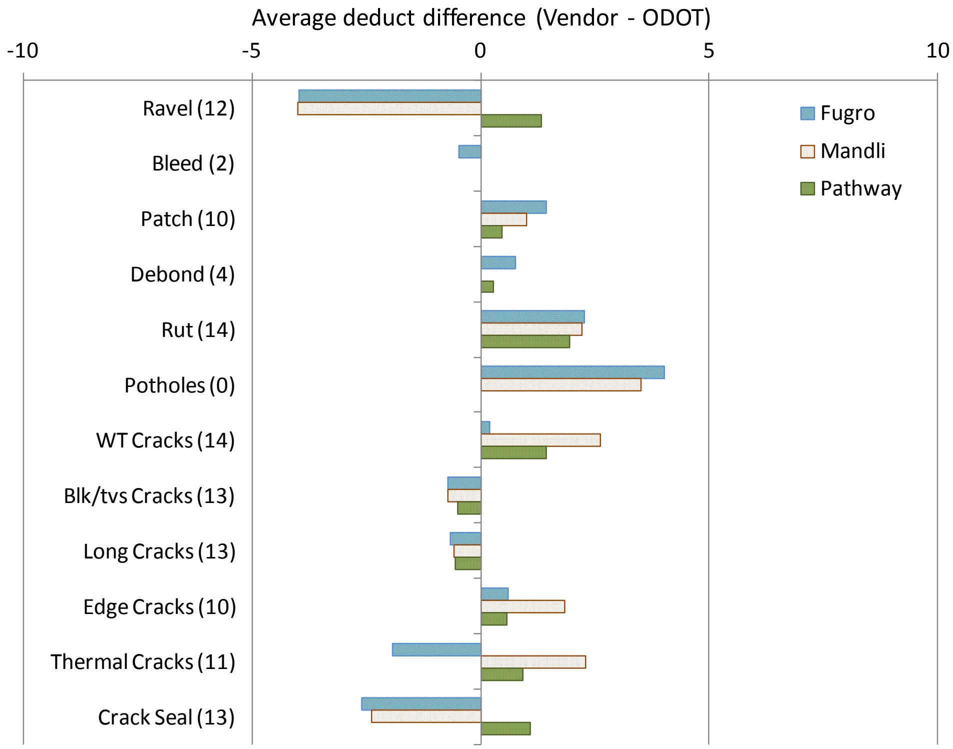


Figure 32. Vendor and ODOT deduct value differences for distresses on AC pavements.

Based on the initial project correlation results and the above described detailed review of vendor distress rating discrepancies, it appears that substantial potential remains for vendors to provide significant improvements in correlations with ODOT ratings. Maximizing this correlation will require additional vendor training and advanced field optimization efforts by vendors and ODOT personnel. Although the final correlation levels cannot be defined until optimization is complete, research team estimates are offered in Table 9 as ballpark indicators. This table also indicates the correlation ratings achieved in the initial project evaluation. Note that Mandli intends primarily to use automated methods for their state-wide evaluations and therefore, does not anticipate providing the intense level of manual evaluation effort they expended to achieve their initial evaluation results. Instead, they suggest that raveling, bleeding, debonding, thermal cracking, and crack seal deficiency be removed from ODOT's AC distress data collection, and that AASHTO LCMS distresses (rutting, longitudinal cracks, transverse cracks, and fatigue cracks) remain.

General items that should be clarified to enhance vendor correlation with ODOT ratings include:

1. Bridges and approach slabs should not be included in the distress survey (25-50 ft [7.6-15.2 m] standard highway, 100 ft [30.5 m] interstate highway).
2. Intersections should not be included in the distress survey.
3. Distresses within 3 ft (0.9 m) of manholes or drain inlets should not be included in the distress survey.

Table 9. Estimated probability for matching ODOT ratings on AC pavements.

	Fugro		Mandli		Pathway	
Distress	**Initial**	**Estimated**	**Initial**	**Estimated**	**Initial**	**Estimated**
Raveling	(L, P, P)	(M, L, L)	(L, L, P)	(M, L, L)	(H, L, P)	(H, M, M)
Bleeding	(H, M, M)	(M, M, M)	(H, H, H)	(L, L, L)	(H, H, H)	(M, M, M)
Patching	(H, L, P)	(H, H, H)	(H, L, L)	(L, L, L)	(H, L, L)	(H, H, H)
Debonding	(H, L, L)	(H, M, M)	(H, M, M)	(L, L, L)	(M, L, L)	(H. M. M)
Rutting	(H, L, L)	(H, H, M)	(H, L, L)	(H, H, M)	(H, L, L)	(H, H, M)
Potholes	N/A	(H, M, M)	N/A	(H, M, M)	N/A	(H, M, M)
Wheel track cracking	(H, P, P)	(H, H, H)	(H, L, L)	(H, M, M)	(H, L, L)	(H, H, H)
Block/transverse cracking	(H, M, L)	(H, H, M)	(H, M, L)	(H, L, L)	(H, M, L)	(H, H, M)
Longitudinal cracking	(H, L, P)	(H, H, H)	(H, M, L)	(H, M, M)	(H, M, L)	(H, H, H)
Edge cracking	(H, M, M)	(H, H, M)	(H, M, L)	(H,M, L)	(H, L, L)	(H, H, M)
Thermal cracking	(L, L, P)	(M, M, M)	(H, L, L)	(M, L, L)	(H, L, L)	(M, M, M)
Crack seal deficiency	(L, -, L)	(M, -, M)	(M, -, P)	(L, -, L)	(H, -, L)	(H, -H, H)

Probability of accurate rating: H (high, 75-100%), M (moderate, 50-74%), L (low, 10-49%), P (poor, <10%).
(Distress match, Distress/Severity match, Distress/Severity/Extent match), e.g., (H, H, M).

4. Debonded areas must be at least 6 inches (152.4 mm) in diameter to be counted. ODOT does not count debonding until it occurs 2 to 3 times per mile.
5. Pothole areas must be at least 6 inches (152.4 mm) in diameter to be counted. ODOT does not count potholes until they occur 2 to 3 times per mile.
6. Longitudinal (widened lane) joint cracks that fall in the wheelpath should be counted as longitudinal not wheelpath cracks.
7. Vendors should not include edge cracking with the wheelpath cracking if it extends into the wheelpath. Instead, they should count it as edge cracking.

8. Transverse cracks are not rated as thermal unless they traverse from pavement edge to pavement edge. They also should be distressed sufficiently to indicate full-depth cracking.
9. Edge cracking can only be rated if there is no curb and the shoulder is less than 4 ft (1.2 m) wide.
10. Thermal cracking is not incorporated into block/transverse cracking. If ODOT sees only four full edge to edge thermal cracks per mi (2.5 per km), they will not count it.

6 BLOCK CRACKING DOES NOT OVERRIDE OTHER DISTRESSES, SUCH AS THERMAL, LONGITUDINAL, EDGE, AND WHEELPATH CRACKING.

6.1.1 AC/PCC Pavements

Comparisons for AC/PCC overlay pavements reveal a 5 to 10 percent reduction in vendors' ability to identify DSEs, compared to their ability to identify AC pavement DSEs. Fugro noted the existence of AC/PCC distresses at 67 percent of sites noted by ODOT raters. Mandli matched ODOT distress identification on 64 percent, and Pathway matched on 58 percent. Overall vendor distress/severity rating accuracy was reduced by about 16 percent from AC pavement ratings, while DSE correlations fell 58 percent. Table 10 summarizes the vendor correlations with ODOT ratings for AC/PCC test sites, and Figures 33-35 provide summaries of the vendor matches for DSE. It should be noted that transition from manual to automated data collection and semi-automated distress identification will be infeasible if these correlations are not improved.

Table 10. Summary of vendor match with ODOT DSE ratings for AC/PCC pavements.

		Distress/severity match, %				DSE match, %			
Distress	**Sites**	Fugro	Mandli	Pathway	Avg.	Fugro	Mandli	Pathway	Avg.
Ravel	20	40	0	55	**31.7**	5	0	20	**8.3**
Bleed	1	100	100	0	**66.7**	100	0	0	**33.3**
Patch	19	68	53	37	**52.7**	11	11	21	**14.3**
Debonding	9	0	33	11	**14.7**	0	22	0	**7.3**
Rutting	19	16	26	16	**19.3**	5	5	5	**5.0**
Pumping	6	0	0	0	**0.0**	0	0	0	**0.0**
Pressure	7	0	0	0	**0.0**	0	0	0	**0.0**
Corner Break	6	17	0	0	**5.7**	0	0	0	**0.0**
Long Cracks	20	40	70	60	**56.7**	10	5	15	**10.0**
T Cracks - unj	8	63	50	25	**46.0**	50	25	13	**29.3**
T Cracks - joint	12	50	67	58	**58.3**	0	17	17	**11.3**
T Cracks - int	12	17	42	8	**22.3**	0	8	0	**2.7**
Crack Seal	20	n/a	n/a	n/a	**-**	0	10	30	**13.3**
Punchout	5	0	20	0	**6.7**	0	0	0	**0.0**
Shat Slab	1	100	0	0	**33.3**	100	0	0	**33.3**
Weighted Avg:		**31.5**	**32.7**	**26.7**	**30.3**	**7.3**	**7.9**	**9.1**	**8.1**

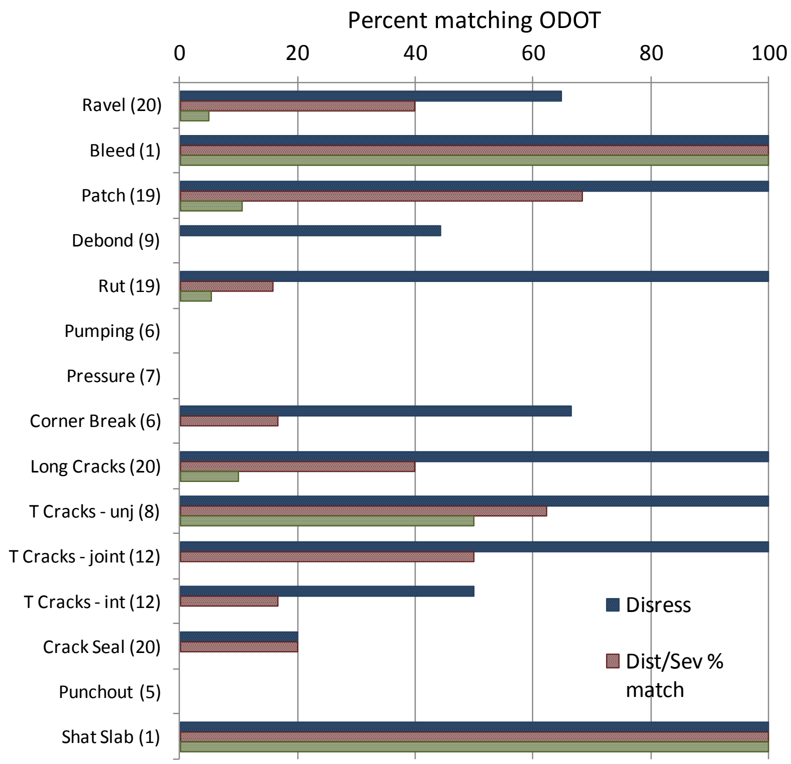


Figure 33. Fugro DSE rating match with ODOT for AC/PCC pavements.

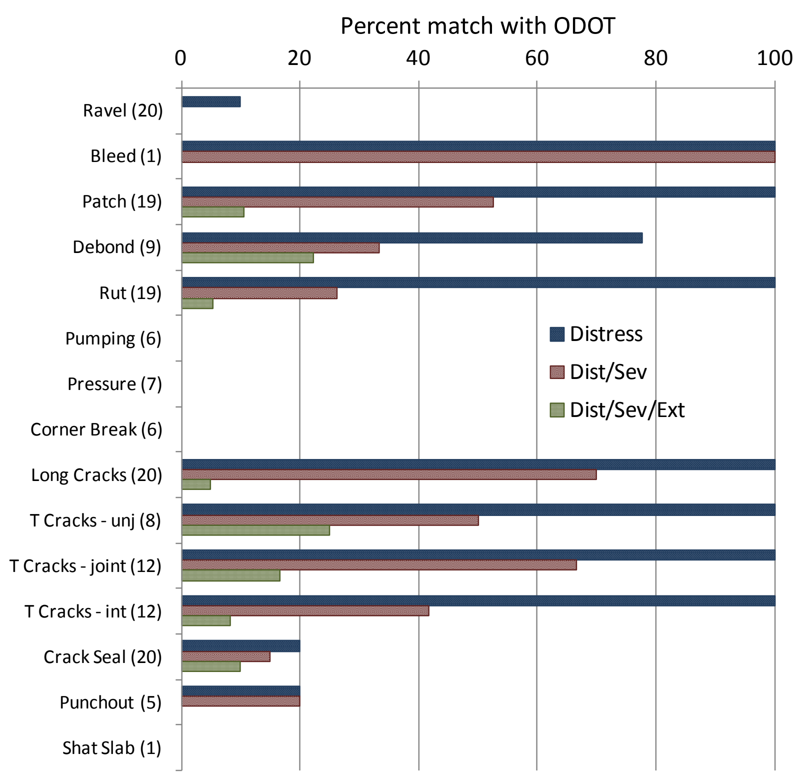


Figure 34. Mandli DSE rating match with ODOT for AC/PCC pavements.

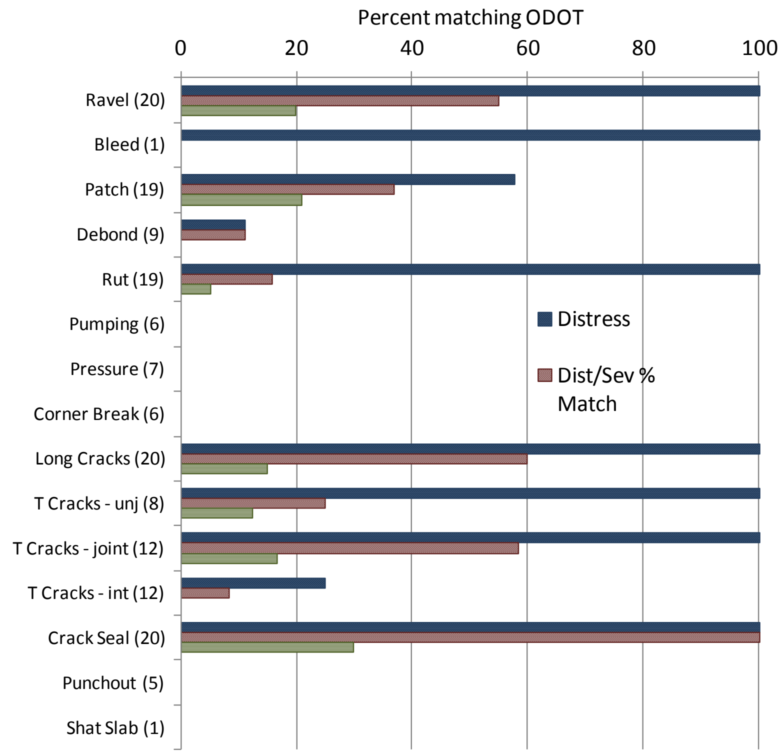


Figure 35. Pathway DSE rating match with ODOT for AC/PCC pavements.

As with AC pavements, clarifications of general items should improve correlation between ODOT and vendors for AC/PCC pavement DSEs. In addition, if the following undocumented ODOT criteria are applied, vendor distresses should better match ODOT ratings:

1. Patches must be at least 6 inches (152.4 mm) in diameter to be counted. Patches along joints within a slab are combined.
2. Longitudinal cracking on AC/PCC includes lane-shoulder joints and edge cracking within 1 ft (1.8 m) of outside edge stripe.
3. Corner breaks on AC/PCC should typically be depressed (unless positively identified) with an area at least 2 ft^2 (0.19 m^2). Corner breaks are automatically rated high if pumping is present.
4. Punchouts include localized areas that are cracked and usually sunken.
5. Shattered slabs should be large areas with longitudinal and transverse cracking, depressed and possibly pumping. The surface undulations cause much vehicle motion.

Demonstrated and anticipated vendor capability of identifying and rating AC/PCC DSEs is discussed below.

Raveling: As on the AC sites, two vendors were limited in their ability to identify the presence of raveling, reporting this distress on only 10 (Mandli) and 65 (Fugro) percent of raveled sites. Their DSE ratings matched only 5 percent of ODOT's values. This underreporting resulted in average deduct levels less than those resulting from standard ODOT ratings (see Figure 36). Mandli and Fugro used visual methods, supplemented with macrotexture data, to identify raveling. Alternately, Pathway identified raveling on all sites noted by ODOT, using a combination of automated methods. Although they noted all raveled sites, they also incorrectly reported raveling on two chip seal sites. Additionally, where Pathway noted block cracking for sites 6, 7, 11, and 35, they did not report raveling. Consequently, this reduced Pathway's raveling extent rating, decreasing their DSE correlation to 20 percent of the sites flagged by ODOT. Although significant improvements in DSE correlation are expected to result from calibration and optimization, matching ODOT raveling ratings with greater than 75 percent success using digital image systems is not anticipated at this time. Medium and high severity raveling is expected to provide better correlations.

Bleeding: All participating vendors noted the only ODOT-reported AC/PCC bleeding on site 43. Fugro matched ODOT's severity and extent and Mandli matched ODOT's severity. Pathway rated the severity as high – a miscall that could have been avoided by additional training. Additionally, two vendors rated the bleeding as "extensive" (greater than 30 percent of the area), whereas only about 25 percent of the single-lane surface area was affected (noted as "frequent" extent). One vendor mistook surface seal as bleeding on site 23. A second vendor noted bleeding on site 32 where horseshoes had rutted the right wheelpath and exposed underlying AC. Both situations could be resolved by further instruction. As a result of these variances, however, two vendors over-reported bleeding, as shown in Figure 36. Vendors are not expected to match ODOT DSE rating above the 75 percent level.

Patching: Fugro and Mandli identified patches on all sites noted by ODOT, as shown in Figure 33 and Figure 34. These vendors matched ODOT severity levels more than 50 percent of the time but were only able to match 11 percent of combined severity and extent ratings. This shortfall may be related to differences in vendor patch counts. Fugro noted 943 patches in AC/PCC pavements, while Mandli identified 352. Since extent ratings are based on patch frequency, these variances may have led to the higher deduct values shown in Figure 36. Pathway fell short in identifying patches, noting only 60 for all AC/PCC sites. This led to the moderate distress presence match rate (58 percent) shown in Figure 35. Their severity and DSE correlations remained low (21 percent) as well. Pathway reported initially setting the electronic limits too high for patch identification. After a "relatively simple adjustment," reanalysis using their automated software identified nearly all spray patches. Additionally, when Pathway noted what they normally identify as block cracking on several AC/PCC sites, they followed ODOT protocol by not identifying it as block cracking. However, they did not reincorporate the cracking or associated patching into the distress data, consequently underreporting patching levels. Finally, vendors were unaware that ODOT only rates patches greater than 36 inches^2 (232 cm^2) and combines patches along transverse or longitudinal joints that are within a slab. Incorporation of these ODOT processes is expected to raise the vendor correlation with ODOT patch ratings to more than 75 percent.

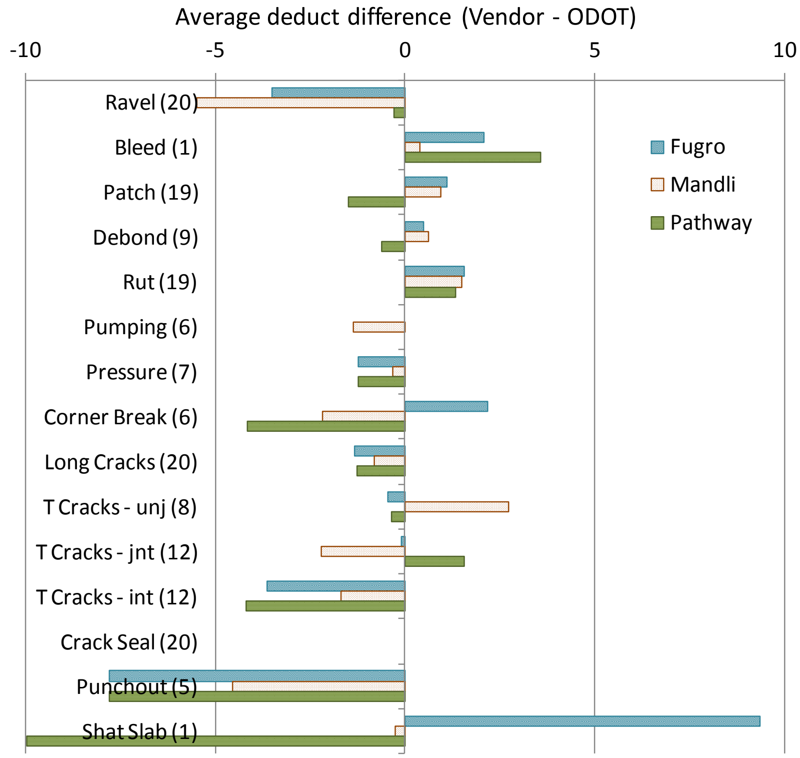


Figure 36. Vendor and ODOT deduct value differences for DSE on AC/PCC pavements.

Debonding: While Mandli showed the greatest success (78 percent), most vendors evidenced only low to moderately ability (11 and 44 percent) to identify and match ODOT ratings for disintegration/debonding in AC/PCC pavements. Moreover, vendors reported debonding in six sections not designated by ODOT. Further review of these sites indicates that some vendors incorrectly rated debonding when it should have been identified as severe transverse and longitudinal crack damage. Clarification for vendors regarding the difference between spalls and debonding, detailed descriptors of how many debonded areas must be present (2 to 3 per mile) [1.2 to 1.9 per km] to record debonding, and a second field optimization is expected to increase several vendors' ability to match ODOT ratings to between 50 and 75 percent.

Rutting: As with AC pavements, vendors rated presence, severity, and extent of rutting very consistently, producing the same amount of vendor rating variation as occurred between ODOT raters. Because the average vendor-reported rutting level of the AC/PCC sites was (0.19 inch [4.8 mm]), and the site standard deviations between vendors averaged 0.03 inch [7.6 mm], there is good indication that vendors' rutting results are repeatable and precise. Although automated system rutting values may not match ODOT ratings at high levels, they appear to offer a higher level of representation and accuracy.

Pumping: No vendors were able to identify the six sites exhibiting pumping, although Pathway searched for it automatically (within the lane stripes) and other vendors looked for it manually. Subsequent review of vendor forward and downward images by ODOT raters confirmed the presence of pumping on sites 1, 6, 40, and 42. This success indicates the possibility of manually identifying pumping from digital images. However, pumping, noted by ODOT raters in field surveys, was not visually evident on images from sites 11 and 18. Therefore, while the possibility of identifying pumping manually from images is realistically achieved through training and detailed review, vendor reporting of pumping in more than 50 percent of sites in which ODOT raters identify pumping is not likely.

Pressure Damage: Pressure damage, noted by ODOT raters at seven sites, was not identified by vendors, although Mandli reported pressure damage at four sites not confirmed by ODOT. Subsequent discussions revealed that the lack of vendor familiarity with this distress resulted in their not using automated means to search for it. ODOT raters, viewing vendor forward and downward images, identified pressure damage (evidenced by bumps at distressed transverse reflection cracks) at sites 21, 34, and 36. After clarification, two vendors indicated that, with additional focus, pressure damage can reasonably be identified using surface profiles and forward camera images. This approach is not expected to provide more than a 50 percent match with ODOT raters.

Corner Breaks: Similarly, Mandli and Pathway were unable to identify corner breaks in their initial evaluation. While Fugro noted ODOT-reported corner breaks at more than 60 percent of sites, they inaccurately reported corner breaks at six additional sites. One reason for vendor difficulty was ODOT's practice of rating depressed and damaged areas as corner breaks, although they do not necessarily exhibit typical corner break patterns. Additionally, instead of automatically searching for corner breaks larger than 18 inches (46 mm), Pathway sought only corner breaks less than 18 inches (46 cm) wide. Another rating intricacy about which vendors were unaware led to discrepancies. That is, ODOT records only corner breaks which are depressed over at least a 2-ft^2 (0.2-m^2) area. Additionally, vendors were unaware of ODOT's unwritten practice of overlooking damage near storm drains and manholes, which may have resulted in different ratings. During subsequent review, ODOT raters successfully identified corner breaks using forward and downward vendor images from sites 1, 9, 18, 40, and 42. This indicates the possibility of improved vendor identification. However, the difficulties associated with identifying corner breaks on AC/PCC pavements indicate that vendors will not match ODOT ratings with more than a 50 percent success rate.

Longitudinal Cracks: As with AC pavements, vendors proved capable of identifying nearly all sites containing longitudinal cracks, but they displayed limited ability to match ODOT's severity (57 percent) and extent (10 percent) ratings. Vendor variability in average longitudinal cracking reported at each test site (Fugro: 1,720 ft [524 m]; Mandli: 2,070 ft [631 m]; Pathway: 1,050 ft [320 m]) led to the realization that Pathway did not include centerline joint cracks in their evaluations. As Figure 36 reveals, all vendors underreported severity and extent levels. Additional vendor training and supplemental field optimization is expected to increase the DSE correlations of several vendors to greater than 75 percent.

Transverse Cracks: Vendors proved capable of identifying all sections where ODOT noted transverse cracks in jointed and unjointed pavements. This only became possible after the underlying pavement type designated by ODOT for each site was provided to the vendors, as vendors encountered numerous difficulties in determining underlying pavement type from surface distresses. Typically, vendors were able to match ODOT severity levels more than 50 percent of the time. However, they could only match ODOT DSE for unjointed and jointed reflection cracks at 38 and 6 percent, respectively. Vendors reported difficulty differentiating joint reflection cracking from intermediate crack reflection cracking. Additionally, Pathway, due to time constraints, lumped all transverse jointed pavement cracking into joint reflection cracking, resulting in the over-reporting shown in Figure 36. They also did not report transverse cracking when they noted block cracking (e.g., site 21). Vendors show consistent ability to identify the presence and width of transverse cracks. As a result, if vendors are notified that underlying layers are unjointed, several vendors can be expected to match at least 75 percent of ODOT ratings for transverse cracks in unjointed pavements. However, vendor correlation with ODOT DSE ratings is not expected to exceed 50 percent for joint reflection cracking, even if the underlying layer properties are provided. This results from the vendors' difficulty differentiating between transverse joint reflection and intermediate transverse cracks.

Intermediate Transverse Cracks: Mandli was able to identify intermediate transverse cracks at all twelve sites noted by ODOT. Fugro and Pathway identified about 50 and 25 percent, respectively, with average overall match rates below 5 percent. Contributing to this variability and severe shortcoming was the difficulty vendors reported differentiating between cracks which reflect transverse joints and those reflecting intermediate cracks. To improve this correlation, some vendors requested estimated underlying slab length for each site, which, of course would improve correlation values. Only moderate improvement in this rating is expected without detailed slab length information. As a result, correlation of this distress, severity, and extent with ODOT ratings is not anticipated to exceed 50 percent.

Crack Seal: Fugro and Mandli were unable to identify crack seal deficiency for more than 80 percent of the sites. As noted above, Mandli elected only to note when the deficiency was present. Alternately, Pathway identified the distress and severity of seals on all sites, matching ODOT DSE ratings for 30 percent of sections. Further, although the Pathway automated method of seal detection appears relatively successful, the report that Pathway and Fugro did not rate unsealed cracks that were wider than 0.125 inch (3 mm) indicates that correlations of greater than 75 percent with ODOT ratings are possible, after further vendor training and field optimization.

Punchouts: Every participating vendor encountered difficulty recognizing punchouts. Mandli reported only one of the five sites containing ODOT-recognized punchouts, while the remaining vendors did not recognize any punchouts. These low correlations resulted from vendors' limited understanding of the range of pavement surface distortions that ODOT includes in the punchout designation. During their evaluations, vendors assumed that punchouts followed the rectangular pattern typical of continuously reinforced concrete pavements. Instead, ODOT identifies punchouts in localized areas that are cracked and sunken. If vendors become more familiar with the expanded ODOT criteria, correlations with ODOT are expected to moderately improve. However, because of the above limitations, and ODOT's practice of recording patched punchout areas as both patches and punchouts, vendors are not expected to match more than 50 percent of ODOT punchout ratings.

Shattered Slabs: While Mandli and Pathway did not report shattered slabs, Fugro correctly identified the DSE of the only ODOT-identified shattered slabs (site 18). However, Fugro also recorded shattered slabs at two other sites. This limited success is due in part to an unclear understanding of ODOT's ratings. ODOT rates shattered slabs on jointed pavements that display significant depressions, uncomfortable ride, and inadequate base properties. Therefore, although the distresses at site 18 do not represent typical shattered PCC cracking, their roughness and severe alligator cracking resulted in an ODOT shattered slab rating. Although vendor training and field optimization is expected to slightly increase correlation, vendors are not expected to exceed a 50 percent match with ODOT shattered slab ratings.

Based on the above review, it appears that acceptable levels of correlation with ODOT ratings can be achieved for patching, rutting, longitudinal cracking, and crack seal deficiency. An adjusted approach will be necessary to assess raveling, debonding, pumping, pressure damage, corner breaks, joint reflecting transverse cracking, intermediate transverse cracking, punchouts, and shattered slabs. Maximizing these correlations will require additional vendor training and advanced field optimization efforts. Research team estimates of anticipated correlation levels are shown in Table 11, although final correlation levels cannot be defined until final optimization. This table also provides the initial project evaluation correlation ratings. Note that, instead of providing the intense level of manual evaluation effort they expended in the current project, Mandli intends to primarily use automated methods for state-wide evaluation. Therefore, they suggest that a monitoring system evaluating only AASHTO LCMS distresses (rutting, longitudinal cracks, transverse cracks, and fatigue cracks) be implemented.

6.1.2 PCC Pavements

Vendors were able to identify the presence of a large percentages of the PCC distresses noted by ODOT raters (Fugro: 74 percent, Mandli: 64 percent, and Pathway: 69 percent). Primarily, they encountered difficulties matching ODOT surface deterioration, pumping, and pressure damage. Severity matches with ODOT ranged from 40 percent (Mandli) to 33 percent (Pathway), with perfect matches of DSE occurring about 16 percent of the time. Figures 37 through 39 and Table 12 detail these matches and are discussed below.

Table 11. Estimated probability for matching ODOT ratings on AC/PCC pavements.

Distress	Fugro		Mandli		Pathway	
	Initial	Estimated	Initial	Estimated	Initial	Estimated
Raveling	(M, L, P)	(M, L, L)	(L, P, P)	(M, L, L)	(H, M, L)	(H, M, M)
Bleeding	(H, H, H)	(M, M, M)	(H, H, P)	(L, L, L)	(H, P, P)	(M, M, M)
Patching	(H, M, L)	(H, H, H)	(H, M, L)	(L, L, L)	(M, L, L)	(H, H, H)
Disintegration, debonding	(L, P, P)	H, M, M)	(H, L, L)	(L, L, L)	(L, L, P)	(H. M. M)
Rutting	(H, L, P)	(H, H, H)	(H, L, L)	(H, H, H)	(H, L, P)	(H, H, H)
Pumping	(P, -, P)	(L, -, L)	(P, -, P)	(P, -, P)	(P, -, P)	(L, -, L)
Pressure damage	(P, P, P)	(L, L, L)	(P, P, P)	(P, P, P)	(P, P, P)	(L, L, L)
Corner breaks	(M, L, P)	(L, L, L)	(P, P, P)	(P, P, P)	(P, P, P)	(L, L, L)
Longitudinal cracking	(H, L, L)	(H, H, H	(H, M, P)	(H, M, M)	(H, M, L)	(H, H, H)
Tvs. Cracking – unjointed	(H, M, M)	(H, H, H)	(H, M, L)	(H, L, L)	(H, L, L)	(H, H, H)
Tvs. Cracking – joint reflection	(H, M, P)	(H, H, M)	(H, M, L)	(P, P, P)	(H, M, L)	(H, H, M)
Tvs. Cracking – intermediate	(M, L, P)	(H, H, M)	(H, L, P)	(P, P, P)	(L, L, P)	(H, H, M)
Crack sealing deficiency	(L, -, P)	(H, -, M)	(L, -, L)	(L, -, L)	(H, -, L)	(H, -, H)
Punchouts – unjointed base	(P, P, P)	(M, L, L)	(L, L, P)	(P, P, P)	(P, P, P)	(M, L, L)
Shattered slab	(H, H, H)	(M, L, L)	(P, P, P)	(P, P, P)	(P, P, P)	(M, L, L)

Probability of accurate rating: H (high, 75-100%), M (moderate, 50-74%), L (low, 10-49%), P (poor, <10%).
(Distress match, Distress/Severity match, Distress/Severity/Extent match), e.g., (H, H, M).

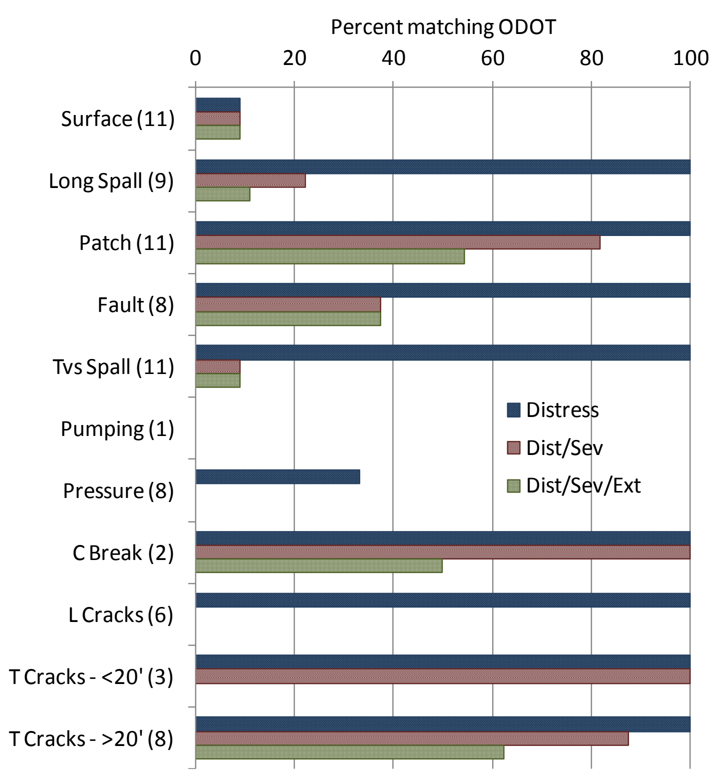


Figure 37. Fugro DSE rating match with ODOT for PCC pavements.

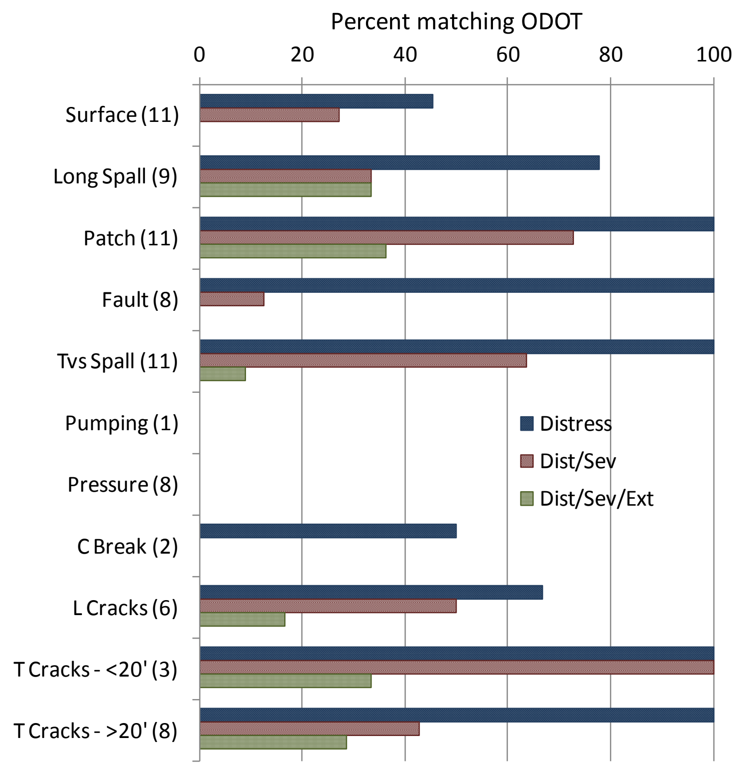


Figure 38. Mandli DSE rating match with ODOT for PCC pavements.

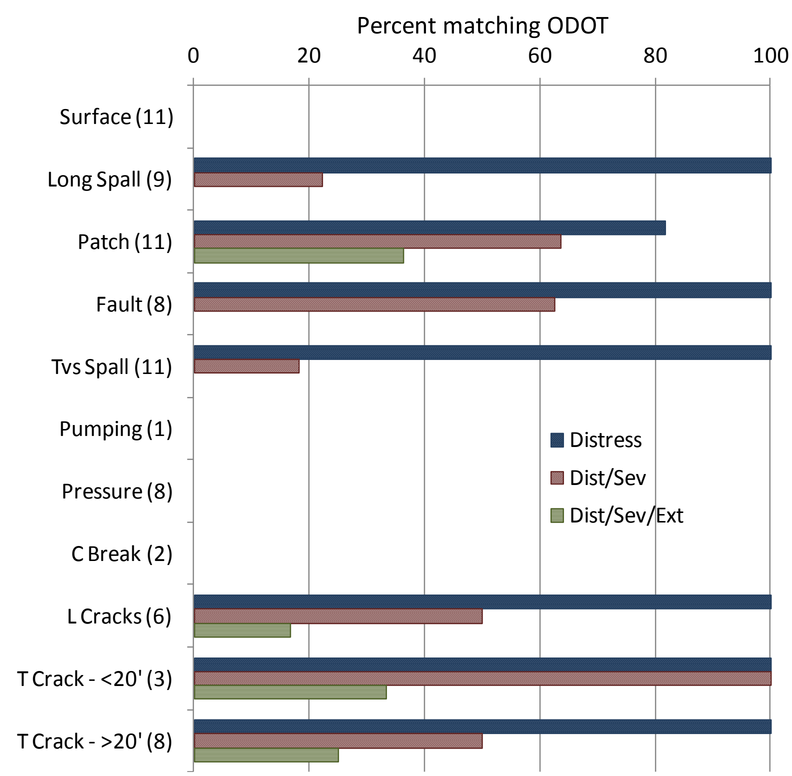


Figure 39. Pathway DSE rating match with ODOT for PCC pavements.

Table 12. Summary of vendor match with ODOT DSE ratings for PCC pavements.

Distress	Sites	Distress/severity match, % Fugro	Mandli	Pathway	Avg.	DSE match, % Fugro	Mandli	Pathway	Avg.
Surface	11	9	27	0	**12.0**	9	0	0	**3.0**
Longit. spall	9	22	33	22	25.7	11	33	0	14.7
Patch	11	82	73	64	73.0	55	36	36	42.3
Fault	8	38	13	63	38.0	38	0	0	12.7
Transverse spall	11	9	64	18	30.3	9	9	0	6.0
Pumping	1	0	0	0	0.0	0	0	0	0.0
Pressure	8	0	0	0	0.0	0	0	0	0.0
Corner break	2	100	0	0	33.3	50	0	0	16.7
Longit. cracks	6	0	50	50	33.3	0	17	17	11.3
Tvs. cracks <20'	3	100	100	100	100	0	33	33	22.0
Tvs. cracks >20'	8	88	43	50	60.3	63	29	25	39.0
Weighted Avg:		**35.9**	**39.7**	**33.3**	**36.3**	**23.1**	**15.4**	**10.3**	**16.3**

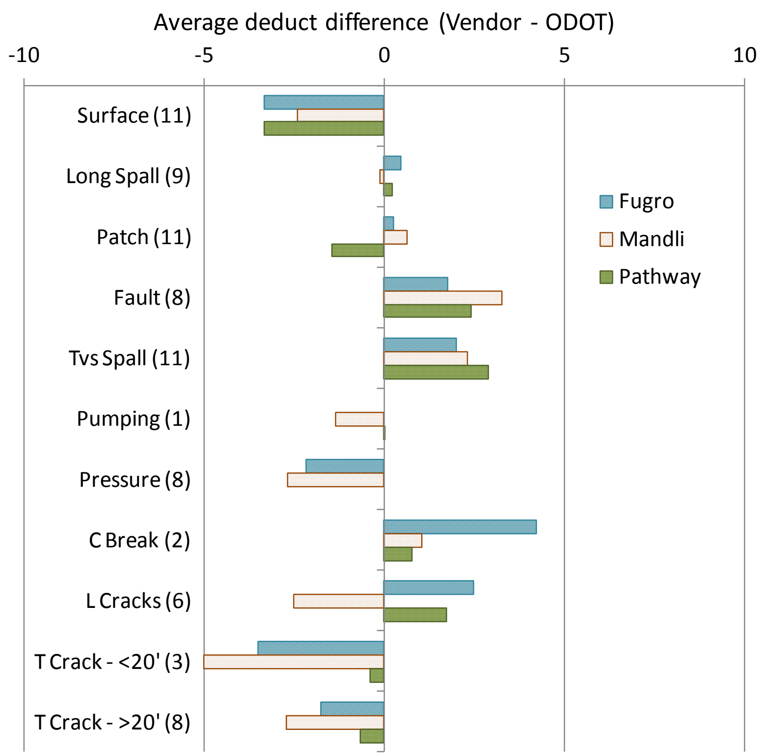


Figure 40. Vendor and ODOT deduct value differences for distresses on PCC pavements.

Surface Deterioration: While Pathway did not evaluate surface deterioration due to time constraints, Mandli reported 45 percent of the ODOT deterioration, and Fugro only noted 9 percent. Severity and extent matches followed a similar pattern, resulting in the under-reported deduct values shown in Figure 40. Vendors reported that surface deterioration is difficult to detect automatically or manually. In particular, surface abrasion—the primary contributor—cannot be accurately identified at this time. However, macrotexture ratings may be calibrated to match ODOT ratings in the medium and high-severity categories. Review of forward images may be necessary to further refine the ratings. As a result, vendor training and field optimization is not expected to increase vendor correlation with ODOT DSE ratings to more than 50 percent.

Longitudinal Joint Spalls: Longitudinal joint spalling was recognized by vendors in most cases; however, the reported average length of spalling per site varied (Fugro: 333 ft [101 m]; Mandli: 132 ft [40 m]; Pathway: 578 ft [176 m]). Fugro and Mandli analyzed spalling manually, while Pathway identified spalls automatically. Differences in total spall length may have resulted from associating corner spalls with different joints. While ODOT raters indicated that spalls connecting to transverse and longitudinal joints should be counted with the longitudinal joint spalling, it appears that Pathway recorded these spalls with transverse joints. As a result, ODOT longitudinal spall ratings exceeded Pathway ratings, and Pathway transverse spall ratings exceeded ODOT ratings. All told, these differences produced little effect on the overall deduct value assigned to the PCC test sites for longitudinal joint spalling. Recently, Pathway demonstrated their ability to automatically reprocess pavement images linking corner spalls to longitudinal joints, which is expected to improve their correlation. Following vendor DSE evaluations, it was learned that patched longitudinal joint spalls should be rated as both spalls and patches. While vendors did not attempt this approach for the current project, they all anticipate difficulty with this combined rating, particularly when spalls are repaired with spray patches. As a result, vendor correlations of longitudinal joint spalls with ODOT DSE ratings are not expected to exceed 75 percent.

Patches: Vendors reported the presence of sites with asphalt patch distresses more accurately on PCC pavements than on AC surfaces, averaging 94 percent success. This significant match is corroborated by the small difference in the overall number of vendor-reported patches (Pathway 354; Fugro 368; Mandli 316). However, the average distress/severity match fell to 64 percent and the average DSE match reduced to 42 percent. Portions of this variability can be attributed to Pathway noting only PCC patches on concrete sites. In subsequent review, Pathway demonstrated their ability to automatically identify these patches. Additionally, while ODOT raters combined spalls along longitudinal slab joints and along transverse joints, Fugro, Mandli, and Pathway did not. Lastly, all vendors reported patches less than 36 inches^2 [0.02 m^2], whereas ODOT raters ignore these distresses. Vendor training, field optimization, and revisions in automated or manual distress identification processes to incorporate these items are expected to increase vendor patch correlations to more than 75 percent.

Faulting: Although faulting was noted by all vendors on all faulted sites, low correlations (38 percent average) were obtained for severity. This indicates that further confirmation will be necessary to ensure both faulting accuracy and correlation with ODOT ratings. Conventional thought assumes that automated fault measurement systems will provide better precision and accuracy than visual estimates. However, the average joint faulting measurements from all sites varied significantly between vendors (Fugro: 0.31 inch [7.9 mm]; Mandli: 0.20 inch [5.1 mm]; Pathway: 0.06 inch [1.5 mm]). Additionally, the average counts of joints/cracks per site exhibiting faulting varied noticeably (Fugro: 69; Mandli: 126; Pathway: 90). Further evaluation of both the vendor fault measuring methods and their correlations with ODOT ratings will be necessary to improve accuracy and correlation levels. Following vendor evaluation and field optimization, faulting accuracy and precision is expected to reach high levels; however, it is unclear how closely these results will match manual ratings obtained by ODOT raters.

Transverse Joint/Crack Spalls: Vendors reported the presence of transverse joint and crack spalls at all ODOT-designated sites. However, only low- to moderate-severity correlations were achieved, and the vendors perfectly matched ODOT's ratings at very few sites. As previously mentioned, much of the variation may have occurred because vendors included spalls intersecting longitudinal and transverse joints/cracks with the transverse joints/cracks. As a result, vendor extent and severity ratings commonly exceeded those of ODOT, resulting in an average deduct increase of more than two points. If vendors adjust for this approach, and complete field optimization, their ratings are expected to match more than 75 percent of ODOT DSE ratings.

Pumping: As with AC/PCC pavements, vendors were not able to identify areas of pumping. However, ODOT confirmed its presence on images from site 5. Vendors indicated that manual and automated identification of pumping visually from forward and downward images is feasible, given time and effort; however, it is not anticipated that a high level of correlation can be achieved at this time.

Pressure Damage: Fugro reported the presence of pressure damage spalls on three of the eight sites (5, 22, 25) noted by ODOT raters. Many of these distresses were simply patched spalls. Neither Mandli nor Pathway evaluated or reported this distress, due to time constraints and their limited understanding. However, ODOT has identified several examples at project sites, and Pathway reports confidence that the presence of this distress can be visually and possibly automatically identified. Following vendor training and final field optimization, vendors are expected to achieve less than 50 percent correlation with ODOT DSE ratings, in part because of the difficulty associated with identifying and reporting pressure damage spalls after they have been patched.

Corner Breaks: Although Fugro identified corner breaks at the two sites noted by ODOT, they also recorded corner breaks on six additional sites. Pathway reported five additional sites with corner breaks, and Mandli recorded two additional sites. Corner breaks identified by the vendors typically looked like larger corner spalls. However, ODOT raters do not call corner breaks unless they are greater than 18 inches (0.46 m) from the corner, instead noting the distress as a crack or spall. Vendors experience difficulty automatically isolating corner breaks from longitudinal and transverse slab cracking. If manual or semi-automated methods are employed, vendors are expected to increase their correlation to more than 75 percent of ODOT DSE rater levels.

Longitudinal Cracks: Vendors matched presence, severity, and extent of longitudinal cracks in PCC pavements with 0 to 17 percent effectiveness. Several factors contributed to this low rating. One vendor marked as cracking a longitudinal joint that fell in the left wheelpath of site 14. Longitudinal edges of partial-width patches were also mistakenly counted in some cases. Other vendors noted one or two small longitudinal cracks for a site (e.g., site 17), where ODOT would not have counted such a small number. Additionally, vendors reported longitudinal cracks around the perimeter of manholes and drain inlets, which ODOT raters typically do not include. As a result, vendors varied on the average number of slabs at all sites containing longitudinal cracking (Fugro: 10.5; Pathway: 13.0; Mandli 3.3). Mandli's limited ability to note longitudinal cracking led to a more than two-point increase in average PCR values, as shown in Figure 40. Technology for identifying longitudinal cracking appears well advanced, and with proper training and final optimization, vendors can be expected to provide accurate DSE summaries.

Transverse Cracks: As Figures 37 through 39 indicate, vendors correctly matched the presence of sites with transverse cracking distress for short- and long-jointed slabs. Additionally, their severity valued did not differ greatly from ODOT's (80 percent average). Their success is confirmed by the observation that although vendors varied in their slab joint identification methods (Fugro and Mandli manually, Pathway automatically), the average number of recorded short slab joints was consistent (Fugro: 145; Mandli: 153; Pathway: 152). Long-jointed slab counts varied more notably (Fugro: 172; Mandli: 195; Pathway: 136). However, vendors matched only 31 percent of ODOT's DSE ratings. Moreover, Fugro and Mandli underestimated the deduct values for transverse cracking by an average of two to five points (see Figure 40). The above-noted differences can be attributed, in part, to the need for supplemental training and calibration. Review of the transverse crack images indicates that, on occasion, vendors automatically rated tining and transverse joints as transverse cracking (site 2). On site 13, Mandli appears to have underrated the severity of transverse cracks. It is noted that automated measurement of transverse joints and cracks is a fairly advanced technology for all vendors. With additional training and final field optimization, it is expected that vendors will achieve correlations with ODOT raters of more than 75 percent.

The above review indicates that acceptable correlations with ODOT ratings can be achieved for longitudinal joint spalls, patching, faulting, transverse joint spalling, corner breaks, longitudinal and transverse cracking. These levels are anticipated following additional vendor training and field calibration to optimize vendor ratings. An alternate method of defining or reporting surface deterioration, pumping, pressure damage, and settlement will be necessary to account for these distress types. Table 13 presents a summary of the initial project results and estimated optimized results for each vendor. Note that Mandli does not anticipate providing detailed manual review, instead offering to report only AASHTO LCMS distresses (faulting, corner breaks, longitudinal and transverse cracks).

Table 13. Estimated probability for matching ODOT ratings on PCC pavements.

Distress	Fugro Initial	Fugro Estimated	Mandli Initial	Mandli Estimated	Pathway Initial	Pathway Estimated
Surface deterioration	(L, L, L)	(L, L, L)	(L, L, P)	(L, L, L)	Not rated	(L, L, L)
Longitudinal joint spalling	(H, L, L)	(H, H, H)	(H, L, L)	(H, M, M)	(H, L, P)	(H, H, H)
Patching	(H, H, M)	(H, H, H)	(H, H, L)	(M, M, M)	(H, M, L)	(H, H, H)
Faulting	(H, L, L)	(H, M, M)	(H, L, P)	(H, M, M)	(H, M, P)	(H, M, M)
Transverse joint spalling	(H, L, L)	(H, H, H)	(H, M, L)	(H, H, H)	(H, L, P)	(H, H, H)
Pumping	(P, -, P)	(L, -, L)	(P, -, P)	(L, -, L)	Not rated	(L, -, L)
Pressure damage – spalls	(L, P, P)	(H, H, M)	Not rated	(L, L, L)	Not rated	(H, H, M)
Corner breaks	(H, H, M)	(H, H, H)	(M, P, P)	(L, L, L)	(P, P, P)	(H, H, H)
Longitudinal cracking	(H, P, P)	(H, H, H)	(M, M, L)	(H, H, H)	(H, M, L)	(H, H, H)
Tvs. Cracking - < 20 ft slabs	(H, H, P)	(H, H, H)	(H, H, L)	(H, H, H)	(H, H, L)	(H, H, H)
Tvs. Cracking - > 20 ft slabs	(H, H, M)	(H, H, H)	(H, L, L)	(H, H, H)	(H, M, L)	(H, H, H)
Settlement	Not rated	(L, L, L)	Not rated	(L, L, L)	Not rated	(L, L, L)

Probability of accurate rating: H (high, 75-100%), M (moderate, 50-74%), L (low, 10-49%), P (poor, <10%).
(Distress match, Distress/Severity match, Distress/Severity/Extent match), e.g., (H, H, M).

6.2 PCR ANALYSIS RESULTS

Rating differences evidenced themselves in the resultant vendor and ODOT PCR values. Although analysis of PCR data is informative, it should not be seen as the definitive results of this research. Slight improvements in the DSE rating correlations, for which approaches are described above, can result in significantly improved PCR correlations between ODOT and vendor results. Following is a description of the variability of ODOT and vendor PCR values, along with visual and statistical comparison between the two sources.

6.2.1 ODOT Rater PCR Variability

ODOT's methodology of consulting the previous year's pavement DSEs during site evaluation tends to reduce DSE rating variability between and among raters. This proved true in the current evaluation, where the difference in PCR between the individual and mean of all raters and repetitions averaged 1.1, and the standard deviation of four repeated measurements (two raters) averaged 1.4. Since ODOT PCR values for the sites ranged from 41 to 87, averaging 67, this correlates to a standard deviation of approximately 2 percent, indicating excellent repeatability.

Visual comparison of the ODOT PCR ratings for all pavement types, shown in Figure 41, further reveals the very limited variability of the project PCR ratings from the mean level shown by the blue line. Minor trends can be noted in Figure 42 (AC), Figure 43 (AC/PCC), and Figure 44 (PCC), which indicate that PCR variability increased for AC/PCC and PCC pavements when compared with AC pavements. As Table 14 shows, individual and combined rater standard deviations for AC/PCC sites nearly doubled those of AC sites, and PCC standard deviations topped those of AC sites by about 1.5 times. Additionally, higher standard deviations were noted on AC/PCC pavements when the PCR level fell below 70, evidencing the difficulty inherent in identifying many of ODOT’s AC/PCC DSEs. Other pavement types showed no such trend.

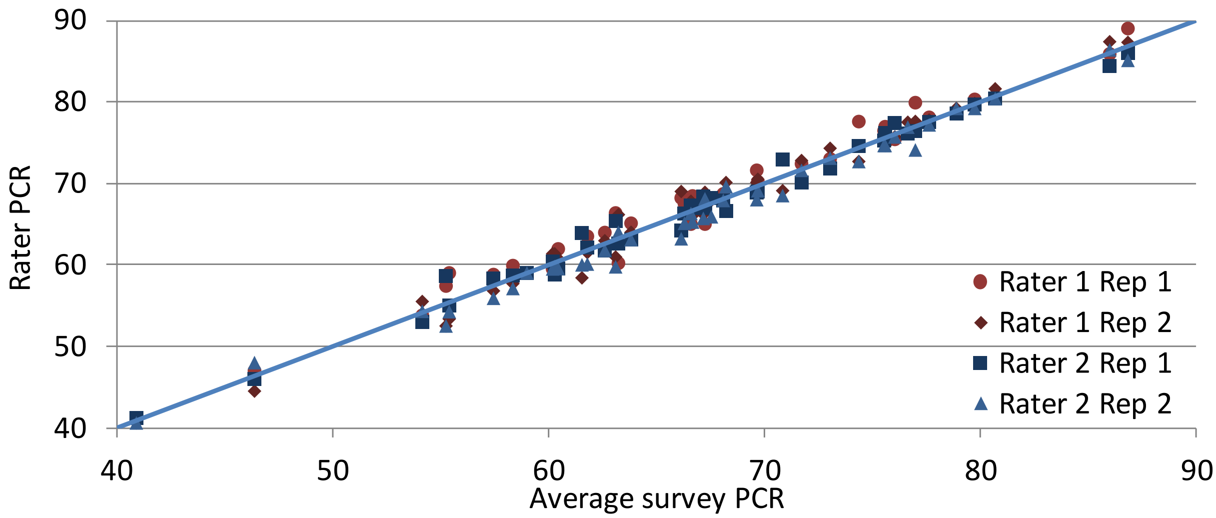


Figure 41. ODOT survey PCR ratings for all sites.

While closed markers in these figures represent PCR values determined during project data collection, PCR values for the same sections evaluated in 2011 and early 2012 are shown by the open markers. Only ratings for sections that exactly match the location of those segments included in the study are shown in these figures. The increased variability may stem, in part, from unreported maintenance activities. Additional variation may have resulted from evaluation of both lanes for the 2011 and 2012 surveys, and a single lane for the project surveys.

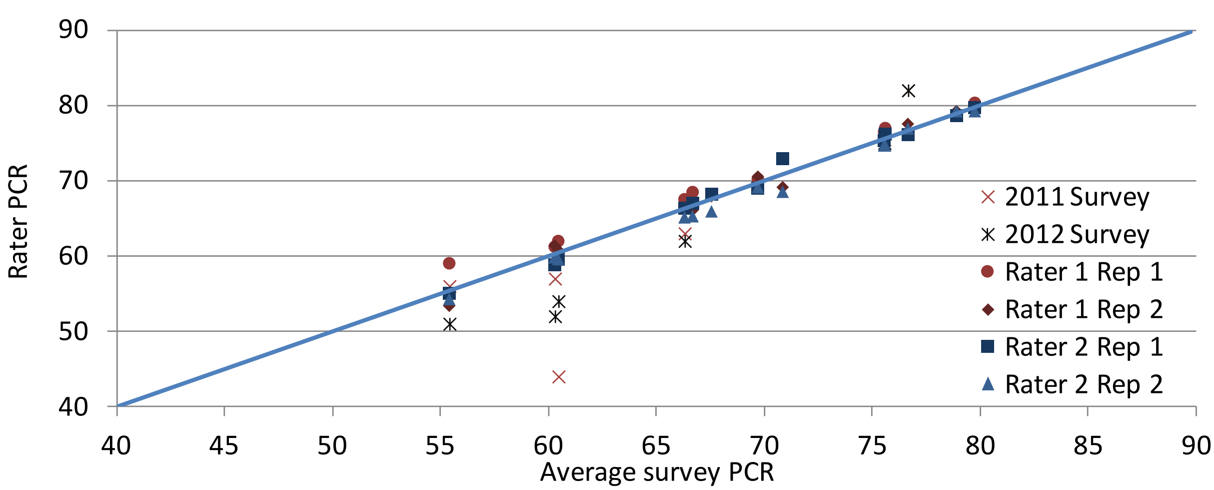


Figure 42. ODOT AC survey PCR ratings.

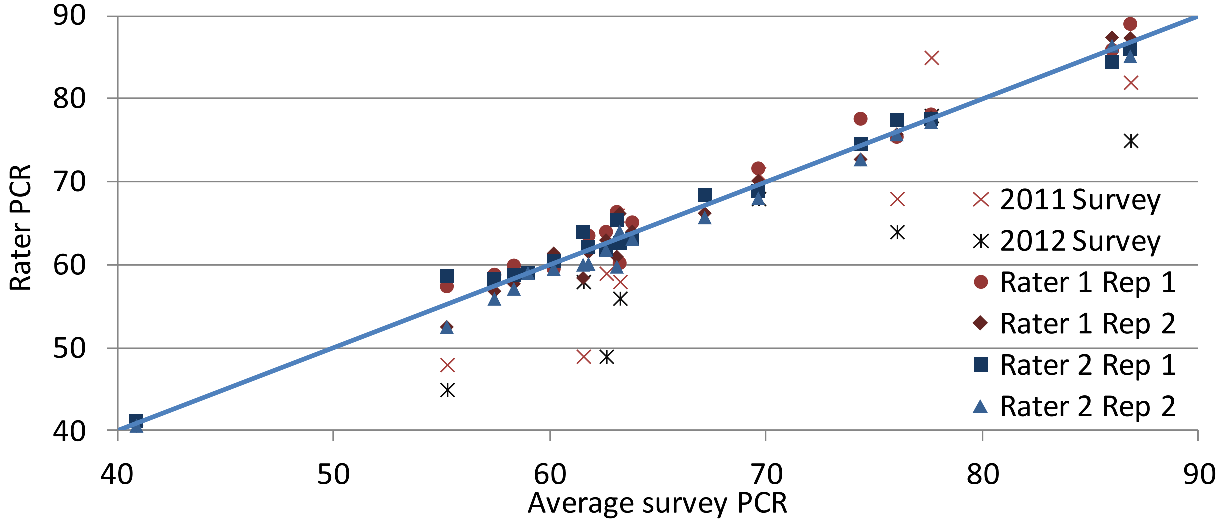


Figure 43. ODOT AC/PCC survey PCR ratings.

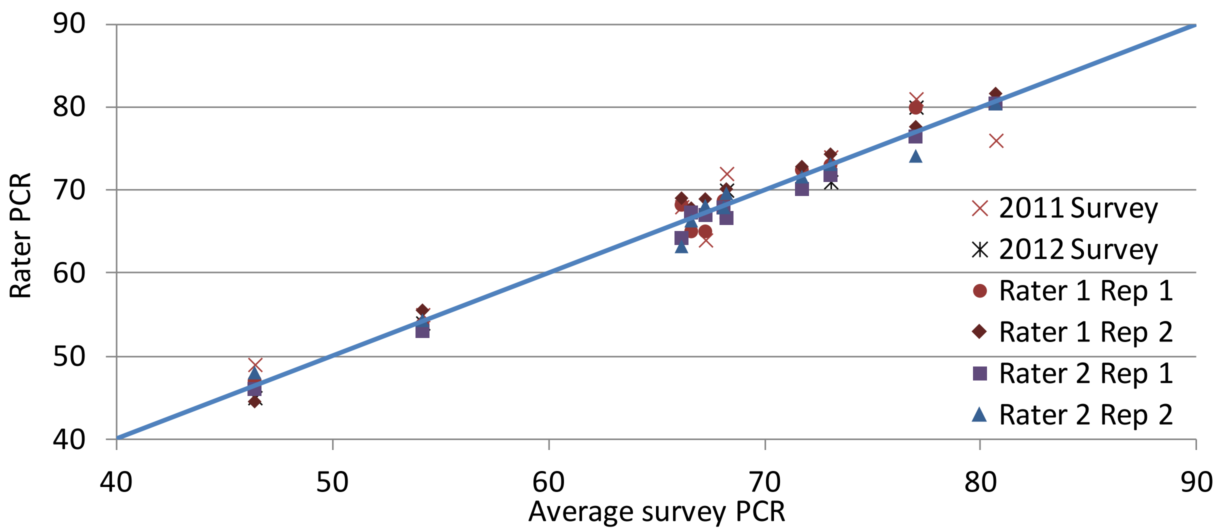


Figure 44. ODOT PCC survey PCR ratings.

Variability between ODOT raters remained very low, below 2.0, as the standard deviations in Table 14 reveal. When the trend for individual ODOT rater PCR values is compared with the average of the raters, r^2 significance ranged from 0.96 to 0.99. PCRs for 2011 and 2012 evaluations, when compared with the average project survey rater PCRs, correlate less well, with r^2 values at or below 0.8. Statistical analysis of variance indicates no statistical differences in PCR values between and among ODOT raters, at a 95 percent confidence limit.

Table 14. Variability of ODOT rater PCR results.

Statistic	All Sites	AC Sites	AC/PCC Sites	PCC Sites
Rater 1 (between replicates) – Std. dev.	1.5	0.8	1.8	1.5
Rater 2 (between replicates) – Std. dev.	1.2	1.1	1.6	1.1
Both raters (all replicates) – Std. dev.	1.4	1.1	1.7	1.6
Rater 1, replicate 1 (vs. average) – r^2	0.98	0.99	0.98	0.96
Rater 1, replicate 2 (vs. average) – r^2	0.98	0.99	0.99	0.99
Rater 2, replicate 1 (vs. average) – r^2	0.99	0.99	0.99	0.99
Rater 2, replicate 2 (vs. average) – r^2	0.99	0.99	0.99	0.98
2011 survey (vs. average) – r^2	0.77	0.77	0.79	0.92
2012 survey (vs. average) – r^2	0.80	0.96	0.80	0.98

6.2.2 Vendor PCR Variability

The ability of vendors to repeatedly collect DSE information leading to the same PCR values was evaluated using repeat runs on sites representing each pavement type. Vendors were asked to collect a second set of distress videos and to evaluate them independently. As Table 15 indicates, very little difference was noted between repeated vendor evaluations of all pavement types. However, the number of distresses, severities, and extents for each site that did not match averaged 1.3 (Fugro: AC 0, AC/PCC 1, PC 0; Mandli: AC 3, AC/PCC 4, PCC 1; and Pathway: AC 3, AC/PCC 0, PCC 0). Much more variability in distresses occurred in the AC and AC/PCC sites, although this did not always translate into larger PCR variability.

Table 15. Variability of vendor PCR results.

	Fugro		Mandli		Pathway	
Site	PCR1, 2	Std. dev	PCR1, 2	Std. dev	PCR1, 2	Std. dev
AC (site 20)	66.8, 66.8	0.0	63.5, 63.05	0.3	57.6, 57.3	0.2
AC/PCC (site 35)	72.3, 71.3	0.7	71.4, 78.6	5.1	71.0, 71.0	0.0
PCC (site 19)	68.2, 68.2	0.0	74.7, 76.2	1.1	77.0, 77.0	0.0

6.2.3 Vendor vs. ODOT Rater PCR Comparison

Figure 45 illustrates the ODOT and vendor PCR ratings and trends for all sites, plotted by increasing PCR. Similar trends can be noted between the vendor and ODOT PCR values; however, correlation coefficients shown in Table 16 indicate only weak interactions. A list of PCR values reported by ODOT and vendors is provided in Appendix E. Several factors contribute to these differences, which will be discussed below.

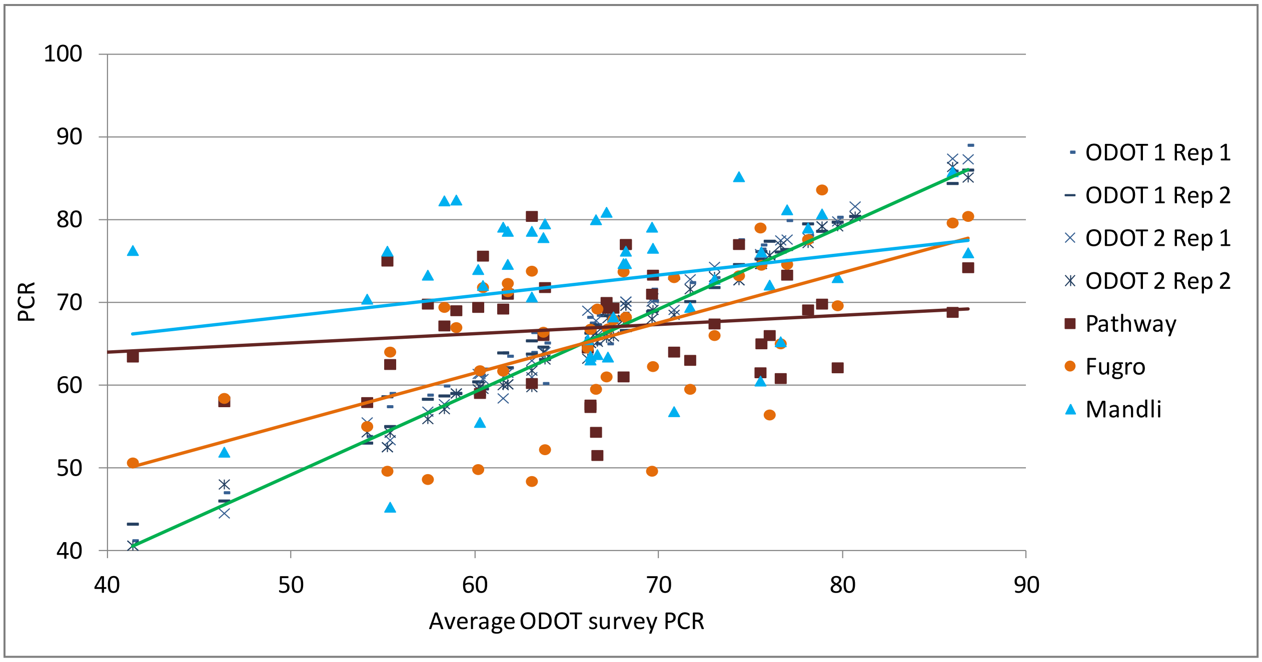


Figure 45. Comparison of vendor PCR with average ODOT PCR for all sites.

For AC pavements, shown in Figure 46, correlations between vendor and ODOT PCR values are poor, with r^2 values less than 0.4. Mandli exhibited the best correlation (see Table 16), although Fugro claimed the least average absolute difference from the ODOT rater averages. Primary causes for these differences include the current inability of vendors to identify and accurately rate raveling, debonding, potholes, thermal cracking, and crack seal deficiency. As discussed earlier, vendor accuracy in reporting several of these DSEs can be improved with additional vendor training.

Table 16. Variability of vendor PCR results.

Statistic	All Sites	AC Sites	AC/PCC Sites	PCC Sites
Between vendor avg. standard deviation	7.3	5.9	9.4	5.4
Fugro (avg. abs. difference from ODOT PCR)	6.4	4.7	8.7	4.5
Mandli (avg. abs. difference from ODOT PCR)	9.8	6.6	14.1	6.1
Pathway (avg. abs. difference from ODOT PCR)	9.0	9.7	9.7	6.7
Fugro (vs. ODOT average PCR) – r^2	0.37	0.32	0.34	0.44
Mandli (vs. ODOT average PCR) – r^2	0.07	0.39	0.07	0.52
Pathway (vs. ODOT average PCR) – r^2	0.02	0.0	0.05	0.29

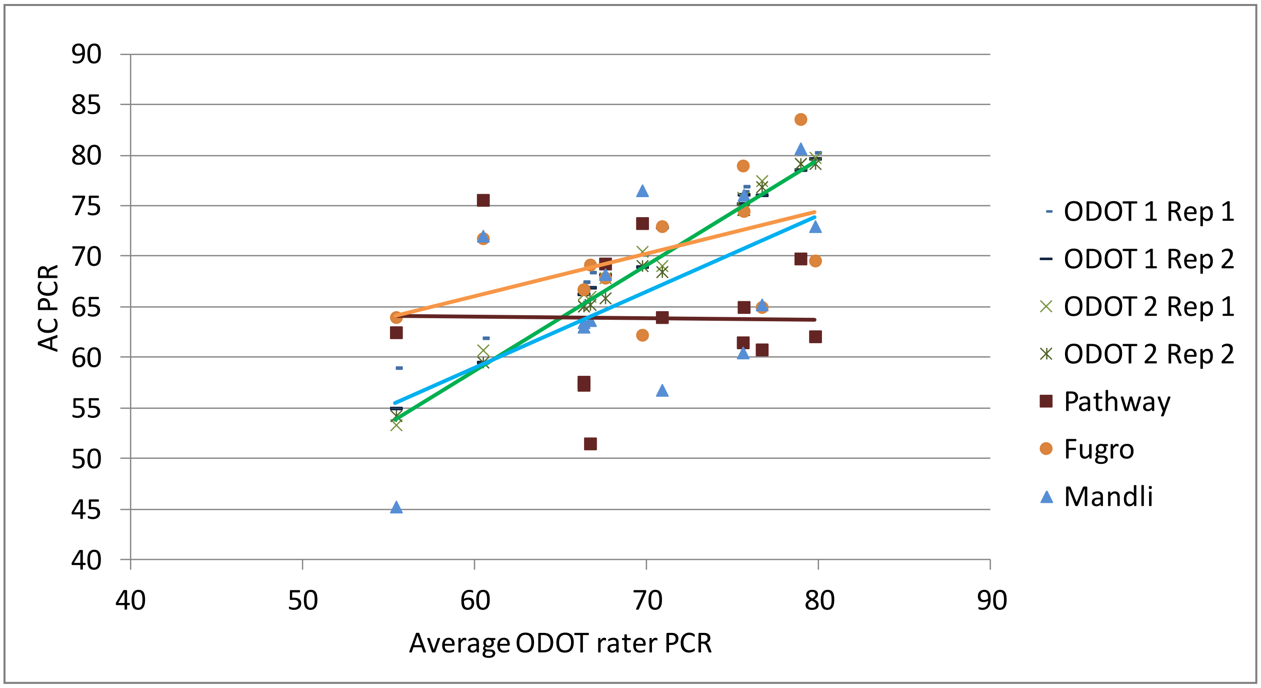


Figure 46. Comparison of vendor PCR with average ODOT PCR for AC sites.

Correlations for AC/PCC pavements, shown in Figure 47, again reveal limited ability of vendors to match PCR levels obtained by ODOT raters. With this pavement type, all vendors experienced their greatest difficulty minimizing the average absolute average difference from the ODOT PCR ratings. Causes for this variability include limitations on the vendors' current ability to identify and rate raveling, patching, debonding, pumping, pressure upheaval damage, corner breaks, intermediate transverse cracks, crack sealing deficiency, punchouts, and shattered slabs. Distresses on AC/PCC pavements will be the most challenging for vendors to accurately match ODOT ratings; however, a period of close communication between ODOT and a vendor is expected to significantly improve rating and PCR correlations. Simply accounting for the shattered slabs, debonding, corner breaks, and intermediate transverse slab cracking in site 18 will pull the correlations closer to the ODOT trend.

As Figure 48 and Table 16 indicate, the best PCR correlations were obtained in identifying DSEs on PCC pavements. This can be attributed to vendors' ability to detect most of the PCC distress types (spalling, patching, faulting, longitudinal and transverse cracking). Vendors' limited capability to detect surface deterioration or pumping, and their incomplete training in rating pressure spall damage and corner breaks, contributed to the variation from ODOT PCR values.

Although project PCR correlations between ODOT raters and vendors are imperfect, vendor training and clarification of DSE properties are expected to bring PCR levels in line as well.

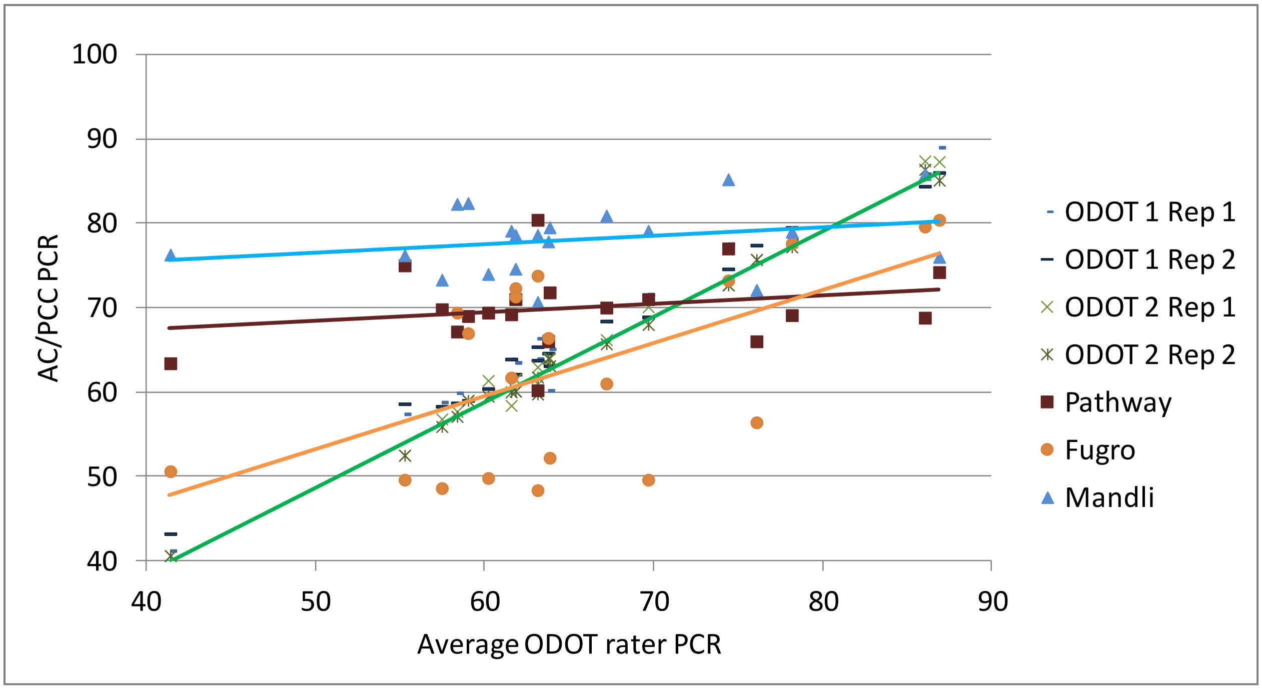


Figure 47. Comparison of vendor PCR with average ODOT PCR for AC/PCC sites.

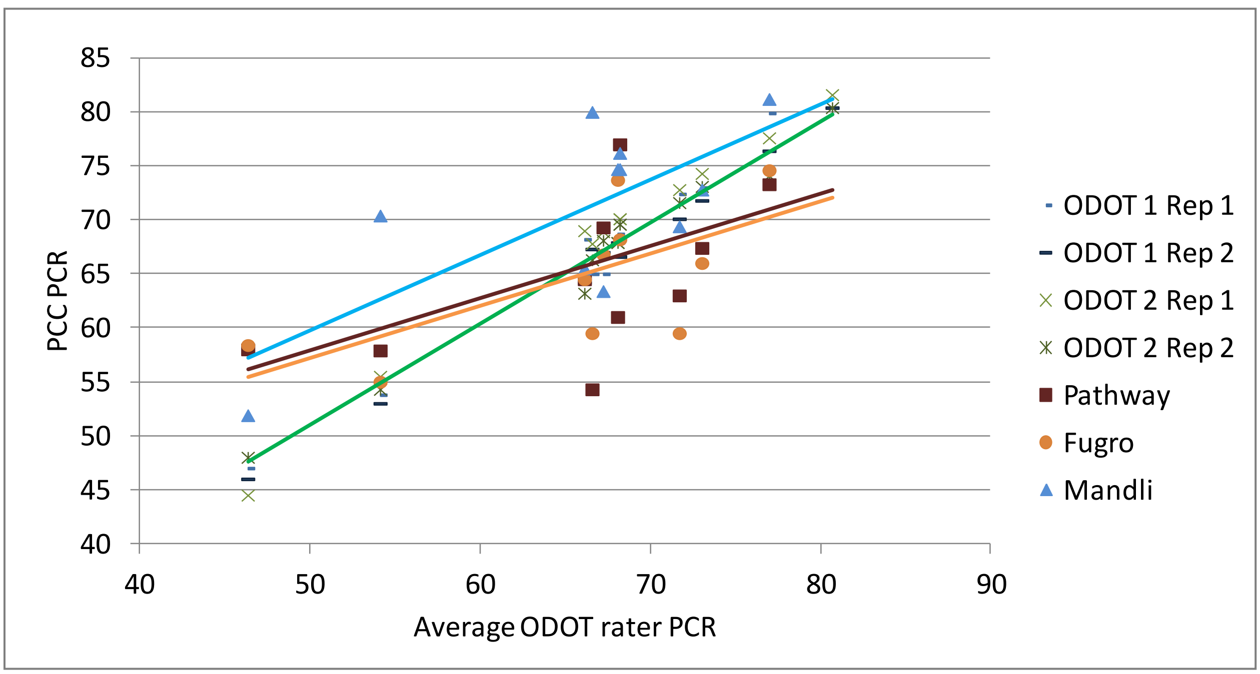


Figure 48. Comparison of vendor PCR with average ODOT PCR for PCC sites.

6.3 VENDOR ESTIMATED COSTS

Fugro, Mandli, and Pathway offer the following four options to support ODOT's pavement distress data collection. Additionally, ODOT holds a fifth option to continue with the current manual services or a sixth option to upgrade the existing technical services vehicle to include a downward camera system. Cost, time, and management effort differences are inherent in each. The sixth option has not been fully evaluated for cost.

1. ODOT purchases collection system from vendor and ODOT collects, processes, and completes QC/QA.
2. ODOT purchases collection system from vendor and collects data. Vendor processes data and completes QC. ODOT conducts QA.
3. Vendor collects data using standard QC procedures and ODOT processes the data in-house and completes QA.
4. Vendor collects and processes ODOT data following standard vendor QC and ODOT completes QA.
5. ODOT collects and processes PCR data according to current manual procedures.
6. ODOT updates its current technical services vehicle to include a downward imaging system and collects data with either ODOT or vendor processing data.

The participating vendors provided cost and time estimates, summarized for each option in Tables 17 through 20 and shown more completely in Appendix F. Options 1 and 2 assume ODOT purchase of one system, and options 1 and 3 assume that ODOT purchases three processing workstations. Costs and hours for ODOT QA activities, which are assumed to be consistent between each option, are not included.

Table 17. Option 1 (ODOT collects and processes data) costs and hours.

Vendor-supplied system and service requirements	**Cost**
Collection system, workstation, web hosting, training ($/system)	$1,230,000
3-year warranty on collection system (not including vehicle)	$150,000
5-year warranty on collection system (not including vehicle)	$300,000
Ongoing annual technical support	$33,000
ODOT personnel requirements	
Estimated annual ODOT collection (6,500 hours/yr)	$500,000
Estimated annual ODOT processing (7,000 hours/yr)	$525,000

Table 18. Option 2 (ODOT collects and vendor processes data) costs and hours.

Vendor- supplied system and service requirements	Cost
Collection system, workstation (1), web hosting, training ($/system)	$1,120,000
3-year warranty on collection system (not including vehicle)	$150,000
5-year warranty on collection system (not including vehicle)	$300,000
Ongoing technical support	$34,000
Annual processing of ODOT-collected data (23,000 mi at $49/mi)	$1,120,000
ODOT personnel requirements	
Estimated annual ODOT collection (6,500 hours/yr)	$500,000

Table 19. Option 3 (Vendor collects and ODOT processes data) costs and hours.

Vendor-supplied system and service requirements	Cost
Workstations (3), web hosting, training ($/system)	$175,000
Ongoing technical support	$6,000
Annual collection of ODOT-collected data (23,000 mi at $45/mi)	$1,030,000
ODOT personnel requirements	
Estimated annual ODOT processing (7,000 hours/yr)	$525,000

Table 20. Option 4 (Vendor collects and processes data) costs.

Vendor-supplied system and service requirements	Cost
Annual collection of ODOT-collected data ($40/lane mi)	$920,000
Annual processing of ODOT-collected data ($49/lane mi)	$1,120,000
Workstation (1), web hosting instance, initial training	$80,000

Table 21. Option 5 (ODOT collects and processes data) costs and hours.

ODOT system and service requirements	Cost
Annual labor costs	$308,000
Annual maintenance costs	$36,000
Annual travel costs	$31,000

If certain ancillary information is assumed, the estimated 10-year equivalent uniform annual costs (EUAC) for each of the four options are shown in Table 22. Assumptions include ODOT purchasing one vehicle with a five-year warranty for options 1 and 2 and three workstations (est. $2,500 each) for options 1 and 3. The system is expected to be replaced in 10 years after 300,000 miles (483,000 km) of driving (est. 30,000 mi/yr [48,000 km/yr]). A five-year system warranty and ongoing collection system technical support is purchased for options 1 and 2. QA costs are estimated at $19,000 per year and are expected to be consistent for each option.

Loaded hourly rates for ODOT employees are estimated at $50/hour, and purchased vehicle fuel and light maintenance costs are assumed to be $0.75 per mile ($0.47 per km).

Table 22. Estimated EUAC of collection and processing options.

Option 1	Option 2	Option 3	Option 4	Option 5
$1,056,000	$1,787,000	$1,472,000	$2,135,000	$386,000

By comparison, ODOT's current manual approach of PCR data collection offers the lowest yearly cost. The ODOT PCR cost does not include the current costs in ODOT's technical services group for purchasing and operating a survey vehicle to collect IRI, rutting, faulting, and right-of-way images which are used for HPMS reporting and other purposes. If PCR data collection were to be performed with options 1 through 4, the PCR data collection could be combined with the technical services data collection and economies of scale would be recognized. Additional benefits associated with automated data collection will be discussed in a subsequent section.

6.4 VENDOR IMAGE QUALITY

If ODOT selects options that include in-house data processing, ODOT technicians will be spending hundreds of hours viewing pavement distresses on forward and downward images. Similarities and differences in vendor images are described below, focusing on resolution and system limitations. It should be noted that most vendors offer higher-resolution images but would recommend the displayed systems, based on their experience.

6.4.1 Forward Image Evaluation

Slight differences are evident between the forward images vendors display on their workstations, due to variations in camera type, processing, and resolution. Figure 49 displays samples of the best quality vendor ROW images provided for the project test sites. Apart from differences in the downward angle, all vendors offer clear forward roadway images. An example of sign resolution variations can be seen in Figure 50.

Forward images can be used to identify and confirm pavement distresses, severities, and extents. Figures 51 and 52 provide examples of each vendor's ability to record cracks and patches in ROW images. Slight differences between vendors in the camera offset from the distress have added some variation in resolution as well. Both cracks and patches are reasonably visible.

Fugro (site 16) Mandli (site 29) Pathway (site 16)

Figure 49. Best quality noted ROW image.

Fugro (pixels) Mandli (pixels) Pathway (pixels)

Figure 50. Sign resolution on site 10.

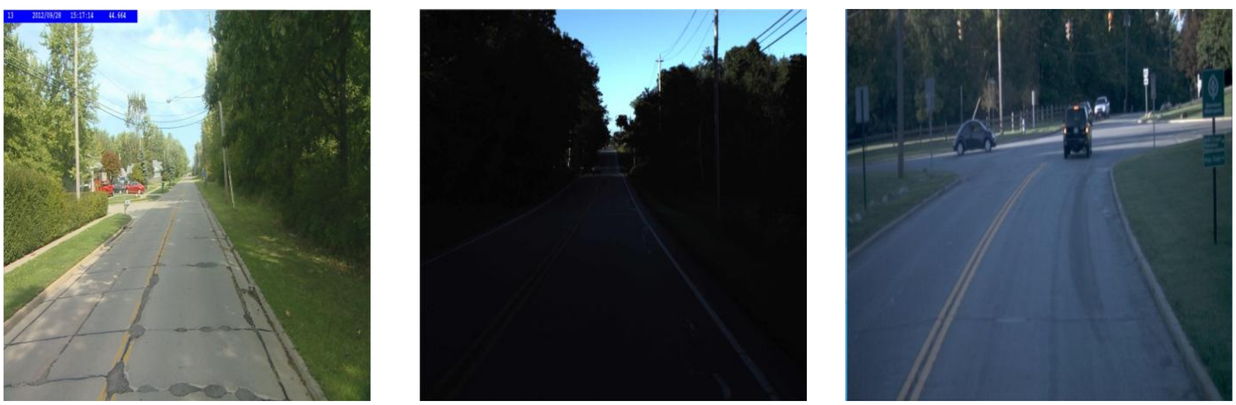
Fugro (pixels) Mandli (pixels) Pathway (pixels)

Figure 51. Crack resolution on site 35.

Fugro Mandli Pathway

Figure 52. AC patch on APC resolution for site 29.

The ability to adjust for variations in lighting conditions varied between vendors. Figure 53 represents each vendor’s lowest quality forward images. As can be seen, the effects of low sun angle and shadows from adjacent trees can reduce the ability to adequately view distresses, severities, and extents in ROW images. In general, the Fugro broadcast quality images provided the best images in low-light or non-ideal sun angle conditions.



Fugro (site 13) Mandli (site 30) Pathway (site 23)

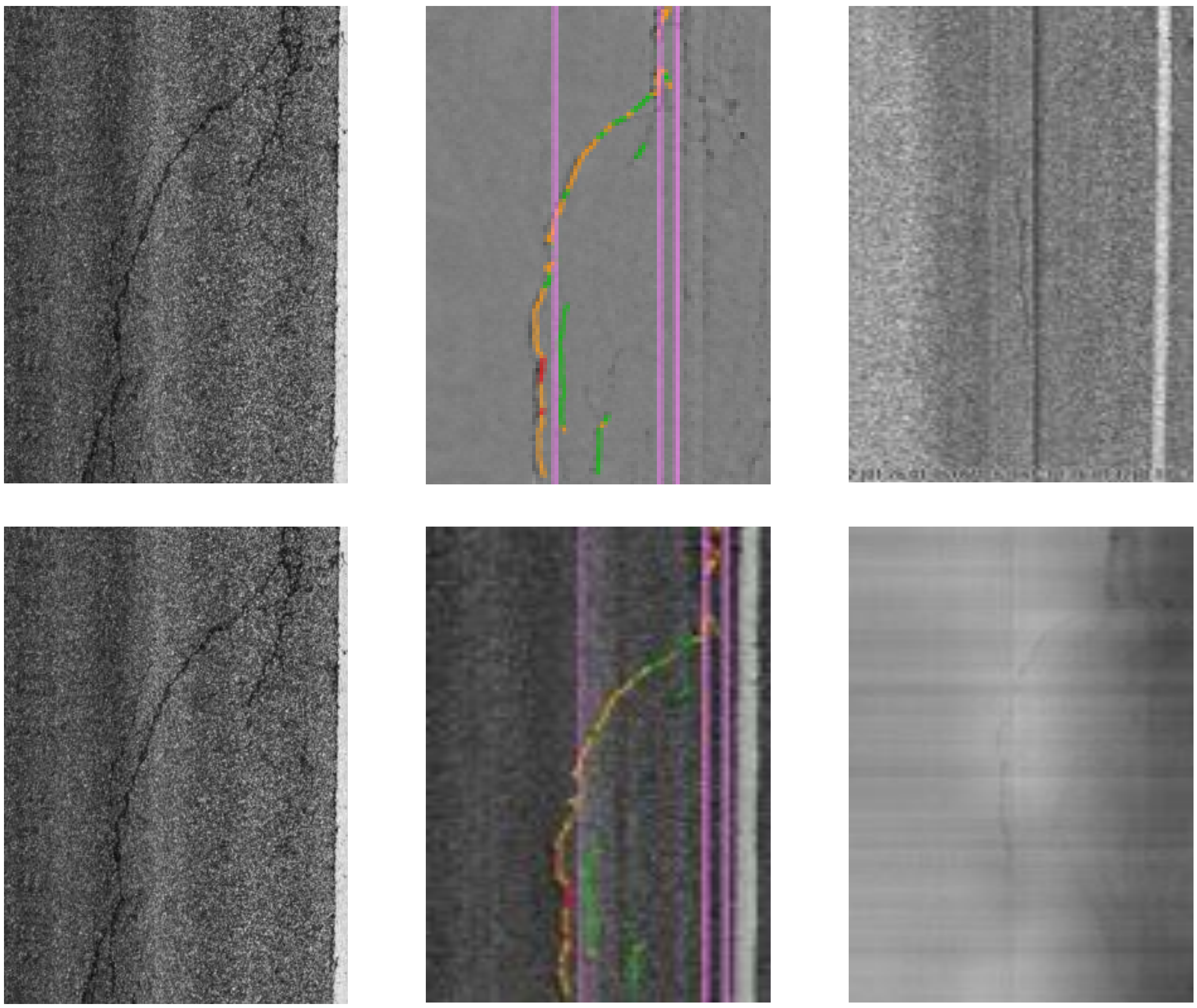
Figure 53. Lowest quality noted ROW image.

6.4.2 Downward Image Evaluation

Each vendor employs infrared laser-illuminated line-scan images, combined longitudinally to form continuous 2D and 3D images. Both Mandli and Fugro use the Pavemetrics INO 5,600 Hz two-camera LCMS system. The Pathway system utilizes a single camera to collect images at 3,000 Hz. While each vendor offers higher resolution systems, the images shown in this section are representative of the systems used in this study.

Downward 2D (top) and 3D (bottom) vendor images of a narrow crack in AC pavement, shown in Figure 54, indicate differences in the resolutions and abilities to display cracks by the current systems. The 3,000-pixel Pathway images do not typically reveal the cracks as well as the 5,600-

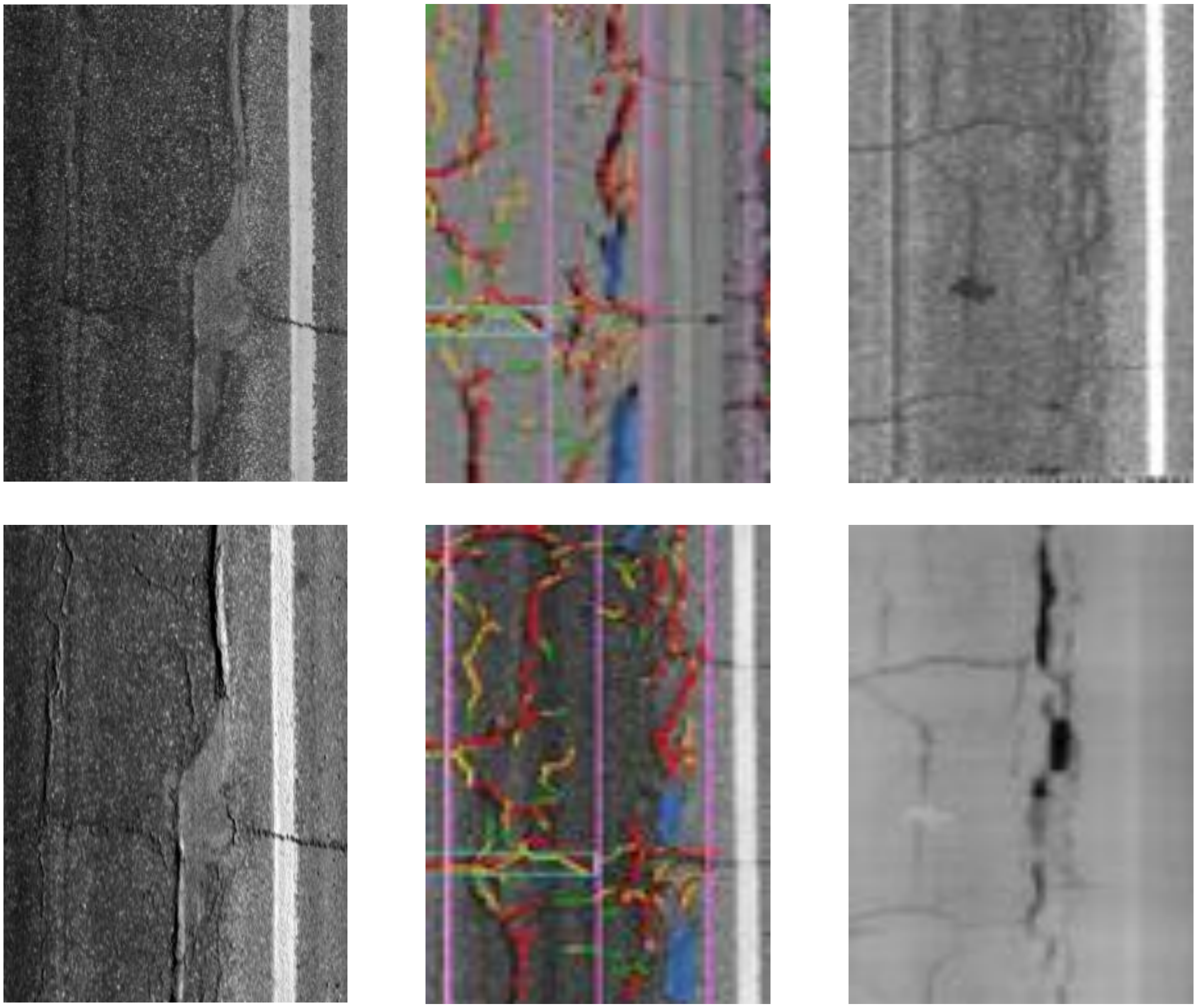
pixel Fugro and Mandli images. However, cracks are evident on all images. An estimated 5 percent improvement in low severity crack rating accuracy could be obtained from higher resolutions; however, variations in vendor methodology resulted in crack severity correlations that do not solidly support this estimation. Note that darker portions of the 3D range images represent areas where the pavement elevation is below the nominal pavement surface level (in the crack).



Fugro (5.6 kHz) Mandli (5.6 kHz) Pathway (3.0 kHz)

Figure 54. Estimated 0.125-in (3-mm) AC crack images (site 24).

Vendors' images of wider AC pavement cracks are shown in Figure 55. Cracks of this width are apparent in all images, with the darker areas of the 3D images becoming more pronounced with increased crack width and depth. Vendors are typically able to identify this type of crack using automatic algorithms.



Fugro (5.6 kHz) Mandli (5.6 kHz) Pathway (3.0 kHz)

Figure 55. Estimated 0.25-in (6.4-mm) AC crack images (site 3).

Figure 56 provides vendor images of longitudinal joint and transverse crack spalls on PCC pavement. These spalls are more pronounced on the lower images (3D), which darken areas where the pavement is lower than the nominal pavement surface. Spalls are easily identifiable on 3D images from all vendors. Additionally, severities of spalls can be visually estimated using each vendor images. Difficulties in identifying spall severities according to ODOT criteria are related more to automating the process of determining spall width, extent along a joint, and severity after it is patched.

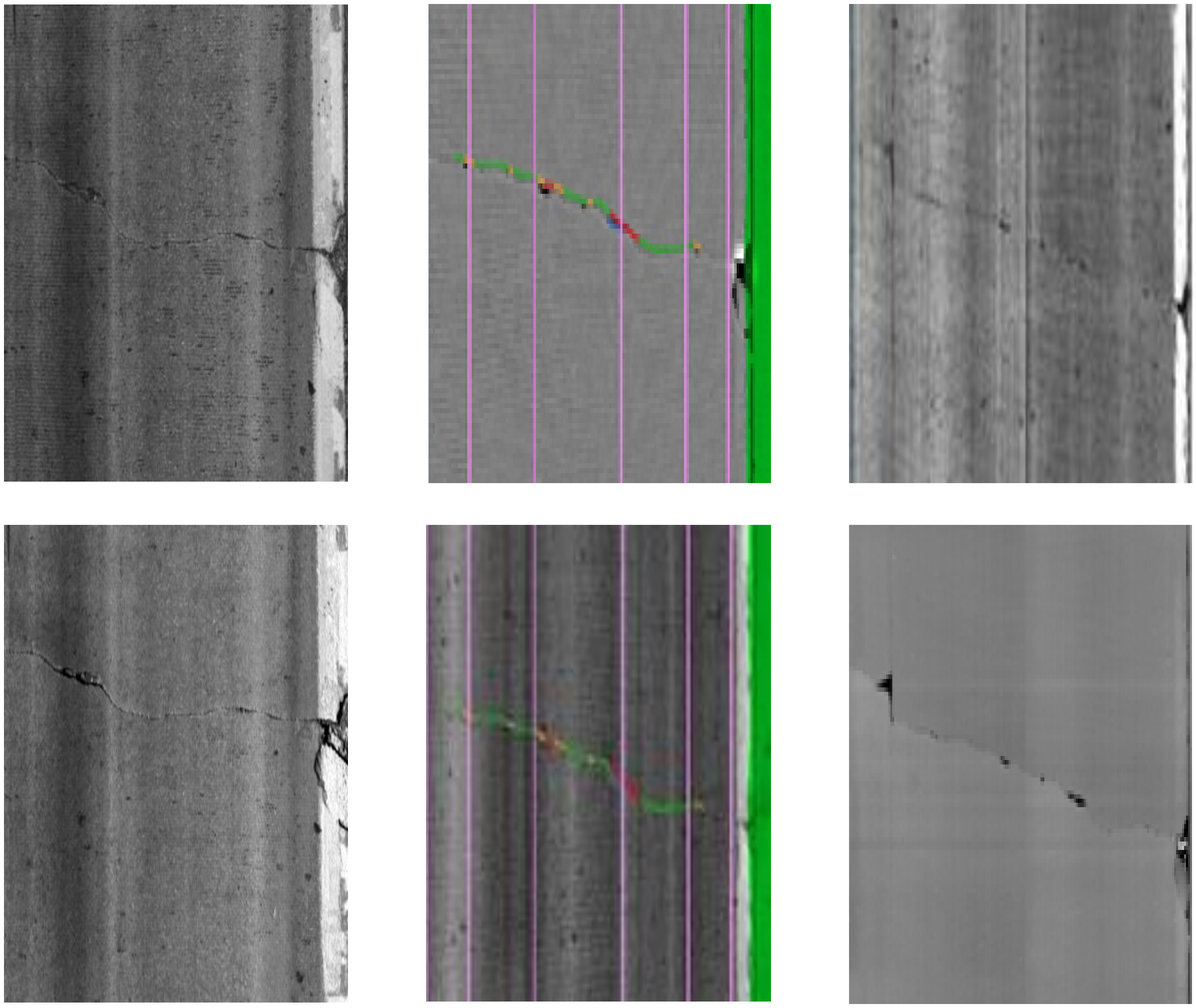
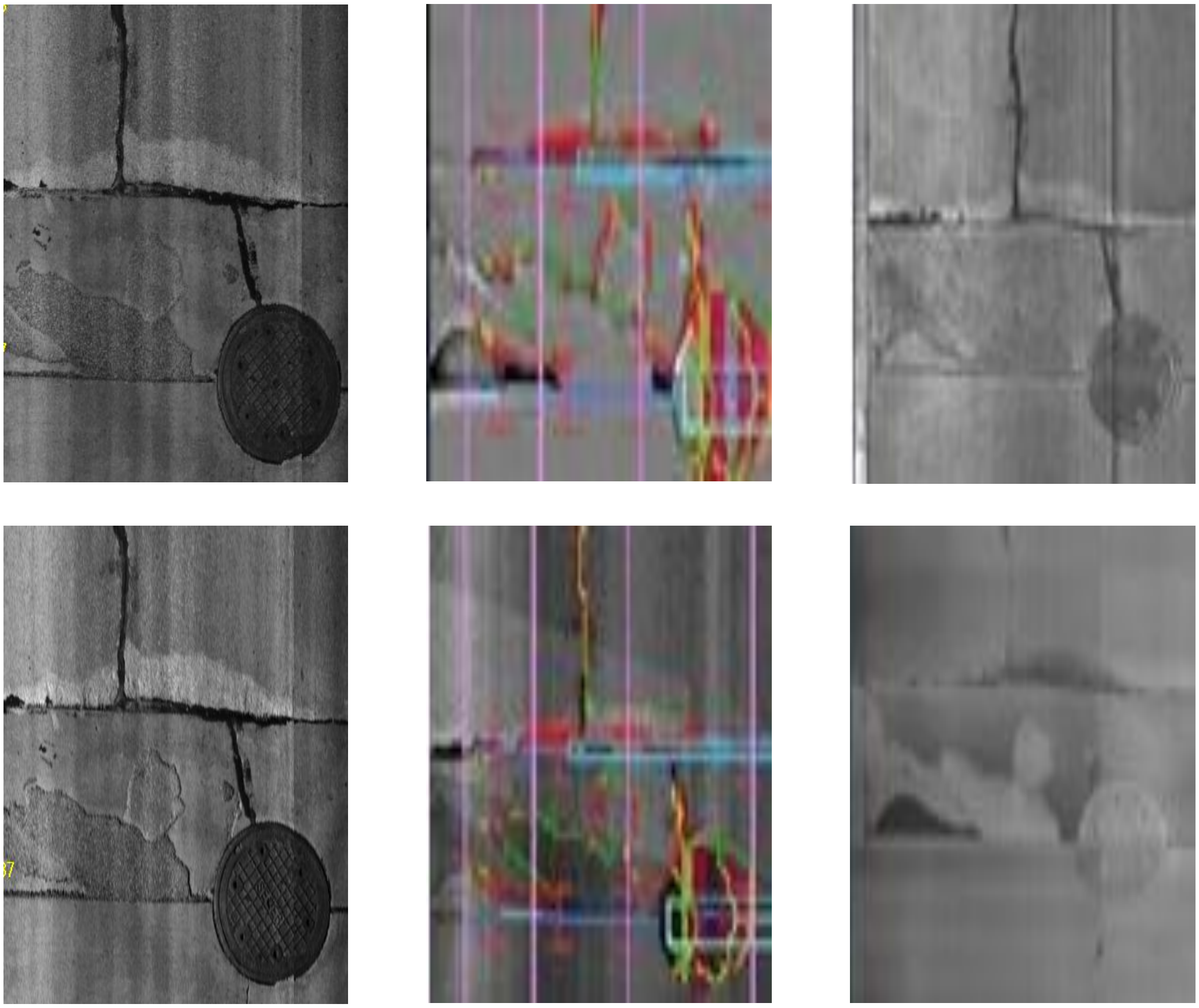


Figure 56. PCC longitudinal joint spall images (site 16).

Wide transverse cracks are shown in Figure 57, which includes 2D (top) and 3D (bottom) images from all participating vendors. Cracks are readily evident, particularly in the 3D images. Other distresses that can be noted in these images include a sunken PCC patch, AC patches on the PCC patch, and joint spalling.

As can be seen in the above images, pavement distresses are visible at a high level, and the 3D depth images provide supplemental information that significantly increases the ability to visually define distress severity. Further improvements in severity identification are expected to focus on automated detection software, capitalizing on the significant enhancements of 3D imaging.



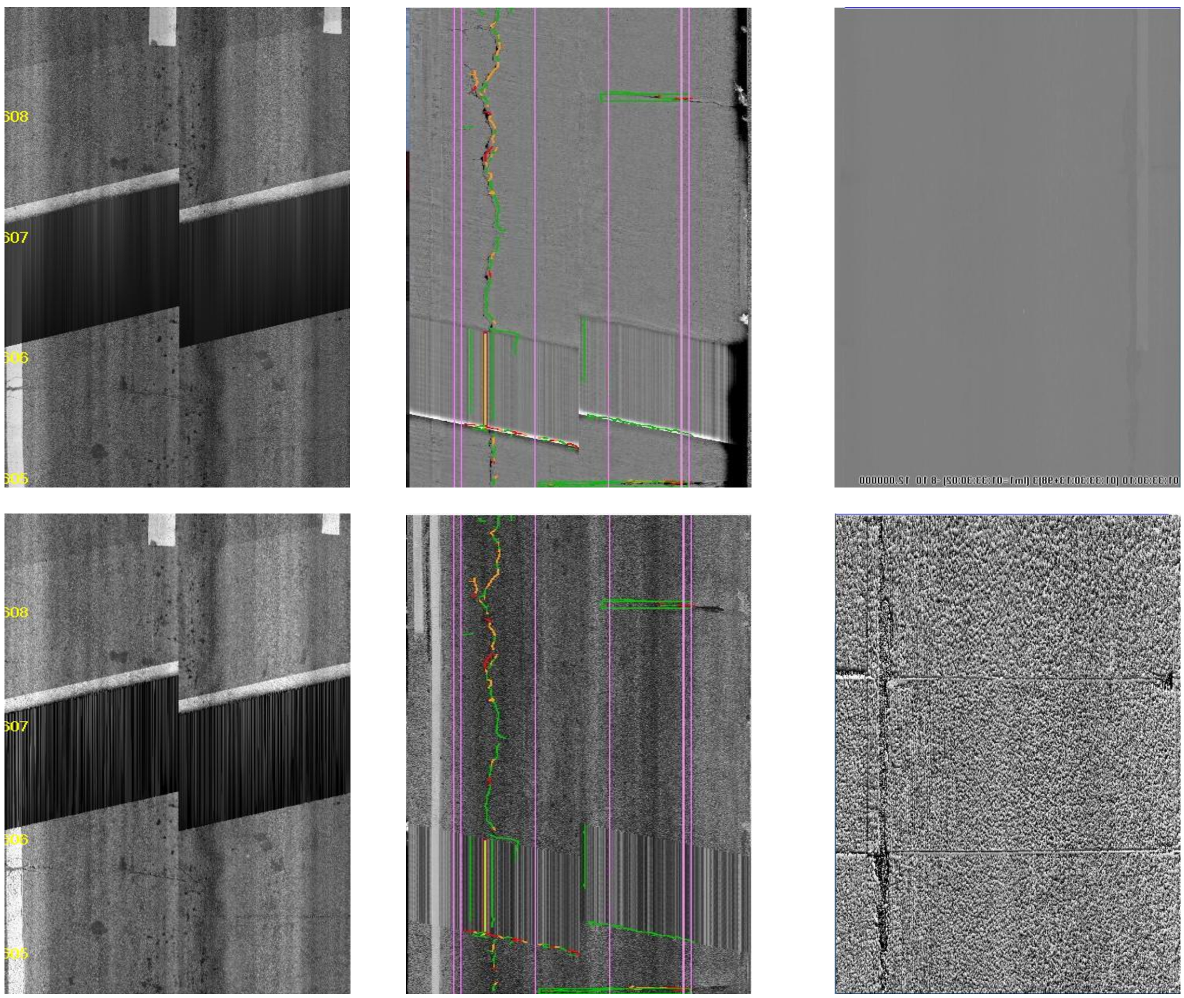
Fugro (5.6 kHz) Mandli (5.6 kHz) Pathway (3.0 kHz)

Figure 57. Estimated 0.25-in (6.4-mm) PCC transverse crack images (site 22).

6.4.2.1 Downward Image Limitations

Occasional system limitations were noted during image review, related to vehicle stoppage, range settings, and vehicle speed. Federal law requires that the scanning lasers be turned off when the vehicle approaches 0 mi/hr. In urban areas, where traffic signals are common, images similar to those shown in Figure 58 are collected. The Mandli and Fugro images reveal about 3 ft (0.9 m) of longitudinally distorted image, whereas the Pathway images show exaggerated surface properties. Reportedly, both of these distortions result from the sensors being turned off at low speeds. Fugro and Mandli turn off their system when speeds fall below 2 to 3 mi/hr (3 to 5 km/hr), and Pathway stalls their sensors below 3 to 4 mi/hr (5 to 6 km/hr). In these cases, the systems will not be able to capture complete pavement images for a short duration; however, the occurrence of this distortion is expected to be minimal.

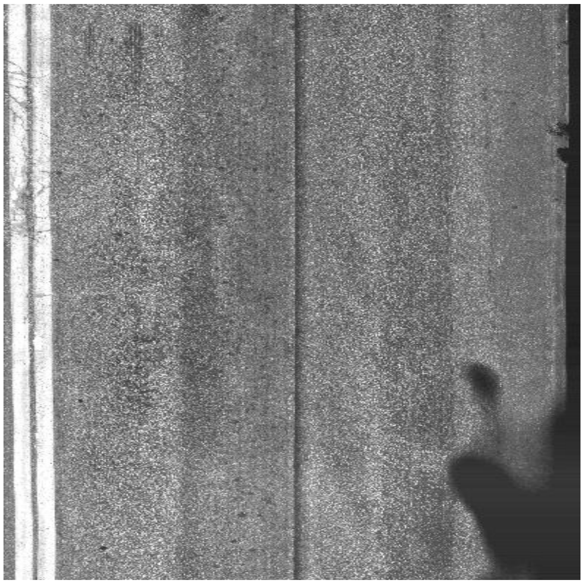
A second limitation, reported by two vendors, occurs when vehicle bounce, large roadway surface variations, or vehicle tilt due to deceleration remove portions of the pavement surface from the focal limit or range of operation. An example of this occurrence is shown in Figure 59. Pathway allows for adjustment to this range but notes that related difficulties arise as the range is extended. One vendor reported occurrence of this limitation in less than 0.003 percent of collected pavement length. Distress data analysis is typically turned off in areas affected by this limitation.

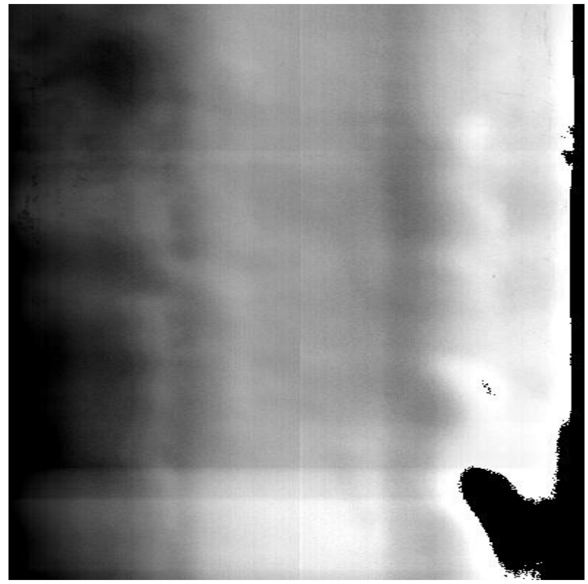


Fugro (site 10) | Mandli (site 35) | Pathway (site 5)

Figure 58. Image resolution problem.

One vendor also reported missing images and artifacts if the maximum allowable speed is exceeded. Field monitoring of images, which is typical, is expected to identify such distortions and allow vendors to easily repeat measurements as necessary.

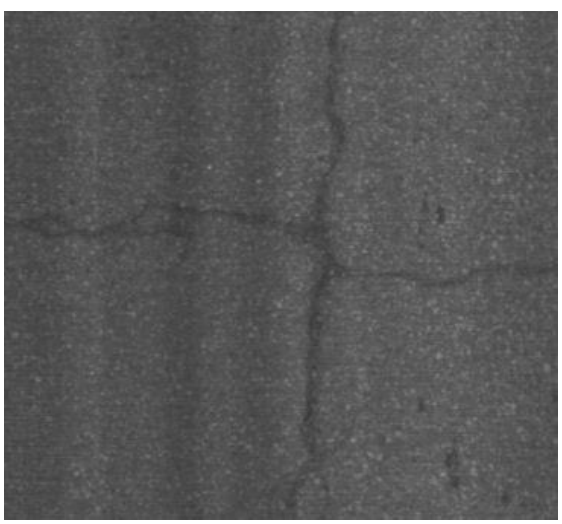


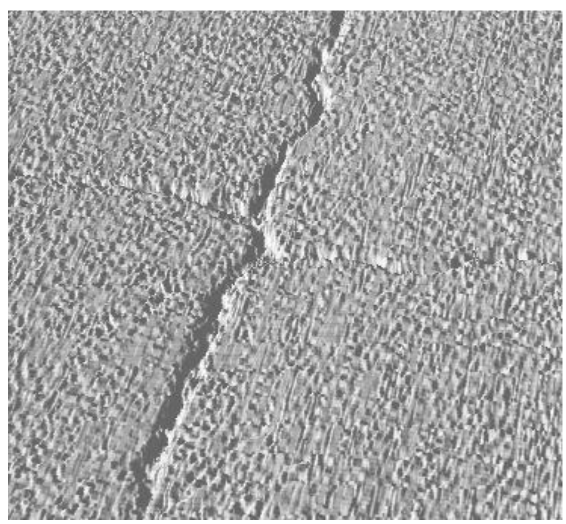


2D Intensity 3D Range

Figure 59. Image resolution problem: site 23, MP 112.543.

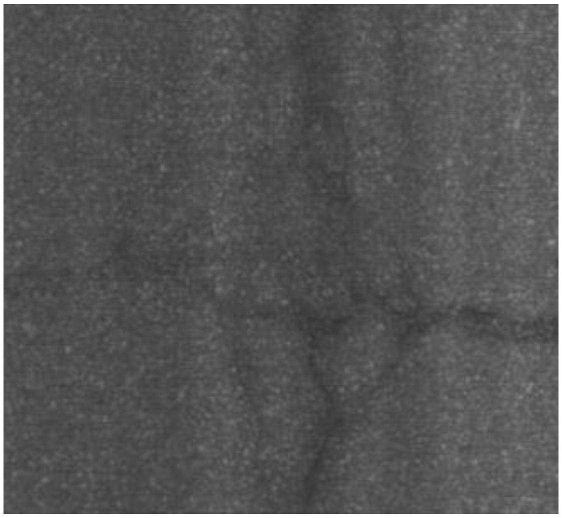
While WayLink did not collect a full set of images or process the images to obtain distress summaries, representative images from their system are included in Figures 60 through 63. Note the expanded downward image detail for cracks and spalls. A full set of collected images was not provided by WayLink. Thus, image resolution problems were not evaluated.



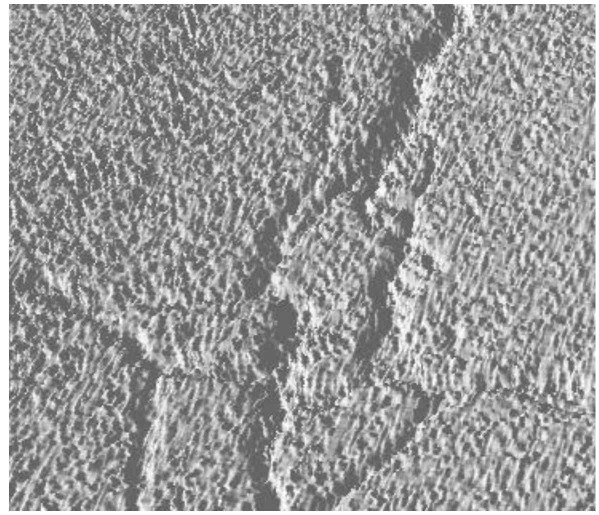


2D Intensity 3D Range

Figure 60. Waylink estimated 0.125-in (3-mm) AC crack images (site 3, image 38).



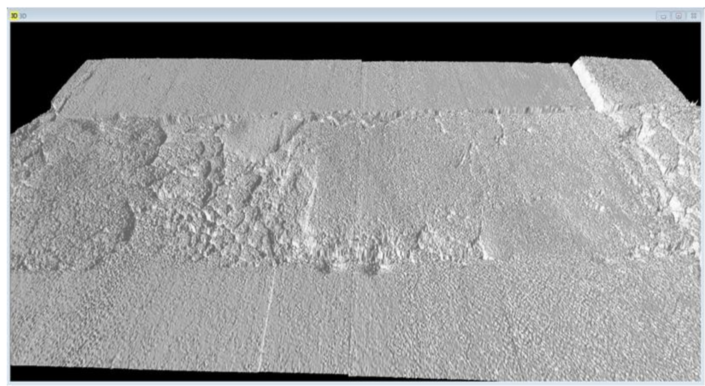
2D Intensity



3D Range

Figure 61. Waylink estimated 0.25-in (6.4-mm) AC crack images (site 3, image 90).

ROW Image



3D Range

Figure 62. Waylink AC patch on PCC images (site 5, image 325).

ROW image

3D Range

Figure 63. Waylink PCC longitudinal joint spall images (site 5, image 201).

6.5 STATE AGENCY SURVEY EVALUATION

A survey of 18 State agencies, distributed in early 2013, provided insights into their pavement distress collection scope of work and identified distresses, collection, and processing methods, privatization criteria, quality management, and satisfaction with current methods. Results of this survey are included in Appendix G. Responding agencies primarily collected between 5,000 and 15,000 lane miles annually, with 31 percent of agencies collecting lane miles similar in scope to ODOT. Ten percent of agencies manually collect pavement surface distress data, while a large number collect 2D full image and line-scan images, and 26 percent collect 3D line-scan pavement surface images, as Figure 64 reveals. Note that three of the responding agencies report using both line-scan and full image systems for their primary data collection. Reporting agencies tend to prefer to conduct manual surveys in-house, while they choose to process their own semi-automated and automated distresses about 1.8 times more than they select contractor processing (see Figure 65). It should be noted that five agencies report using both semi-automated and automated approaches as their primary distress analysis methods.

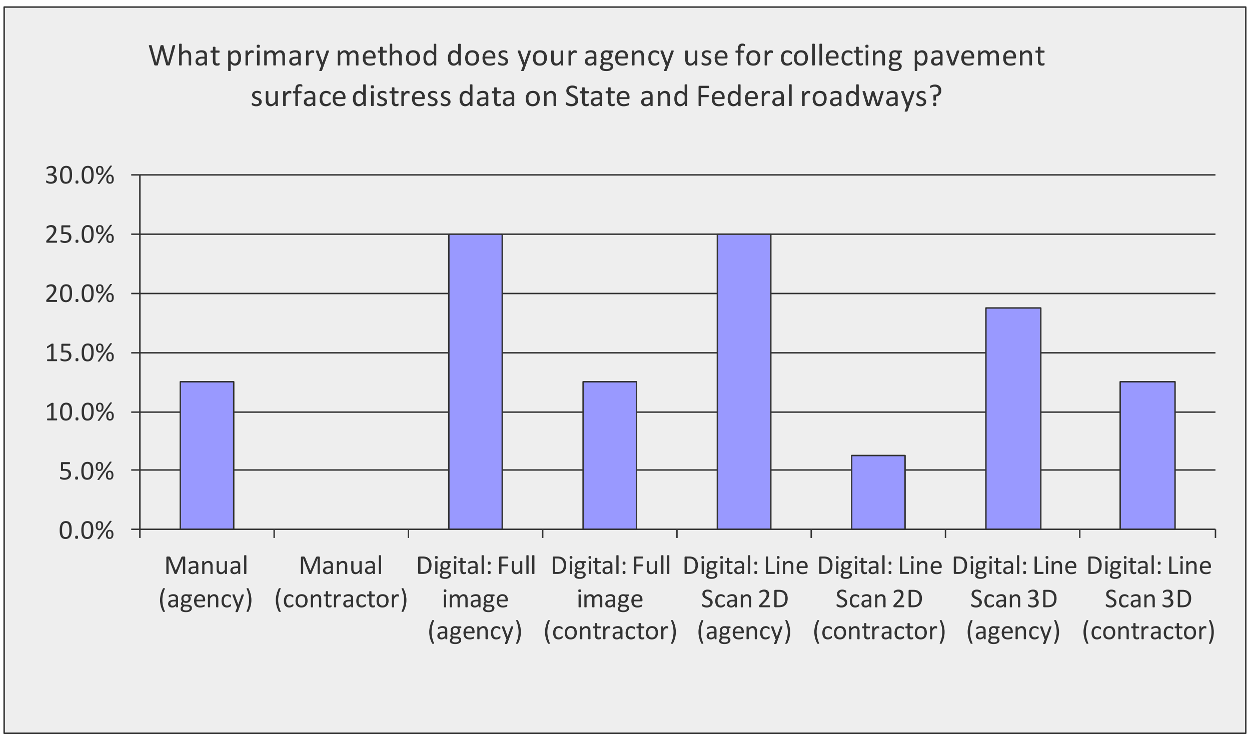


Figure 64. Agency data collection methods.

6.5.1 Distress Type

Agencies using manual methods to collect pavement distress data tend to record a greater number of distresses (22, on average) than the older full image collection systems (16, on average), as shown in Table 23. This is likely the result of the limited ability of full image systems to accurately identify a range of distresses. When 2D and 3D line-scan cameras are employed, the average distress count (19) exceeds that of full image collection, possibly due to increased ability to identify distresses.

Additionally, contractors who collect distress data for the reporting agencies using 2D and 3D systems are being asked to identify more distresses (26 average) than agency 2D/3D (19 average) or agency manual (22 average) collection programs. This may be the result of increased confidence in the capabilities of these systems and higher expectations from outside collection sources.

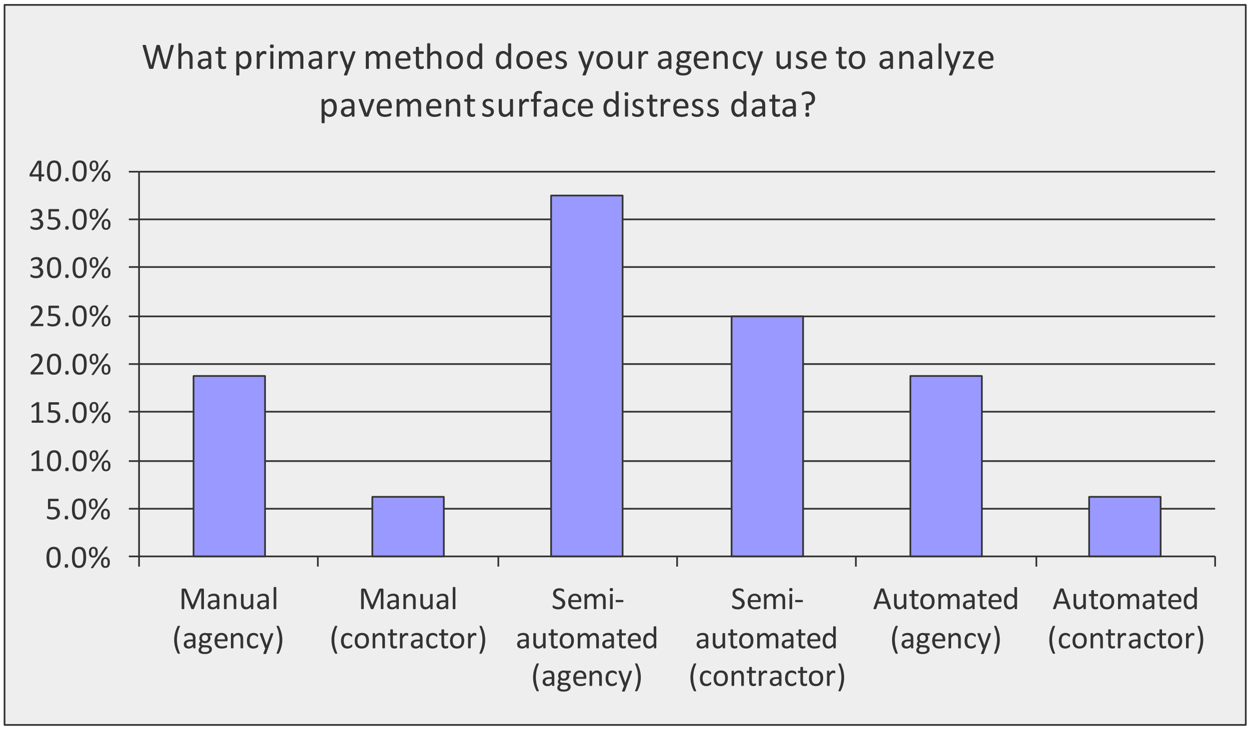


Figure 65. Agency distress processing methods.

Table 23. State agency average number of distresses collected using various methods.

Collection Method	AC Distresses	AC/PCC Distresses	PCC Distresses	All Distresses
Manual (agency)	9	10	8.5	22
Full image (agency)	6	8	6	16
Full image (contractor)	6	5	4	15
2D line-scan (agency)	7	6	6	18
2D line-scan (contractor)	9	7	9	25
3D line-scan (agency)	8	7	7	21
3D line-scan (contractor)	10	8	10	27

Of the 12 AC, 15 AC/PCC, and 12 PCC distresses that ODOT collects, responding agencies reported collecting about 50 percent manually and 46 percent with their State-owned semi-automated collection system, as shown in Table 23. This reveals the challenge faced by ODOT in transitioning to automated collection and semi-automated DSE evaluation. This table's trend toward increased numbers of distresses reported by vendors versus by agencies indicates a possible benefit associated with processing of distress images by contractors.

Table 24. State agency average number of ODOT distresses processed using various methods.

Processing Method	AC Distresses	AC/PCC Distresses	PCC Distresses	All Distresses
Manual (agency)	8	8	6	19
Manual (contractor)	10	10	10	30
Semi-automated (agency)	7	6	6	18
Semi-automated (contractor)	8	7	8	21

6.5.2 Quality Control/Quality Assurance Processes

Many of the 18 agencies that responded to the survey reported using established QC and QA processes as part of their quality management program. Survey respondents were asked to note that QC is conducted by the data collection provider (vendor or agency) and QA by the owner agency. Table 25 lists the number of agencies reporting the use of the listed QC methods. Primarily, calibration of equipment and evaluation criteria, testing of "control" segments before and during data collection, and verification of post-survey procedures served as QC tools.

Table 25. Typical collection and processing quality control methods.

Quality Control Methods	Agencies using
Calibration of equipment and/or analysis criteria before the data collection	15
Testing of known "control" segments before data collection	14
Periodic testing of known "control" segments during production	11
Periodic testing of blind "control" segments during production	3
Verification of sample data by an independent consultant	4
Verification of the post-survey processing software/procedures	11
Cross-measurements (random assignment of repeated segments to different data collection teams or automatic measuring devices)	3

Similar trends were reported for QA evaluation of pavement distress data. As shown in Table 26, a primary QA method is testing control segments prior to data collection. This would involve ODOT setting up and rating DSEs for representative sites for comparison with vendor distress ratings. Agencies also commonly verified the collected distress data by reviewing software, methodologies, and outputs. About half of the respondents conducted or required periodic testing of previously rated control segments during data collection. This type of commonly random periodic testing provides an unbiased review of distress data quality against an agency-established baseline. One agency, using a 3D system for 15,000 to 25,000 miles of collection, "highly recommended using a third-party contractor for data QA/QC." Another agency indicated that they verify collected data by comparing them with ratings from previous years and independent windshield audits.

6.5.3 Collection and Processing Costs

Costs for semi-automated collection and processing, reported by 13 agencies, ranged from $22 to $82 per test mile, as shown in Table 27. Semi-automated agency collection and processing costs ($12 to $60/mile) fell lower than the contractor-collected data ($60 to $82/mile). Contractor costs tended to decrease with the miles of pavement tested and show no correlation with the number of distresses identified.

Table 26. Typical agency QA methods.

Quality Assurance Methods	Agencies using
Calibration of equipment and/or analysis criteria before the data collection	10
Testing of known "control" segments before data collection	13
Periodic testing of known "control" segments during production	9
Periodic testing of blind "control" segments during production	4
Verification of sample data by an independent consultant	5
Verification of the post-survey processing software/procedures	11
Cross-measurements	3

Table 27. Reported total cost for collection and processing.

Collection method	Processing method	$/test-mile ($/km)
Manual (agency)	Manual (agency)	$16 ($10/km)
Manual (agency)	Manual (contractor)	N/A
Digital: Full image (agency)	Manual (agency)	N/A
Digital: Full image (agency)	Semi-automated (agency)	N/A
Digital: Full image (contractor)	Semi-automated (agency)	$77 ($48)
Digital: Full image (contractor)	Semi-automated (contractor)	$80 ($50)
Digital: Line-scan 2D (agency)	Semi-automated (agency)	$22 - $60 ($14-37)
Digital: Line-scan 2D (agency)	Semi-automated (contractor)	N/A
Digital: Line-scan 2D (contractor)	Semi-automated (contractor)	$80 ($50)
Digital: Line-scan 3D (agency)	Manual (agency)	$22 ($14)
Digital: Line-scan 3D (agency)	Semi-automated (agency)	$12 - $37 ($7-23)
Digital: Line-scan 3D (contractor)	Semi-automated (contractor)	$60 - $82 ($37-51)

6.5.4 Performance

Agency experts were asked how satisfied they are with their pavement distress data collection and processing. The four who responded that they are “completely satisfied” collect their own data manually, using digital full images, or employing 3D line-scan systems, as noted in Table 28. Two processed their distress data in-house, and two employed contractors. The one “partially satisfied” agency planned to switch from manual agency data collection to vendor-collected 3D automated collection. “Mainly satisfied” agencies typically collect their own distress data, and two reported planned transitions from full and 2D images to 3D line-scan collection systems.

6.5.5 Privatization Considerations

When asked what criteria their agency used to determine whether to outsource surface condition data collection, most responded that cost-effectiveness was the key consideration (see Table 29). This agrees with the 2009 NCHRP survey completed by more than 50 U.S. and Canadian agencies (5). Cost-effectiveness was cited by all agencies owning 2D or 3D collection systems, but by only one of the three agencies employing contractors. Many noted that increased data collection requirements or desires influenced their decisions. This criterion was cited most frequently by agencies collecting and processing their own distress data. Fifty percent of agencies indicated that safety of agency raters affected their choice of outsourcing. The same number of agencies who employed contractors highlighted rater safety as those agencies collecting in-house. Additional considerations by agencies employing contractors included limited staffing, equipment maintenance concerns, system obsolescence, limited experienced raters, and expected improved data consistency. Agencies collecting their own data additionally cited the ability to immediately collect project-level data as a consideration.

Table 28. Reported agency satisfaction level with collection/processing.

Collection method	Processing method	Satisfaction level
Manual (agency)	Manual (agency)	Partially
Manual (agency)	Manual (contractor)	Completely
Digital: Full image (agency)	Manual (agency)	Mainly
Digital: Full image (agency)	Semi-automated (agency)	Completely
Digital: Full image (contractor)	Semi-automated (agency)	Mainly
Digital: Full image (contractor)	Semi-automated (contractor)	Mainly
Digital: Line-scan 2D (agency)	Semi-automated (agency)	Mainly
Digital: Line-scan 2D (agency)	Semi-automated (contractor)	Mainly
Digital: Line-scan 2D (contractor)	Semi-automated (contractor)	Mainly
Digital: Line-scan 3D (agency)	Semi-automated (agency)	Completely
Digital: Line-scan 3D (contractor)	Semi-automated (contractor)	Mainly-Completely

Table 29. Agency criteria to determine whether to privatize pavement condition data collection.

Selected criteria	2013 Agree (%)	2009 Agree (%)
Cost-effectiveness	75	69
Scope of data collection requirements	63	44
Availability of qualified contractor	31	29
Experience of other agencies with outsourced data collection	19	58
Safety of agency raters	50	33

7 TYPICAL TRANSITION PROCESS

Transitioning from manual to automated or semi-automated pavement distress data collection and processing typically requires a changeover period expected to range from one to four years. All or portions of the following typical activities can be anticipated, should ODOT move forward with a transition:

1. Select a vendor or vendors for evaluation and implementation.
2. Optimize the vendors' ability to match agency distress, severity, and extent ratings.
3. Reevaluate/reconsider the transition process based on actual optimized results.
4. Develop correlations between manual and automated or semi-automated DSEs, and indices to provide data continuity, as needed.
5. Establish QC/QA program to ensure optimized data quality levels.
6. Implement staged or full-scale distress data collection and processing systems and procedures.
7. Adjust pavement DSE reporting methods and distress index to account for limited vendor DSE identification, as needed.
8. Modify Pavement Management System decision trees and performance models, as needed.

7.1 SELECTION OF VENDOR(S)

Agencies opting to transition to 3D collection and analysis systems generally develop a Request for Proposals (RFP) defining the systems, verification methods, and performance results they expect from the selected system. Proposals submitted by vendors are evaluated according to weighted agency-defined criteria. Interviews are conducted with short-listed vendors and again the vendors' potential for success and economic advantage are rated. In most cases a single vendor is chosen to proceed with optimization and initial data collection.

An alternative that offers the agency greater control is selecting one or more vendors and evaluating their equipment and processing capabilities on a reduced scale. Their contracts can include an option for extension, contingent on performance acceptable to ODOT criteria. The single vendor who demonstrates performance at the highest acceptable level can then be contracted for full-scale data collection and processing.

7.2 OPTIMIZATION OF VENDOR CAPABILITIES

As noted previously, several improvements can be made to the methods that vendors employ to identify ODOT's pavement DSEs. These enhancements are expected to improve vendor correlations with ODOT pavement DSE ratings. Steps typical of this optimization include vendor interaction/training, limited field data collection and processing, calibration of vendor ratings, and final verification. Detailed activities include:

1. Collecting and comparing manual and semi-automated pavement DSE ratings on a small scale. This step has been completed under this research program.
2. Identifying and iteratively selecting initial methods to resolve variations in the results. This begins with distress totals and work toward optimizing severities and extents. Much of this step has also been conducted in the current research program. Therefore, this step would include interaction with selected vendors to implement the results of this research and identify means to further improve correlation.
3. Collecting and comparing manual (possibly using pavement images) and semi-automated ratings on a larger set of representative pavements (e.g., one or two districts or the entire State).
4. Identifying and iteratively selecting improved methods to resolve variations in the results.

Perfect correlation cannot be reasonably expected between drive-by manual surveys and semi-automated pavement distress data and PCR values. This is related to limitations of both methods. ODOT's manual surveys provide only estimates of actual distress presence, severity, and extent. Windshield surveys, by nature, are not designed to measure detailed distresses. Rather, they focus on identifying a more global DSE listing. Although vendor surveys provide 100 percent inspection, they may be limited by image resolution and detection algorithms.

As an alternative, agencies may choose to review and optimize their entire set of DSEs to adjust for the capabilities of automated and semi-automated distress identification systems. This approach, currently being implemented in Indiana, allows an agency to upgrade their entire pavement management methodology, establishing an updated system that sets a benchmark from which the agency can better incorporate modern technology and more successfully manage their pavement systems. This alternative would also require extensive modification of the agency's pavement management operations, including decision routines, performance modeling, and software tools.

7.3 REEVALUATE TRANSITION BASED ON OPTIMIZATION RESULTS

Following initial vendor selection and final optimization of distress identification, agencies can reconsider the benefits, risks, and costs associated with transitioning to automated collection. Items to consider include the relative benefits of owning the selected equipment or hiring vendors to collect data. Additionally, the agency can evaluate the optimal method for processing data (in-house or contractor-provided). Agencies may also consider the amount of automated distress identification provided by the new systems and the level of training, expertise, and time required by their in-house data processors.

Also, at this time, the final scope of modifications required by the transition can be defined and evaluated. This includes considering the effects of loss in data completeness, the effort needed for revised PCR development, and the activities necessary for revising agency pavement management decision trees, pavement management approaches, and pavement management software. Finally, the costs associated with developing revised pavement distress progression models and new correlations between current and previous pavement condition data can also be reviewed.

7.4 ADJUST PAVEMENT DISTRESS REPORTING METHODS AND INDEX

Any of the DSEs for which vendors are unable to achieve acceptable accuracies and correlations will require that the design of the agency's pavement condition index be modified. This process may require extensive agency effort to achieve correlations between the original and new distress ratings and indices. In many cases, a revised distress identification manual is developed to incorporate the capabilities and limitations of semi-automated distress identification. This revised manual may include additional DSEs, as well as revise, replace, or remove current distresses for which collection accuracies are insufficient or the distress has become obsolete. Details of the weighting and computation of the revised index must also be defined and documented.

7.5 ESTABLISH QUALITY CONTROL/QUALITY ASSURANCE PROGRAM

QC and QA are the critical means for identifying discrepancies and maintaining accurate data for pavement management and modeling. Agencies should require and/or implement an effective QC program requiring that image and sensor data quality be monitored and maintained by the collection team. Distress analysis results must also be reviewed and verified by the image analysis team. Additionally, tremendous value can be achieved by agencies that establish a QA program using methods described in Table 26.

7.6 IMPLEMENT DISTRESS COLLECTION AND PROCESSING PROGRAM

After optimization of vendor DSE identification is complete, the final DSEs have been established, equipment and methods have been selected, and QC/QA programs are in place, full-scale data collection and processing can begin. As collection and QC/QA continue, any newly identified problems must also be resolved.

7.7 DEVELOP CORRELATIONS BETWEEN CURRENT AND NEW SYSTEM

Most agencies prefer to maintain backwards compatibility with their initial pavement distress reporting and management system. An ideal means of establishing this consistency is a process of concurrently collecting pavement condition information using an agency's current approach and their updated analysis approach. This dual set of data allows the agency to numerically and statistically correlate future pavement condition information with pre-transition data, thereby increasing the usefulness of historical modeling and reporting.

7.8 MODIFY PAVEMENT MANAGEMENT DECISION TREES AND MODELS

Agencies modifying their pavement distress ratings and index typically must alter their maintenance decision trees, develop revised pavement performance models, and modify their pavement management system and software. This process can require a significant amount of effort and may demand two or more years of full-scale data collection to fine-tune the decision tree and develop revised performance models.

8 CONCLUSIONS

The information gained in this research has contributed greatly to achieving the ODOT objective of determining if the state-of-the-practice systems and rating methods are a suitable replacement for ODOT's current manual data collection method. This was primarily achieved through detailed review of the quality and consistency of vendor-collected pavement distress, severity, and extent data. Additionally, factors associated with transitioning to semi-automated distress data collection and reporting, including productivity, cost, benefits, and risks, were identified and evaluated. Finally, the research team developed an understanding of differences in current vendor processes, capabilities, and plans. Based on the research, the following conclusions are presented.

8.1 DATA QUALITY

Evaluation of the participating vendors' ability to match the DSEs of 359 pavement distresses noted on 44 test sites by ODOT raters indicates that vendors were not able to match ODOT ratings at a level acceptable for direct transition. Modification of ODOT's PCR, decision trees, performance models, and pavement management software will be necessary to complete a transition. With varying success, the vendors correctly identified the presence of ODOT-rated distresses 74.5 percent of the time. Their 33.4 percent average match of distress and severity reveals their current limitations and the complexity inherent in repeating ODOT ratings. Further challenges resulted in an average distress, severity, and extent match of 13.5 percent. Because of these distress rating variations, the average standard deviation between single-site PCR values determined by vendors and ODOT raters exceeded 8—six times the standard deviation between repeated ODOT ratings. Follow-up interviews with ODOT raters and vendors revealed areas where better communication, training, and further field optimization is expected to significantly improve correlations. Based on these reviews, a high level (estimated $\geq$ 75 percent) of DSE correlation is anticipated following vendor interaction/training and field optimization include the following. All severities are included in the rating unless otherwise noted.

- AC and AC/PCC – Patching.
- AC – Wheel track cracking.
- AC – Longitudinal cracking.
- AC and AC/PCC – Crack seal deficiency.
- AC and AC/PCC – Rutting.
- AC/PCC – Transverse cracks (unjointed base).
- PCC – Longitudinal joint spalls.
- PCC – Patches.
- PCC – Transverse joint/crack spalls.
- PCC – Corner breaks.
- PCC – Longitudinal cracks.
- PCC – Transverse cracks (short jointed).
- PCC – Transverse cracks (long jointed).

Subsequent to optimization, at least one vendor is expected to achieve 50 to 74 percent correlation with ODOT rater DSE values of the distresses listed below. Some modification of the requirements for these distresses is likely, if transition occurs. It is possible that adjustments to the detailed criteria for these distresses may raise their correlations to an acceptable level. Examples would include combining joint reflection and intermediate joints for AC/PCC pavements, formalizing a repeatable automated faulting methodology, and establishing criteria for transverse thermal cracking that focuses solely on cracks in the pavement lane.

- AC and AC/PCC – Raveling.
- AC and AC/PCC – Bleeding.
- AC and AC/PCC – Debonding.
- AC – Potholes.
- AC – Block/transverse cracking.
- AC – Thermal cracking.
- AC/PCC – Transverse cracks (joint reflection).
- AC/PCC – Transverse cracks (jointed intermediate).
- PCC – Surface deterioration (medium and high severity).
- PCC – Faulting.
- PCC – Pressure damage – spalls.

Additionally, initial evaluations and subsequent reviews with vendor and ODOT raters indicate that, following optimization, vendors will be unable at this time to exceed 50 percent correlation with ODOT ratings. Again, it may be possible to greatly improve the DSE correlations of a few of these distresses. For example, developing more consistent positional criteria for edge cracking or removing the requirement to identify pressure damage severity and extent after the distress has been patched would advance the correlation. However, primarily, ODOT cannot anticipate system vendors to provide acceptable correlations for these distresses.

- AC – Edge cracking.
- AC/PCC and PCC – Pumping.
- AC/PCC – Pressure damage (upheaval).
- AC/PCC – Corner breaks.
- AC/PCC – Punchouts.
- AC/PCC – Shattered slabs.
- PCC – Surface deterioration (low severity).
- PCC - Settlement.

It should be recognized that the capabilities of vendors to automatically identify pavement distresses using 3D imaging and sensor technology increases daily and is being implemented in different ways and at different schedules among the vendors.

Pathway has developed and is employing an array of automated DSE identification software solutions using machine artificial neural networks. Using artificial neural network training, calibrated algorithms, and computer vision tools allows them to quickly adjust and rerun their search routines, based on discussions with and clarifications provided by agency raters. In their standard approach, Pathway completes a suite of automated evaluations and conducts a limited manual review of the flagged distresses. Their DSE correlations with ODOT raters, although limited by an incorrect understanding of edge crack, patch, and reflective transverse crack identification, averaged 14.2 percent.

Fugro is currently developing automated distress identification and is currently using an extensive system of manual ratings and reviews that includes detailed training, evaluation, and quality reviews. For the near future, their processing of ODOT data would primarily be accomplished through manual review. Therefore, short-term changes in rating methods, based on ODOT clarification, could not be rerun quickly with this methodology. However, intense manual reviews can be beneficial as they tend to eliminate obvious discrepancies that partially reviewed automated approaches may miss. Further, Fugro's automation tools can be expected to greatly increase in the near future.

Mandli primarily employs the DSE identification capabilities of the Pavemetrics software as the backbone for their distress reviews. Using this software, for this project they manually evaluated and recorded distresses for all of the ODOT test sites. However, Mandli prefers not to replicate this intense manual survey approach on ODOT's network of pavements. Instead, they suggest that ODOT simplify data collection by focusing attention on automated collection of standard distresses.

8.2 COSTS

Primary costs associated with transition to automated data collection and semi-automated data include that of annual data collection, processing, and reporting. Based on the vendor-supplied estimates listed in tables 17-21 and an assumed 3 percent discount rate, ODOT can anticipate the approximate equivalent uniform annual costs listed in Table 30 for data collection and processing. The costs for the options that upgrade current ODOT equipment and combine the Technical Services group work with the Pavement Evaluation team are not provided.

Table 30. Estimated EUAC of collection and processing options.

Option	Description	EUAC
1	ODOT purchases system, collects, and processes data.	$1,056,000
2	ODOT purchases system and collects data. Vendor processes data.	$1,787,000
3	Vendor collects data. ODOT processes data.	$1,472,000
4	Vendor collects and processes data.	$2,135,000
5	ODOT collects and processes data according to current procedures.	$386,000

Several additional expenses can be expected in association with the process of transition. Estimated person hours necessary for these activities are listed in Table 30. Assuming $50/hour employee compensation, the total estimated cost of these additional transition activities may exceed $175,000.

It is anticipated that the total hours required for ODOT to transition to automated or semi-automated DSE identification is a total of one person year in addition to the hours required for procurement of vendor services and the cost of dual data collection during the transition period. This work could be performed under a research project or can be conducted with ODOT staff, but regardless will require the detailed knowledge and guidance of ODOT's PCR team.

Financially, the option of ODOT retaining their current manual approach offers the least monetary expense. If ODOT transitions to automated distress image collection, costs are minimized if ODOT collects and processes the data in house (option 1). Additionally, if the current ODOT profiling system is retrofitted, the cost of option 1 is further reduced. However, the factors listed below also should be considered.

Table 31. Estimated ODOT person hours associated with additional transition activities.

Item	Description	ODOT hours
1	Vendor procurement	80
2	Vendor distress identification optimization	160
3	Revisions to distress ratings and update of the Distress Manual	240
4	Establishment of QC/QA program	120
5	Maintenance of annual QC/QA program (annually)	120
6	Modification of Pavement Management System decision trees	160
7	Updates of PMS performance models	1,000
8	Dual collection of distress data by vendor/ODOT raters (2 yrs, 2 districts	600
9	Development of correlations between manual and semi-automated	240

8.3 PRODUCTIVITY

ODOT's manual DSE data collection and processing currently is completed in about 10 months by three full-time employees and one part-time technician. For options 1, 2, and 3, ODOT would need to provide about 6,500 person hours for collection and 7,000 hours for processing. If ODOT maintains the current number of project staff, the estimated number of weeks required for full-scale collection and processing are shown in Table 32. It can be noted that ODOT data collection using a purchased system would not allow ODOT to complete their annual distress analysis. Productivity rates of options 1 and 2 can be improved by ODOT's extending the work week for field technicians or rotating field technicians to allow for continuous data collection. If ODOT technicians collect continuously for 10-hour days, seven days per week, annual data collection is estimated to be completed in 46 weeks. This process would require about one additional full-time employee.

ODOT data processing and DSE identification for options 1 and 3 also would not be feasible with the current number of ODOT technicians, as table 32 indicates. Four full time ODOT raters would be necessary to complete the data processing within 10 months. As a result, completion of option 1 within 10 months is estimated to require two additional ODOT employees and options 2 and 3 necessitate one additional technician.

If additional ODOT technicians are employed and an extended work week initiated, the total estimated completion time for option 1 would be 50 weeks. Options 2 and 3 would require about 49 and 46 weeks respectively. Vendor collection and processing for option 4 is expected to require about 28 weeks to complete.

Table 32. Average full-scale production estimates (weeks).

Activity	Option 1	Option 2	Option 3	Option 4
Data collection	60 (1 veh.)	60 (1 veh.)	20 (2 veh.)	20 (2 veh.)
Data processing and QC	93 (1-3 raters)	15	58 (3 raters)	15
Total completion time	98	68	66	28

8.4 POTENTIAL BENEFITS AND RISKS

Depending on the selected option, transitioning to semi-automated 3D data collection and DSE analysis would have several benefits, including:

- Increased rater safety.
- Improved data accuracy for certain DSEs (e.g., rutting and faulting).
- Enhanced timeliness of data collection and processing.
- Ability to easily track, review and reprocess historical data and images.
- Ability to collect data compatible with AASHTO ME requirements.
- Ability to collect data compatible with HPMS requirements.
- District access to pavement images for project level reviews.
- Consistent, well defined methods for future automated DSE identification.
- District access to vendors for ancillary data collection.
- Ability to combine IRI, rutting, and asset collection with pavement distress ratings.

Transitioning to automated collection and semi-automated evaluation is expected to significantly reduce the safety risks experienced by ODOT distress raters. Although the accuracy and precision of several distress data ratings, following calibration, is expected to remain at a high level (e.g., rutting, faulting, and detailed counts of cracks, spalls, and patches), converting to semi-automated distress data processing presents several risks as well. The risks include:

- Losing the ability to record certain critical DSEs.

- Losing the ability to directly correlate with some historical PCR data.
- Uncertainty over the potential for successful modification of ODOT distress ratings, maintenance decision trees, pavement performance models, PMS processes, and district management reports.
- Increased annual collection and processing costs.
- Becoming tied to technological evolution that forces early equipment replacement.
- Difficulties associated with operational change.
- Loss of control due to dependence on a single vendor.
- Potential variability of vendor results year to year.
- Additional initial costs and personnel demands associated with procurement, calibration, and implementation of system.
- Additional costs associated with modifying the DSE ratings, distress manual, decision trees, pavement performance models, and PMS software.
- Breakdowns and long repair delays for ODOT-purchased equipment
- Vendors going out of business.

As noted above, limitations of current systems will require the modification, combination, or elimination of several distresses, severities, or extents. These changes will necessitate the revision of ODOT's distress collection processes, as well as their pavement management system, including decision trees, pavement performance curves, and management software.

A transition from manual to semi-automated pavement distress data collection and processing will significantly exceed the current level of expenditure. However, multiple benefits are associated with semi-automated systems, including those listed above.

Variability of vendor results from year to year is a reasonable concern, particularly with current manual procedures returning very consistent results. Two approaches can be used to address this apprehension. First, adequate attention must be paid to calibrating vendor ratings with ODOT results in the first year of the transition. If variations are sufficiently resolved for the revised set of DSEs, then little change will be required in the evaluations of subsequent years, reducing year-to-year variability. Additionally, vendors offering the highest level of calibrated automation can be expected to return the best year-to-year repeatability, because automation eliminates much of the variability associated with manual data review processes.

Although vendor financial status was not reviewed for this project, all participating vendors report strong demand for their services. In light of the anticipated MAP-21 requirements, future need for their services is expected to continue to rise.

9 RECOMMENDATIONS

This research provides a wealth of information for ODOT to consider, regarding a transition to semi-automated distress data collection. Factors internal to ODOT management may also direct the decision toward a specific option, although the research team is unaware of any such internal factors.

The following recommendations are provided regarding equipment selection, processing approaches, quality control, and implementation.

9.1 SUITABLE EQUIPMENT TYPES

Although vendors vary in their vehicle platform, forward camera type, and downward imaging systems, all of the 2D and 3D systems evaluated in this project appear capable of collecting pavement distress data adequate for automated and manual processing. The forward cameras employed by Fugro appear to provide better, less light-sensitive images than the other vendors. Only a very small percentage (< 0.1 percent) of images from all vendors is rendered unusable by low-light levels, and most of these could have been avoided by adjusting the time of collection. Downward cameras mounted on the Fugro and Mandli systems (5,600 Hz) provide the resolution necessary for analysis, while the Pathway cameras (3,000 Hz) showed visibly lower resolution. Therefore, ODOT might consider asking that Pathway adjust their 2D and 3D camera setting to 5,600 Hz or greater.

9.2 PROCESSING APPROACHES

Vendors differ greatly in their processing approach, ranging from manual, assisted by distress identification software, to highly automated systems, employing neural networks, complicated image search tools, and calibrated algorithms for distress identification. One vendor is moving toward a minimized approach of using only automated methods for collecting HPMS distresses. All vendors continue to progress in the automation of their distress identification processes.

If ODOT selects a vendor primarily utilizing manual distress identification methods, it is recommended that ODOT gain a full understanding of the automation to be developed and employed within the next three years. It is possible that the process of a vendor transitioning from more manual to automated identification may add slight inconsistencies from year to year. However, the complete manual review of all images associated with this process tends to eliminate any unreasonable ratings reported by automated distress identification software. Alternately, if a vendor employing more automated processing software is chosen, it is recommended that sufficient test site calibration against ODOT ratings and manual checks of pavement distress images be completed to ensure that systems and checks are in place to eliminate unreasonable ratings.

9.3 QUALITY CONTROL/QUALITY ASSURANCE

QC/QA approaches vary from vendor to vendor and agency to agency. NCHRP Synthesis 401 provides an excellent summary of State QC/QA activities and preferences (5). If ODOT selects the option for vendor collection and data processing, the vendors will complete the majority of QC activities, which should include at least the first nine activities listed in Figure 66. ODOT surveyors collecting and processing data in-house should follow the same QC/QA procedures.

Primarily, before official data collection, analysis criteria must be clarified and verified between the vendors and agencies. Vendors and agencies should calibrate all sensors prior to data collection and check sensor calibrations during data collection. For a selected portion of the first year's collection (100 to 2,000 mi) [160 to 3,219 km], vendors should compare and calibrate DSE ratings to ensure proper understanding and to develop any adjustments necessitated by semi-automated data collection.

Control segments should be selected and manually evaluated by ODOT raters prior to field survey collection. At regular intervals, the collection systems should survey the nearest control segment and review all automated distress output (e.g., rutting, faulting, and cracking). Significant differences from the baseline values should be identified and resolved.

The collecting agency or vendor should review the pavement images, distresses, and ancillary data daily and weekly. Software routines should be employed at least daily to check that images and distress data are complete and within reasonable ranges. It is also recommended that summaries of daily data, QC results, system settings, and randomly selected images be returned to the office for daily review. Weekly submittal of one removable hard drive to the main office for immediate segmenting and image QC is also suggested.

Following initial processing and QC, managers should employ software routines to verify data completeness, format, and range. Time-series visual and statistical comparisons of new and historical DSE and PCR data should also be conducted, to ensure year-to-year consistency. Other QC/QA methods listed in Figure 66 and described in NCHRP Synthesis 401 can be used if regular inconsistencies and bias are noted.

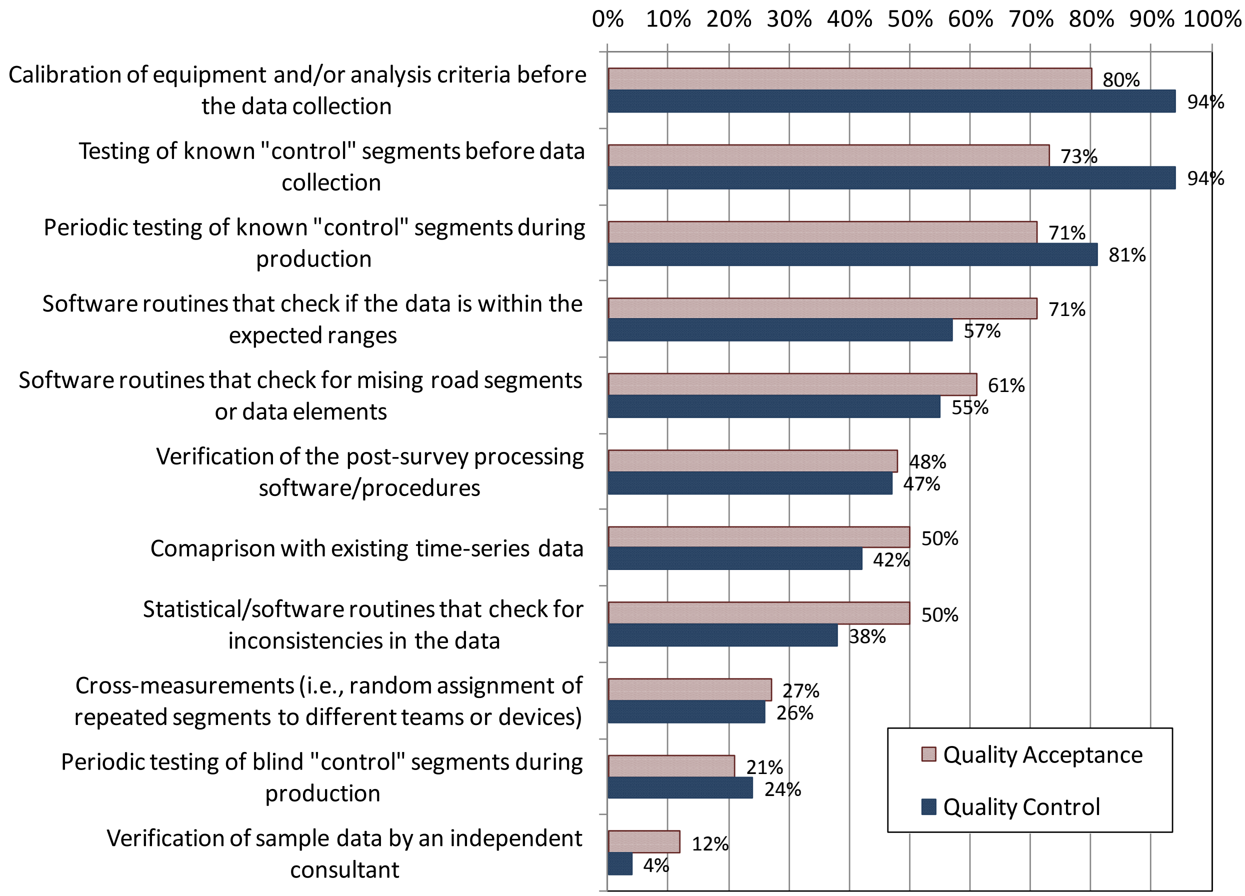


Figure 66. Percentages of agencies using each QC/QA activity (4).

Field operators should be adequately trained and certified by the vendors for data collection and QC review. Likewise, distress raters must be provided with detailed libraries of distress, severity, and extent images and descriptions linked to ODOT requirements. Then they must be trained in the unique aspects of evaluating ODOT pavement distresses. Regular and random QA reviews should be completed to ensure compliant and consistent practices.

10 IMPLEMENTATION PLAN RECOMMENDATIONS

10.1 OVERVIEW

The primary objective of this research was to investigate the current technology for automated and semi-automated collection and processing of ODOT's pavement condition and PCR data to determine if existing systems and rating methods are a suitable replacement for ODOT's current manual method. To that end, the researchers investigated the quality of vendor-collected data, along with the benefits and costs associated with a transition to semi-automated collection and processing. Although the scope of the project did not allow for in-depth consideration of factors such as departmental culture, labor, and political nuances, the following implementation plan is presented as a path to follow, should ODOT choose to transition to automated 3D system collection and semi-automated analysis.

Provided below are the detailed implementation steps.

10.1.1 Determine if Data Quality Potential is Sufficient

Initial evaluations of vendor-reported DSE data from 43 test sites indicate their ability to recognize the existence of ODOT-noted distresses 74.5 percent of the time. They accurately matched ODOT's severity ratings for 33.4 percent of the distresses and provided a perfect DSE match for 13.5 percent of ODOT-rated distresses. While such results would be considered less than adequate to support immediate transition, detailed review of vendor discrepancies indicates that additional training and detailed correlation with vendors can be expected to achieve high correlations for the DSE ratings of 13 distresses and moderate correlations for 16 distresses. These distresses are listed in section 6.1. If the ODOT requirements of nine of the DSEs of distresses for which moderately correlated distresses are slightly modified (rutting, potholes, block/transverse, thermal cracking, transverse cracks – reflection and intermediate, surface deterioration, faulting, and pressure damage), only minimal change to the overall distress rating system is anticipated.

This project's data quality summary also lists nine distresses for which the DSEs are not expected to achieve acceptable correlations. More major modifications, possibly even eliminations, would be required to resolve these limitations. It is possible that edge cracking correlations can be increased by focusing their identification to within designated lane positions. However, only a limited reporting of pumping, pressure damage, corner breaks, punchouts, and shattered slabs on AC/PCC pavements can be anticipated even with significantly increased manual review effort. Low-severity PCC surface deterioration cannot be adequately identified by the current systems.

Based on the above results, the research team continues to see sufficient potential for adequate data quality to move forward with implementation. Improvements necessary to reach optimum data quality can be accomplished in three ways. Initially, improvement can be achieved through minor vendor interactions with ODOT rating experts. Next, many DSE discrepancies will be resolved through more detailed training and correlation calibrations. Finally, several distresses will require modification of the distress manual requirements, alternate means of noting their effects, or elimination. Associated with these changes will be revisions of ODOT's maintenance decision trees, PMS models, and PMS processes.

According to normal market practice, moving forward with implementation would include developing an RFP and selecting a vendor. Following vendor selection, ODOT would train, calibrate, and verify the vendor's final capabilities. This approach includes the risk that the selected vendor may not meet ODOT's standard for final acceptance. To mitigate this concern, the RFP could include the option for ODOT to put the contract on hold or cancel the contract if acceptable levels are not met. In this case, acceptable levels and the methods to verify them should be clearly stated in the RFP to ensure competitive vendor bids. ODOT may also consider establishing a limited contract to determine acceptability with an option for expansion to full-scale testing.

10.1.2 Determine if Automated Data Collection is Desired

In addition to data quality, other factors must be reviewed and resolved before continuing with implementation. Vendors only collect images from one lane at a time, whereas ODOT raters review all lanes present at the site. Transitioning to a semi-automated system would effectively reduce the number of lanes included in the PCR evaluation. NCHRP Synthesis 401 notes that studies in Indiana have shown that, in terms of pavement smoothness, the difference between the driving lanes and passing lanes is statistically insignificant (5). However, variations in lane traffic and maintenance can result in lane-to-lane variations. ODOT can assure year-to-year consistency by specifying that vendors always evaluate pavements in the same lane and direction. This requirement is not unusual for current vendor contracts.

Vendors will also be unable to cost-effectively collect images from widened lanes (greater than 14 ft [4.2 m]), as occurs primarily on Ohio's urban roadways. This limitation may result in underreporting of distresses, severities, or extents. ODOT may consider the scope and effect of this reduction and determine whether the effect will require remediation. The research team found no reports from other agencies indicating concern about this issue.

This research indicates that modification of ODOT's pavement DSE elements will be necessary to adjust for current limitations of vendor systems or to minimize the manual effort required for data processing. This adjustment will also result in changes to ODOT's Priority and General System Decision Trees. Given the current contracting environment, ODOT may not have full understanding of any necessary adjustments until after contract award and vendor verification. As noted above, ODOT may consider placing a caveat in the contract allowing contract suspension or cancellation if results prove unsatisfactory.

Finally, ODOT currently reports aggregate pavement distress ratings for pavement sections that are 0.03 to 13 mi (0.05 to 20.9 km) in length, using linear referencing. Automated data collection systems can replicate this approach, and this method would be necessary if both

ODOT and vendor data were initially collected and compared. However, for subsequent network analysis, ODOT may consider converting to more consistent sample groups that can be dynamically combined for planning construction.

10.1.3 Select a Purchase or Contracting Option

If ODOT concludes that transitioning to semi-automated collection and analysis is optimal, the type of contract must be selected. Details of the different options are described in the report, including the EUAC summary, shown in Table 33.

Table 33. Estimated EUAC of collection and processing options.

Option	Description	EUAC
1	ODOT purchases system, collects, and processes data.	$1,056,000
2	ODOT purchases system and collects data. Vendor processes data.	$1,787,000
3	Vendor collects data. ODOT processes data.	$1,472,000
4	Vendor collects and processes data.	$2,135,000
5	ODOT collects and processes data according to current procedures.	$386,000

Additional factors, such as productivity rates, employee availability, timeliness, ability to expand distress and asset collection, system availability, and responsibility for resolving problems, should also be considered and optimized.

10.1.4 Develop an RFP for Purchase or Contract

If ODOT selects option 1 or 2 in step 3, an RFP for equipment purchase must be prepared. This RFP should include, at a minimum, the necessary ODOT contracting details and the following detailed information:

- Schedule of events.
- Scope of work.
- Proposal requirements and format.
- Proposal evaluation criteria and award process.
- Technical specifications.
- Information technology requirements.
- Cost proposal template – including standard and optional items.

An example equipment purchase RFP is shown in Appendix I.

If ODOT chooses options 2, 3, or 4, an RFP for collection and/or data processing services will be required. ODOT should include contracting details along with the following items:

- Schedule of events.

- Scope of work – Include the system accuracy (vs. ODOT raters) and repeatability requirements. Describe the expected pilot optimization and evaluation process to achieve maximum data accuracy. Note required levels of accuracy and repeatability.
- Terms of contract – Include the contract length and options for renewal or extension. Note whether lump sum or unit price submissions are required. Note any allowances for cost increases associated with contract renewal or extension. Note any caveats for contract continuation based on defined levels of effectiveness.
- Proposal requirements and format – including a detailed work plan, company and project personnel experience, and a detailed vendor QC plan.
- Evaluation criteria and award process – Include a description of plans for a Pilot Evaluation of the maximum level of correlation with ODOT raters.
- Special contract terms and conditions.
- Location referencing system requirements.
- Data delivery format.
- Cost proposal template – including standard and optional items.
- Work statement – describing in detail the means by which the contractor will meet the contract scope of work, accuracy requirements, and deadlines.

Several examples of service contract details are included in Appendix H.

10.1.5 Implement a QC Program

Whether ODOT or a vendor collects distress data and images, a comprehensive QC program is required to achieve the highest quality of data. Basic aspects of a viable QC program are listed below; however, many additional strategies, along with simple operator and reviewer attentiveness, can also affect data quality. ODOT should obtain a detailed QC plan from the selected vendor, or prepare their own, if ODOT collects DSE data. ODOT should request regular reporting and verification of the completion of all QC activities. This report should also include collected items that have not yet been completely reviewed.

- Regular operator training – The plan should ensure that field equipment operators are trained and checked at least annually through documented procedures and tested to ensure their competency. Particularly, operators must be familiar with system calibration, system checks, system warnings, data quality review, system image review, system backup, reporting requirements, and troubleshooting procedures. Certification procedures and requirements will help to ensure high operator competency.

- Regular reviewer training – It is critical that image distress reviewers are properly trained, updated, tested, and verified for their approach to pavement distress identification. ODOT or the vendor should prepare and implement training guides and programs for this purpose. Additionally, vendors or ODOT should assist raters with visual, verbal, and written assistance within their image review software, with which reviewers should be familiar.

- Regular equipment calibrations – ODOT and/or vendors must verify calibration of elevation sensor components, DMI, downward line-scan cameras, GPS, etc. Manufacturer requirements should be completed and reported, at a minimum.

- Regular equipment checks – Operators must regularly check the condition of the support vehicle (fluids, tires, lights) and must frequently check forward and downward images for contrast and completeness, surface profile and rutting data for reasonableness, and positioning and distance systems for accuracy. Some manufacturers have built many of these checks into their software, and one manufacturer provides voice commands when data problems are encountered or test site boundaries are encountered.

- Regular field data checks – Many manufacturers have incorporated software checks to ensure that road segments and data elements are not missing. Others check for data within reasonable range requirements. These must be completed, reported, and verified by supervisors.

- Regular field image checks – Although equipment operators are not able to visually inspect all images during data collection, as complete an inspection as possible should be done by the operating assistant. One additional option is to send randomly selected images to ODOT or the vendor's main office for daily review.

- Regular image and data backup – All participating vendors simultaneously record data to two hard drives during data collection, providing instantaneous backup. One of these disks can be sent to the main office for review at the end of the week, keeping the remaining drive in the vehicle. During the week, at least one of these drives should be taken into the operator's hotel room to ensure that vehicle theft or other damage does not eliminate backup data.

- Regular full image reviews – As soon as hard drives are returned to the main office, trained reviewers should review the entire set of images to ensure that data completeness and quality requirements are met. Results should be reported and discrepancies resolved.

- Regular distress rating checks – After raters complete the distress ratings, QC managers should complete regular random checks to ensure DSE rating quality. All discrepancies should be recorded and a record of resolutions and subsequent rater training should be reported.

- Regular control section checks – Vendors or ODOT surveyors should evaluate known control sections before, during, and after data collection to ensure repeatability and reproducibility. These sections should have been recently evaluated by experienced vendor or ODOT raters and represent the typical DSEs encountered on ODOT roadways.

If discrepancies fall outside typical confidence intervals, the surveys since the last successful control check are called into question.

- Regular reporting – Reporting requirements should be stated in the vendor or ODOT QC program plan. This should include verification of completion of all QC activities and records of all problems encountered and resolutions enacted.

The QC plan should include the following essentials:

- Clear descriptions of all responsibilities.
- Documented manuals and procedures.
- Training requirements and methods for survey personnel.
- Defined procedures for equipment calibration, certification, and inspection.
- Verification procedures for ensuring equipment and process quality.
- Confirmation criteria for data reasonableness, consistency, and completeness.

10.1.6 Optimize Accuracy

Improved correlations between vendor and ODOT DSE ratings will be necessary to achieve satisfactory vendor data quality. After the vendor is selected, the following steps should be completed to optimize vendor accuracy:

1. Review and resolve with the vendor all rating methodology items raised in this research.
2. Review differences between recorded ODOT and vendor distress ratings, and resolve all discrepancies satisfactorily.
3. Develop a modified semi-automated pavement distress rating guide.
4. Account for the effect of any changes in the distress guide on the General Decision Tree and performance modeling.
5. Ensure the vendor has incorporated all resolutions and clarifications into their distress collection and rating practices.
6. Conduct initial field verification, calibration, and further optimization of vendor accuracy.

Step 6 can be accomplished in several ways. Some agencies have asked vendors to collect from 50 mi (80 km) up to 2,000 mi (3,220 km) of pavement images and analyzed distress data. These data are either compared with comparable agency manually collected distress data or results of image reviews conducted by agency raters. Where discrepancies exist, vendors should be asked to adjust their processes and confirm the success of their revised methodology.

The research team suggests that the vendors collect 100 miles (160 km) of forward and downward images, which will be reviewed by ODOT for image quality, distress clarity, positioning accuracy, and missing data. Accuracy of the global positioning and information and linear referencing results will also be reviewed. ODOT raters will have already manually evaluated these sections just prior to vendor data collection.

If image quality and positioning accuracy meet defined ODOT acceptance levels, the vendor can be released to continue to collect distress images. However, if the contract is suspended or terminated during the accuracy review and optimization, ODOT may choose to reimburse only up to 500 mi (805 km) of data collection.

Next, the vendor will rate DSEs on the first 100 miles (160 km) of collected data. ODOT will compare these distress, severity, and extent ratings with their recent manual survey results and meet with a qualified vendor representative to resolve discrepancies. After these discrepancies are resolved, the Automated Distress Rating Guide is modified, and the vendor has updated their rating processes, the vendor will be allowed to rate the next 100 miles (160 km) of pavement. ODOT raters will also evaluate the DSEs at these sites. This process will be repeated until the maximum accuracy is achieved.

At this point, ODOT will review the final set of comparison results to determine whether vendor rating accuracy is sufficient to achieve ODOT pavement management requirements. Options for revising the Distress Guide and/or the General Decision Tree may also be considered at this time.

When satisfactory data quality has been achieved, the vendor will be released to collect the remaining pavement images, following the established QC procedures.

10.1.7 Adjust Pavement Distress Reporting Methods

In addition to noting the undocumented distress rating details reported previously, three types of adjustments to the pavement distress reporting method are expected to be necessitated by a transition to semi-automated pavement distress identification. First, even with distresses that display perfect correlation with ODOT rating, modifications will be needed to account for the differences in collection approach. For example, to assist in project management, ODOT may ask vendors to record the numbers of patches at each severity within a section, or they may elect to ask vendors to report the total length of crack seal deficiency to assist in maintenance planning.

When distresses correlate moderately with ODOT ratings and vendor reporting methods can be modified to consistently quantify the distress in an alternative manner, revised distress definitions will need to be prepared. Also, the distress weightings used in PCR computation must be evaluated and modified, to account for differences in the relative pavement condition effect generated by the DSE description modification.

Finally, distresses (severities and extents) for which vendors are unable to achieve acceptable accuracies and correlations with ODOT ratings must be replaced with alternative DSE ratings, accepted with a reduced level of correlation, or eliminated from ODOT's future pavement distress inventory. If alternate distress ratings with reduced correlation are selected, the revised effect on pavement performance needs to be estimated, as adjusted distress weighting factors are developed. Should the distress or a severity level be eliminated, all remaining distress weights may need to be revised to account for the loss. This process requires an iterative approach that results in a new PCR2 statistic that closely matches the structural and overall ratings obtained using the current PCR methods. Collecting distress data from at least one district using both the current and revised DSE identification methods would improve the success in developing weighting factors and an index that correlates well with the current system, as discussed below.

10.1.8 Implement QA Program

Whether ODOT or a vendor collects or analyzes the pavement images, a QA plan must be developed and followed. While the purpose of the QC plan is to assess and adjust data collection processes, a QA program is intended to assure ODOT that the quality of the purchased data is maintained at an acceptably high level. While the intent is different, in many ways the methods for QA review are similar to those of QC operations. The following approaches are commonly used for QA programs and recommended for ODOT implementation:

- Control site testing – ODOT should evaluate the ability of the vendor to accurately identify the DSEs at random "blind" control sections. These sections should be located such that they are surveyed at regular intervals during vendor data collection. Sites should be representative of typical DSEs encountered on ODOT roadways. Experienced ODOT raters should evaluate the lanes and directions of these sites evaluated by the vendor. Results of ODOT raters and the vendor on these control sections should be compared as soon as feasible. If discrepancies fall outside defined ODOT confidence intervals, the surveys since the last successful control check are called into question.
- Verification site testing – Verification site testing should be used to determine repeatability and reproducibility. The vendor should be directed to repeat measurements of the same tested sites using the same equipment before, during, and following data collection. This allows for verification of repeatability. If the vendor employs more than one data collection system, the vendor should be directed to also repeat measurements of the same verification sites using both collection systems to evaluate reproducibility.
- Random data quality checks – In 2009, 34 percent of agencies completed random checks of more than 10 percent of the submitted distress data using database and/or distress image checks. ODOT should consider establishing a program of random data quality checks.
- Database checks – ODOT should incorporate software checks for 100 percent of their newly submitted database, searching for missing data, misidentification, incorrect segment sizes, improper format, and out of range discrepancies.
- GIS-based quality checks – The visualization capabilities associated with GIS systems allows ODOT to visually check submitted data for missing sections, inconsistent section locations, and unexpected changes in pavement conditions. In conjunction with distress

data from previous years, this tool could be directed to visually flag unusual distress data changes. ODOT should consider incorporating this type of check into their QA program.

- Time history comparisons – In a recent survey, approximately half of responding agencies reported comparing time histories to evaluate and ensure pavement DSE data quality. While this approach allows reviewers to search for discrepancies in individual sections, it also has been used to identify the number of pavement sections in various condition ranges over an extended time period. This assists in highlighting possible collection difficulties.

10.1.9 Modify PMS Decision Trees and Performance Models

The logical decision trees used by ODOT to select appropriate maintenance and rehabilitation keys on each section's reported PCR level, its structural deduct value, and the reported distress, severity, and extent present. Current decision trees are included in Appendix B. If a revised set of DSE values does not match current ODOT values, the entire decision process can be affected. Limitations of current vendor capability to rate ODOT DSEs indicate that these decision trees must be modified, if a transition is made.

These modifications should be finalized after vendor correlations have been optimized, adjustments have been made to distress definitions, and infeasible distresses have been eliminated. Additionally, data from at least one district should be collected using the current and revised rating methodology. This information can be used to adjust the decision thresholds and to define key distresses, severities, and extents.

A portion of the performance models ODOT uses to estimate the formation of additional severities and extents over time will require modification during a transition. At least two years of distress data collected using both current and revised methods will be needed to adjust these models. The data must be representative of all state sections containing the distresses to be remodeled. Therefore, information from all or portions of at least three districts may be necessary, as a minimum. These modified decision trees and performance models must then be incorporated into ODOT's Deighton pavement management software.

10.1.10 Develop Correlations Using a Dual Collection System

Continuity in the PCR distress rating will be essential to evaluating and reporting the historical condition of ODOT's pavements. Transition to semi-automated distress data analysis and a revised PCR index is expected to interfere with this continuity. Therefore, to provide an unbroken record of ODOT's pavement condition, ODOT would need to develop an effective correlation between the currently collected distresses, severities, extents, and PCR ratings and new system statistics. This can be accomplished using a dual collection system wherein both the current ODOT rating system and the final ODOT rating method are employed in evaluating the same representative pavement sections. The scale of this dual collection system can be adjusted according to ODOT's funding level, but should include sufficient data to represent, at a minimum, all critical DSEs included in the current and revised distress rating systems. Implementation of this dual collection system and correlation could be accomplished through an upgrade of the current ODOT measuring system or through a small vendor contract.

10.2 IMPLEMENTATION TIMEFRAME

Several factors must be considered in selecting a timeframe, including:

- Equipment requires about three months to build (an upgrade to Pathway system requires 2 weeks).
- A services contract should ideally be awarded three months prior to data collection.
- ODOT collection typically begins in April.

As a result, the following implementation timeframe is suggested if ODOT purchases equipment and processes its own data.

1. Develop and post equipment Request for Proposals (month 2).
2. Receive vendor proposals (month 4).
3. Award equipment contract (month 6).
4. Receive ODOT equipment QC recommendations from vendor (month 6)
5. Receive equipment delivery and operator training (month 8).
6. Install workstations and conduct distress rater training (month 8).
7. Establish initial ODOT QC/QA plans (month 8).
8. Begin field optimization data collection and processing – (1-3 districts, current and new procedures) (month 9).
9. Resolve rating discrepancies with help of vendor (months 9-11).
10. Conduct QC/QA procedures and resolve issues (months 9-11).
11. Determine the system's final DSE rating capabilities ((month 12).
12. Reevaluate the transition effects on PCR, decision trees, and PMS program (months 12-13).
13. Establish extended full-scale contract, based on reevaluation (month 14).
14. Revise distress ratings and update Distress Manual (month month 15).
15. Establish final QC/QA program (month 15).
16. Collect full scale distress data using new system (months 15-24).
17. Collect partial or full-scale manual distress data (dual collection as needed) (months 15-17).
18. Develop correlations between current and automated DSE and PCR ratings (months 18-25).
19. Modify PMS decision trees (months 16-26).
20. Modify PMS performance models (months 27-42)

If ODOT procures collection and processing services from a vendor, the following implementation timeframe is suggested:

1. Develop and post services RFP (month 2).

2. Receive vendor proposals, including QC commitments (month 4).
3. Award services contract (month 5).
4. Receive/finalize vendor QC plans (month 5).
5. Finalize ODOT QA plans (month 5).
6. Begin field optimization data collection and processing – (1-3 districts, current and new procedures) (month 6).
7. Resolve rating discrepancies with help of vendor (months 6-9).
8. Conduct QC/QA procedures and resolve issues (months 6-9).
9. Determine the system's final DSE rating capabilities ((month 9).
10. Reevaluate the transition effects on PCR, decision trees, and PMS program (months 9-10).
11. Establish extended full-scale contract, based on reevaluation (month 11).
12. Revise distress ratings and update Distress Manual (month month 12).
13. Establish final QC/QA program (month 12).
14. Collect full scale distress data using new system (months 12-21).
15. Collect partial or full-scale manual distress data (dual collection as needed) (months 15-17).
16. Develop correlations between current and automated DSE and PCR ratings (months 18-22).
17. Modify PMS decision trees (months 15-23).
18. Modify PMS performance models (months 24-36).

Note that the implementation timeframe should establish a contract that allows for collection and processing of the first year's data within seasonal and analysis limitations.

10.3 EXPECTED BENEFITS OF IMPLEMENTATION

Several benefits associated with implementation are expected:

- Increased rater safety.
- Improved data accuracy for certain DSEs (e.g., rutting and faulting).
- Enhanced timeliness of data collection and processing.
- Ability to easily track, review, and reprocess historical data and images.
- Ability to collect data compatible with AASHTO ME requirements.
- Ability to collect data compatible with HPMS requirements.
- District access to pavement images for project level reviews.
- Consistent, well defined methods for future automated DSE identification.
- District access to vendors for ancillary data collection.
- Ability to combine IRI, rutting, and asset collection with pavement distress ratings.

Additionally, implementation will provide pavement distress details necessary for HPMS and most likely for MAP-21 requirements.

10.4 RESOLUTION OF POTENTIAL RISKS AND OBSTACLES

The potential risks and obstacles to implementing more automated data collection methods are summarized in Table 34. This table also includes suggestions for resolving these issues.

Table 34. Implementation risks, obstacles, and possible resolutions.

Risks and obstacles	Possible resolutions
Losing the ability to record critical distresses	Work with vendor to optimize distress identification and ratings that match ODOT criteria. Determine which distresses, severities and extents are critical. Establish in the contract ODOT's ability to delay or cancel implementation if acceptable levels are not met on critical items.
Losing the ability to correlate with historical PCR data	Particularly with AC/PCC pavements, this may be an issue. Possibly the weighting of automatically measured distresses (e.g., transverse cracking) could be adjusted to match that of unjointed, jointed, and intermediate cracking.
Uncertainty over successful modification of distress ratings, decision trees, performance models and district PMS management.	The dual collection and comprehensive transition processes described herein should allow ODOT to successfully adopt an advanced collection and processing system. It also is designed to permit ODOT to carefully adjust their distress fields and ratings and effectively update their PMS toolbox.
Increased collection and processing costs	Elevated costs can be partially offset by the State's increased ability to combine data collection efforts using automated systems. Modern systems also will allow ODOT to collect much asset information that is expected to benefit anticipated MAP-21 and growing HPMS reporting requirements. These systems also allow for project-level evaluations using online images, reducing the need for site visits by project engineers. If ODOT selects a vendor offering a high level of automation, processing costs should be reduced and passed along to ODOT.
Becoming tied to technological evolution	The concern that technological changes will limit ODOT capabilities is viable. However, if ODOT continues to employ modern technology to more completely meet their demands and desires, this becomes a continuing benefit.

Table 35. Implementation risks, obstacles, and possible resolutions (continued).

Risks and obstacles	Possible resolutions
Difficulties associated with operational change	The effects of operational change can be minimized by simplifying the transition process and assisting ODOT employees with adjustments to new critical roles. The expertise of ODOT employees will be critical, should ODOT transition to automated systems. The need for their expertise will continue with QA verification and ongoing data quality reviews.
Loss of control due to dependence on a single vendor	ODOT can address this concern in the RFP and contract award process by evaluating which vendors can be expected to best cooperate and assist ODOT in achieving their goals.
Potential variability of vendor results year to year	If the optimization and pilot study maximization processes are carried out completely, vendor variability will be minimized. Vendors with calibrated, more automated distress identification software can be expected to achieve greater year-to-year repeatability.
Additional costs and personnel demands associated with procurement and transition	Many of the additional costs and demands are listed below. While much of the time-consuming effort has been completed by the current study, transition efforts can be further minimized by selecting an analysis service contract that places responsibility on vendors for achieving optimal quality and correlation. A third party contractor could be used to conduct the QC/QA operations as recommended by NC DOT.
Additional costs associated with modifying DSE descriptions, PCR ratings, distress manual, decision trees, performance models, and PMS software.	The significant costs associated with transition to an automated system can be minimized by optimized planning, big-picture engineering, and equipment sharing. ODOT can accomplish this by building on the current research results to optimize identification of critical DSEs through specific vendor training and focused field testing. Additionally, to address DSEs requiring modification, ODOT can engineer modifications to distress identification, rating, and pavement management routines based on a global understanding of key pavement distresses, their interactions and appropriate maintenance and rehabilitation responses. Finally, the ODOT Research group may find ways to reduce costs by sharing with other departments the equipment and expanded services available with automated systems.

Table 36. Implementation risks, obstacles, and possible resolutions (continued).

Risks and obstacles	Possible resolutions
Breakdowns and long repair delays for ODOT-purchased equipment	If ODOT were to purchase equipment, this concern could be addressed by a maintenance contract in which the contractor ensure that the system will be returned to functionality within a designated time limit. That contract could also require annual maintenance and inspection by the vendor.
Vendors going out of business	Participating vendors have been collecting DSE data for many years. ODOT may consider vendor experience, financial status, and related projects under contract in their selection of a viable vendor.

10.5 EVALUATE POTENTIAL EFFECTS ON ODOT AND OTHER ORGANIZATIONS

If ODOT transitions to vendor-collected and vendor-processed pavement DSE data, they are expected to experience the following effects:

- Long-term elimination of safety concerns for ODOT raters traveling at reduced speeds and stopping along roadsides.
- Greater ability to implement HPMS, AASHTOWare Pavement ME, and possibly MAP-21 requirements.
- Capacity to combine pavement distress evaluation with rutting, IRI, and asset evaluations (including signs, markings, shoulders, bridge clearance, pavement slope, grade, curvature, curb and gutter, pavement thickness, pavement texture/friction, etc.).
- Effort required to prepare a comprehensive RFP and to evaluate vendor responses.
- Effort required to optimize vendor accuracy during the final calibration.
- Effort needed to update the current manual to a Guide to Automated Pavement Distress Evaluation.
- Effort needed to modify ODOT decision trees and pavement management processes to account for the required changes in DSE data collection.
- Effort demanded to develop and implement ODOT QA reviews and blind control section evaluations.
- Time savings by allowing project level evaluations to be conducted remotely using collected images. These images can be viewed year-to-year, allowing for DSE progression rates to be evaluated.
- Time savings through the ability of district and local managers to review images of all roadways over the internet.

- If the profiler currently used by the ODOT Office of Technical Services is retrofitted to include distress identification data, coordination will be necessary to ensure completion of required activities by both offices.

No effect on other organizations is anticipated.

10.6 EVALUATE IMPLEMENTATION COSTS

In addition to the option costs listed in step 3, ODOT can anticipate increased initial costs associated with the activities listed below:

- Preparing a comprehensive RFP and evaluating vendor responses.
- Optimizing vendor accuracy during the pilot study.
- Updating the current manual to establish a Guide to Automated Pavement Distress Evaluation.
- Modifying ODOT decision trees.
- Revising ODOT pavement management processes (including pavement performance models).
- Developing and implementing ODOT QA reviews and blind control section evaluations.

10.7 EVALUATE ONGOING DATA QUALITY

With any transition comes the risk of a decline in data quality. Implementation of ongoing system calibration, QC, and QA tasks seek to eliminate this risk and ensure ongoing data quality. In conjunction with these tasks, ODOT should establish ongoing statistical checks for consistency and reasonableness in reported DSEs for each evaluated site. Linking reported distress data with pavement rehabilitation and maintenance records will simplify the process by flagging sites where changes can be anticipated.

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APPENDIX A—DSE COMBINATIONS (2011-12)

Table A-1. Number of ODOT 2011 AC segments with distress, severity, and extent combinations.

Code	Distress	LO	LF	LE	MO	MF	ME	HO	HF	HE	O	F	E
1	Raveling	1498	1436	1625	1047	311	97	21	15	1			
2	Bleeding	5	1	2	143	30	15	4	3	4			
3	Patching	558	2	2	444	34	14	435	20	5			
4	Debonding	329	13	4	69	7				1			
5	Crack seal damage										1069	616	2396
6	Rutting	1431	951	572	386	165	17	27	3				
7	Settlement	617	8	3	120	8	3	11	1				
8	Corrugation												
9	Wheelpath cks.	1222	339	12	850	217	32	325	106	1			
10	Block cks.	1897	696	125	501	251	90	489	286	156			
11	Longit cracks	1122	891	105	1136	1006	127	204	381	49			
12	Edge cracks	833	227	87	939	300	119	424	119	21			
13	Random cks.												
14	Thermal cks.	627	107	42	578	316	90	51	45	18			
15	Potholes	4			5								

Table A-2. Number of ODOT 2011 PCC segments with distress, severity, and extent combinations.

Code	Distress	LO	LF	LE	MO	MF	ME	HO	HF	HE	O	F	E
1	Surface distress	282	85	74	6	15	9						
2	Popouts												
3	Patching	57	2		44	4	1	49	25	25			
4	Pumping										15		
5	Faulting	82	18	4	35	19	2	5	1				
6	Settlement	31			5	1		1	1				
7	Tvs. joint spalls	227	32	10	26	7		5	2	2			
8	Joint seal												
9	Pressure damage										88	27	30
10	Tvs. cks. >20'	36	15	20	42	32	52	3	12	15			
11	Longit. cracks	77	5	2	66	6	2	20	2				
12	Corner breaks	18		1	32	3	1	22	3				
13	Lgt. joint spalls	150	17	18	36	8	1	20	3	4			
14	Tvs. cks. <20'	25	3	3	18	1	8	8	4	2			

Table A-3. Number of ODOT 2011 AC/PCC segments with distress, severity, and extent combinations.

Code	Distress	LO	LF	LE	MO	MF	ME	HO	HF	HE	O	F	E
1	Raveling	1295	1283	1359	511	97	60	619	282	162			
2	Bleeding	4	1	3	41	17	2	2					
3	Patching	435	8	2	550	72	46	654	91	37			
4	Debonding	424	22	10	82	12	6	2					
5	Rutting	1267	1101	610	363	165	37	28	10	5			
6	Pumping										314	11	
7	Shattered slab	7			6	1		5	1				
8	Settlement	238	5	1	33	6		9					
9	Tvs. cks. – unj.	342	16	3	400	87	36	80	24	6			
10	Tvs. cks. – refl.	618	279	222	643	711	695	77	361	247			
11	Tvs. Cks. – int.	936	244	144	727	427	437	36	80	76			
12	Longit. cracks	672	884	185	765	1224	370	132	660	185			
13	Pressure damage	860	262	138	345	102	43	22	6				
14	Crack seal damage										1156	828	2466
15	Corrugation												
16	Corner breaks	151			182	15	1	37	10	2			
17	Punchouts		1		94	20	4	23	7	4			

Table A-4. Number of ODOT 2012 AC segments with distress, severity, and extent combinations.

Code	Distresses	LO	LF	LE	MO	MF	ME	HO	HF	HE	O	F	E
1	Raveling	1464	1496	1620	1165	307	84	39	14	1			
2	Bleeding				148	36	15	3	3	5			
3	Patching	516	5	1	447	27	14	432	40	6			
4	Debonding	379	8	5	60	6				1			
5	Crack seal damage										982	597	2390
6	Rutting	1562	940	527	407	154	23	34	4	2			
7	Settlement	583	6	3	103	4	2	10	2				
8	Corrugation												
9	Whp. cracks	1190	300	18	892	214	36	294	85	1			
10	Block cks.	1813	601	120	552	205	76	537	289	166			
11	Longit cracks	1047	738	99	1105	1140	165	195	406	60			
12	Edge cracks	762	181	77	921	312	123	413	135	27			
13	Random cks.												
14	Thermal cks.	591	87	33	623	261	102	71	64	19			
15	Potholes	3			1								

Table A-5. Number of ODOT 2012 PCC segments with distress, severity, and extent combinations.

Code	Distresses	LO	LF	LE	MO	MF	ME	HO	HF	HE	O	F	E
1	Surface distress	288	81	79	5	13	10		2				
2	Popouts												
3	Patching	62	2		50	1	4	50	24	29			
4	Pumping										17		
5	Faulting	74	18	3	42	20	2	7	1	1			
6	Settlement	33			6	1		1	1				
7	Tvs. joint spalls	234	37	10	24	8		7	2	2			
8	Joint seal damage												
9	Pressure damage										96	40	31
10	Tvs. cks. >20'	37	14	20	41	32	54	2	11	16			
11	Longit. cracks	80	3	2	67	8	3	21	2				
12	Corner breaks	25		1	27	5	1	26	2				
13	Lgt. joint spalls	160	17	18	41	7	1	25	3	4			
14	Tvs. cks. <20'	22	5	3	26	1	6	8	4	2			

Table A-6. Number of ODOT 2012 AC/PCC segments with distress, severity, and extent combinations.

Code	Distresses	LO	LF	LE	MO	MF	ME	HO	HF	HE	O	F	E
1	Raveling	1202	1339	1361	598	102	43	612	291	177			
2	Bleeding	1			47	11	4	1					
3	Patching	422	9	1	535	59	37	735	78	31			
4	Debonding	410	25	4	70	5	4		1				
5	Rutting	1324	1105	563	395	160	46	33	13	9			
6	Pumping										318	14	
7	Shattered slab	11			9	1		4	1				
8	Settlement	234	5	1	35	7		5					
9	Tvs. cks. – unj.	292	10	3	445	81	41	99	19	5			
10	Tvs. cks. – refl.	537	264	192	707	672	755	84	307	236			
11	Tvs. cks. – int.	851	214	125	757	400	436	27	78	82			
12	Longit. cracks	666	774	161	770	1241	426	121	632	205			
13	Pressure damage	884	254	144	325	94	48	13	7	2			
14	Crack seal damage										1097	751	2448
15	Corrugation												
16	Corner breaks	149	3		156	7	2	43	12	1			
17	Punchouts	1			105	17	3	28	4	3			

APPENDIX B—ODOT DECISION TREES

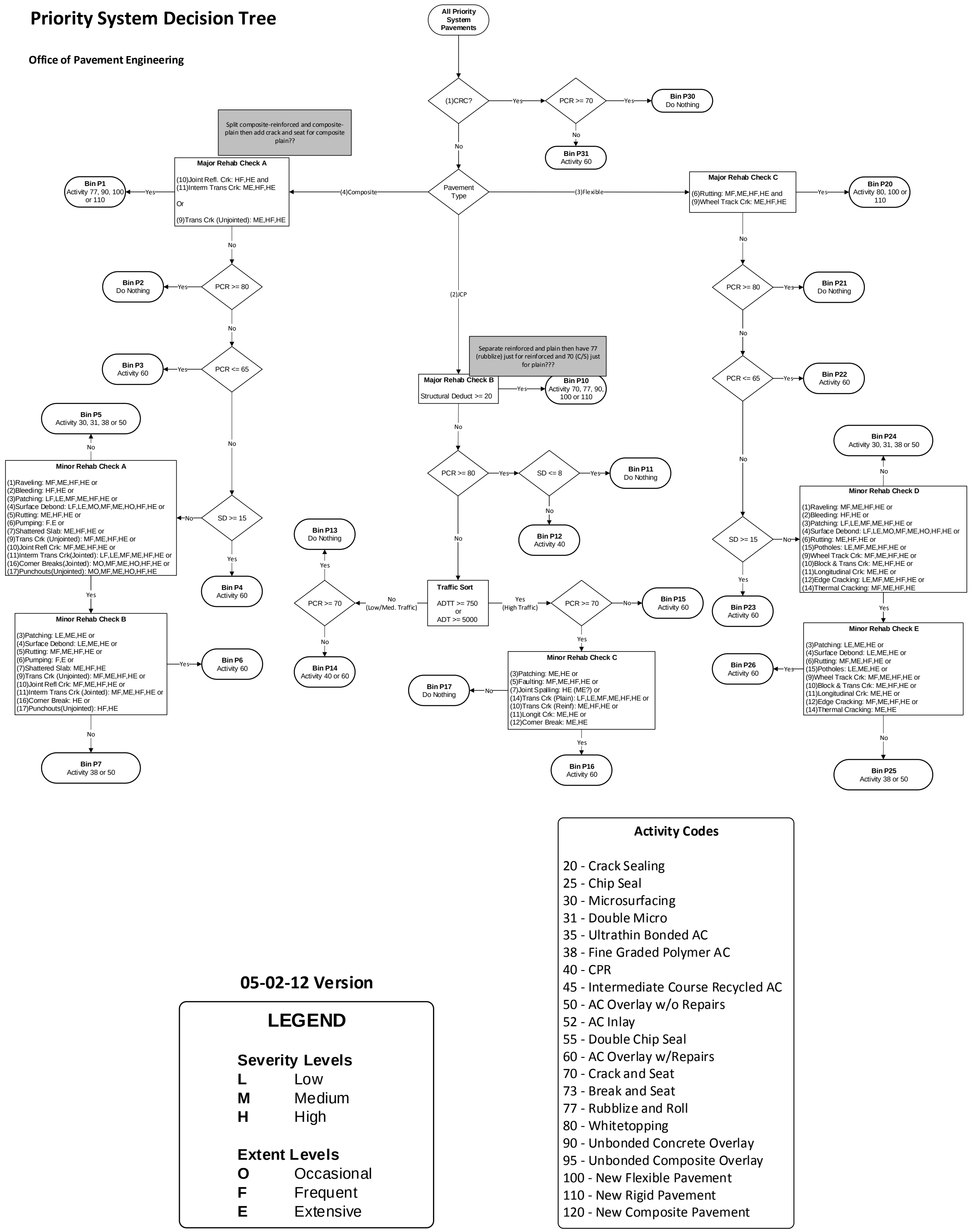


Figure B-1. ODOT's Priority System Decision Tree.

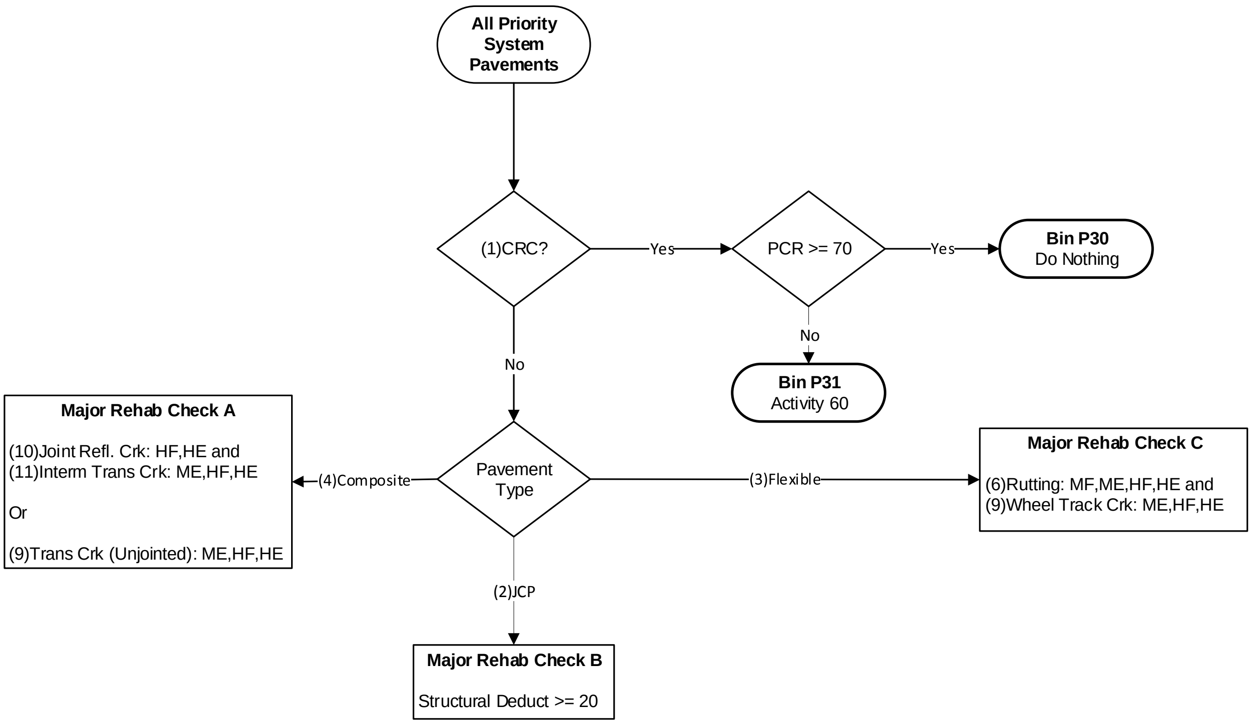
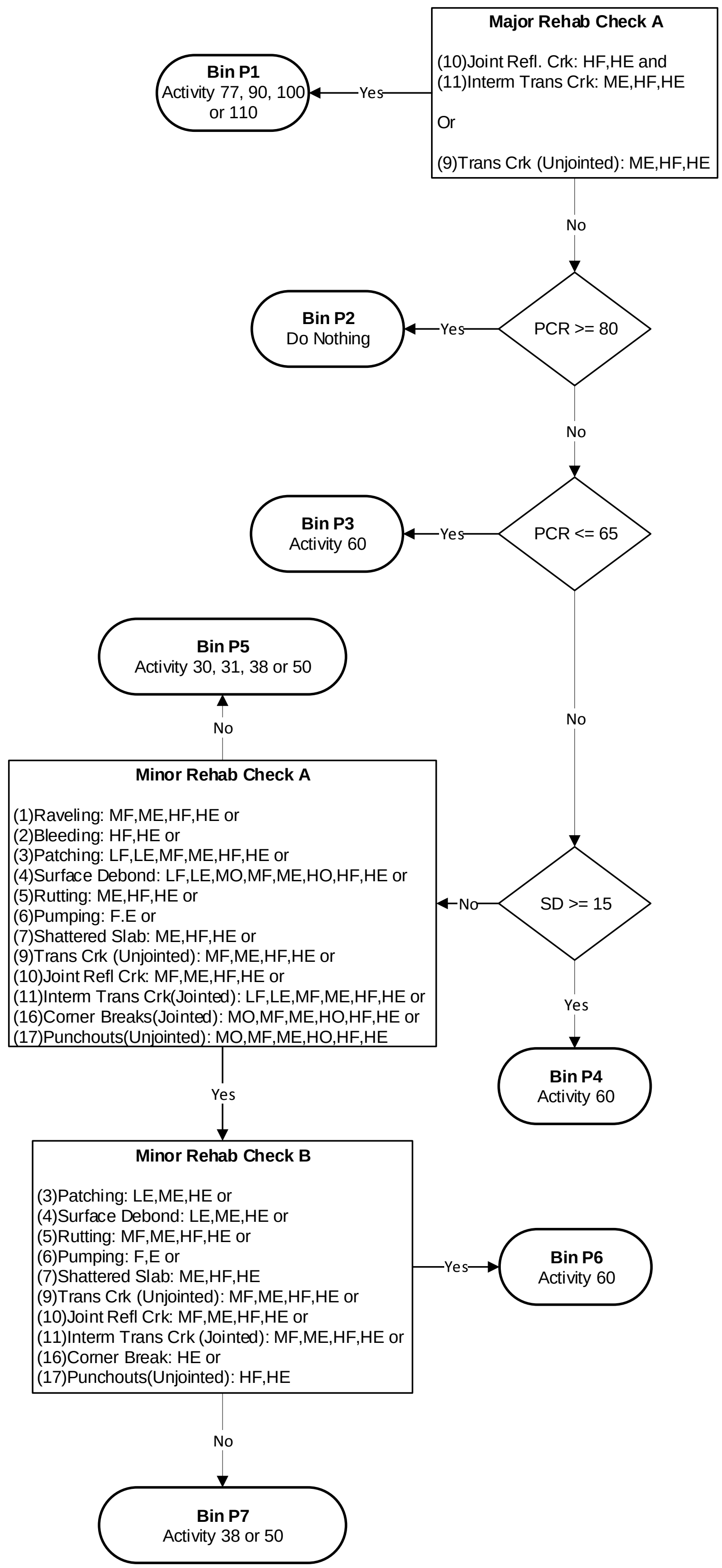


Figure B-2. ODOT's Priority System Decision Tree (continued).



Major Rehab Check A
(10)Joint Refl. Crk: HF,HE and
(11)Interm Trans Crk: ME,HF,HE
Or
(9)Trans Crk (Unjointed): ME,HF,HE
Yes
Bin P1
Activity 77, 90, 100 or 110
No
PCR >= 80
Yes
Bin P2
Do Nothing
No
PCR <= 65
Yes
Bin P3
Activity 60
No
SD >= 15
Yes
Bin P4
Activity 60
No
Minor Rehab Check A
(1)Raveling: MF,ME,HF,HE or
(2)Bleeding: HF,HE or
(3)Patching: LF,LE,MF,ME,HF,HE or
(4)Surface Debond: LF,LE,MO,MF,ME,HO,HF,HE or
(5)Rutting: ME,HF,HE or
(6)Pumping: F.E or
(7)Shattered Slab: ME,HF,HE or
(9)Trans Crk (Unjointed): MF,ME,HF,HE or
(10)Joint Refl Crk: MF,ME,HF,HE or
(11)Interm Trans Crk(Jointed): LF,LE,MF,ME,HF,HE or
(16)Corner Breaks(Jointed): MO,MF,ME,HO,HF,HE or
(17)Punchouts(Unjointed): MO,MF,ME,HO,HF,HE
No
Bin P5
Activity 30, 31, 38 or 50
Yes
Minor Rehab Check B
(3)Patching: LE,ME,HE or
(4)Surface Debond: LE,ME,HE or
(5)Rutting: MF,ME,HF,HE or
(6)Pumping: F,E or
(7)Shattered Slab: ME,HF,HE
(9)Trans Crk (Unjointed): MF,ME,HF,HE or
(10)Joint Refl Crk: MF,ME,HF,HE or
(11)Interm Trans Crk (Jointed): MF,ME,HF,HE or
(16)Corner Break: HE or
(17)Punchouts(Unjointed): HF,HE
Yes
Bin P6
Activity 60
No
Bin P7
Activity 38 or 50

Figure B-3. ODOT's Priority System Decision Tree (continued).

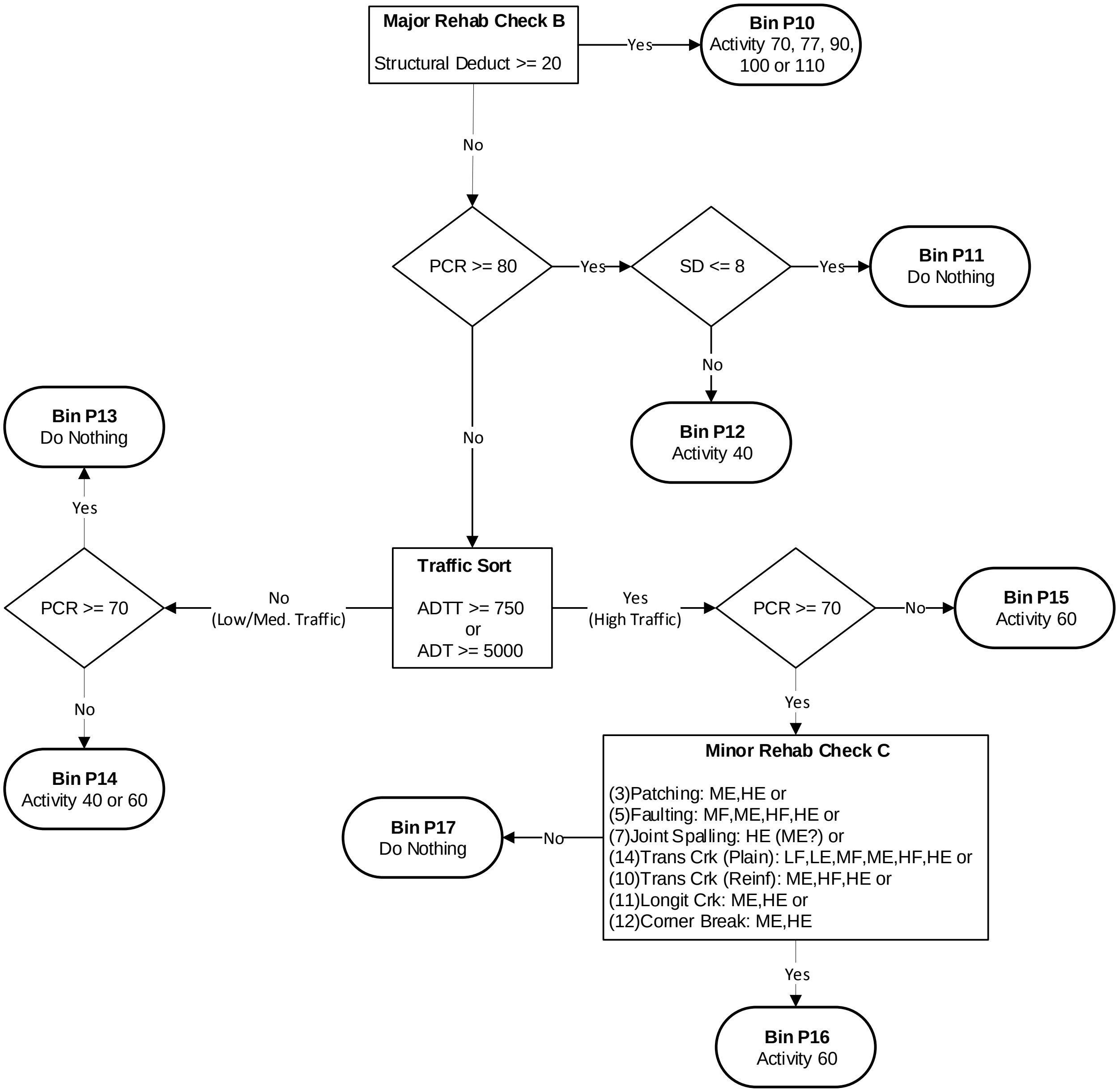


Figure B-4. ODOT's Priority System Decision Tree (continued).

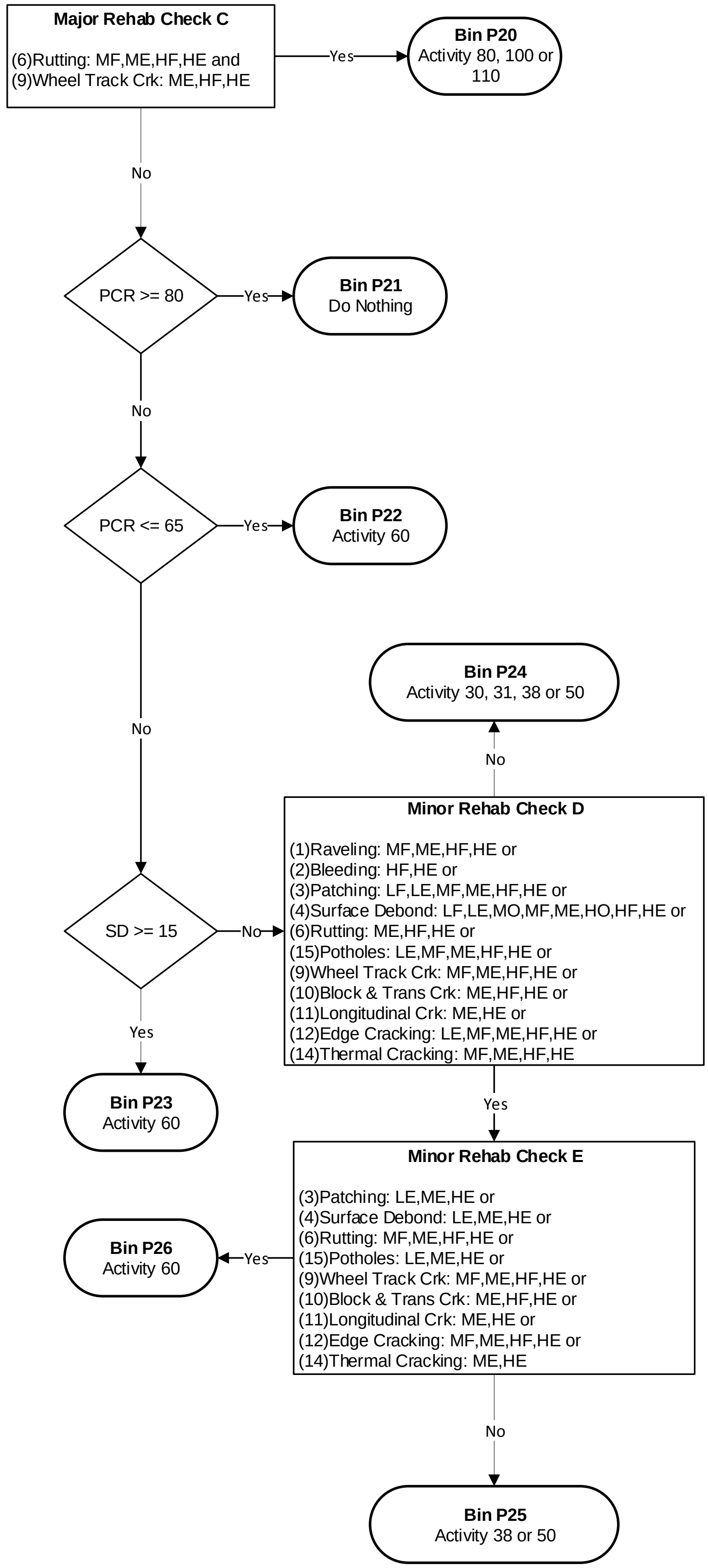


Figure B-5. ODOT’s Priority System Decision Tree (continued).

General System Decision Tree

Office of Pavement Engineering

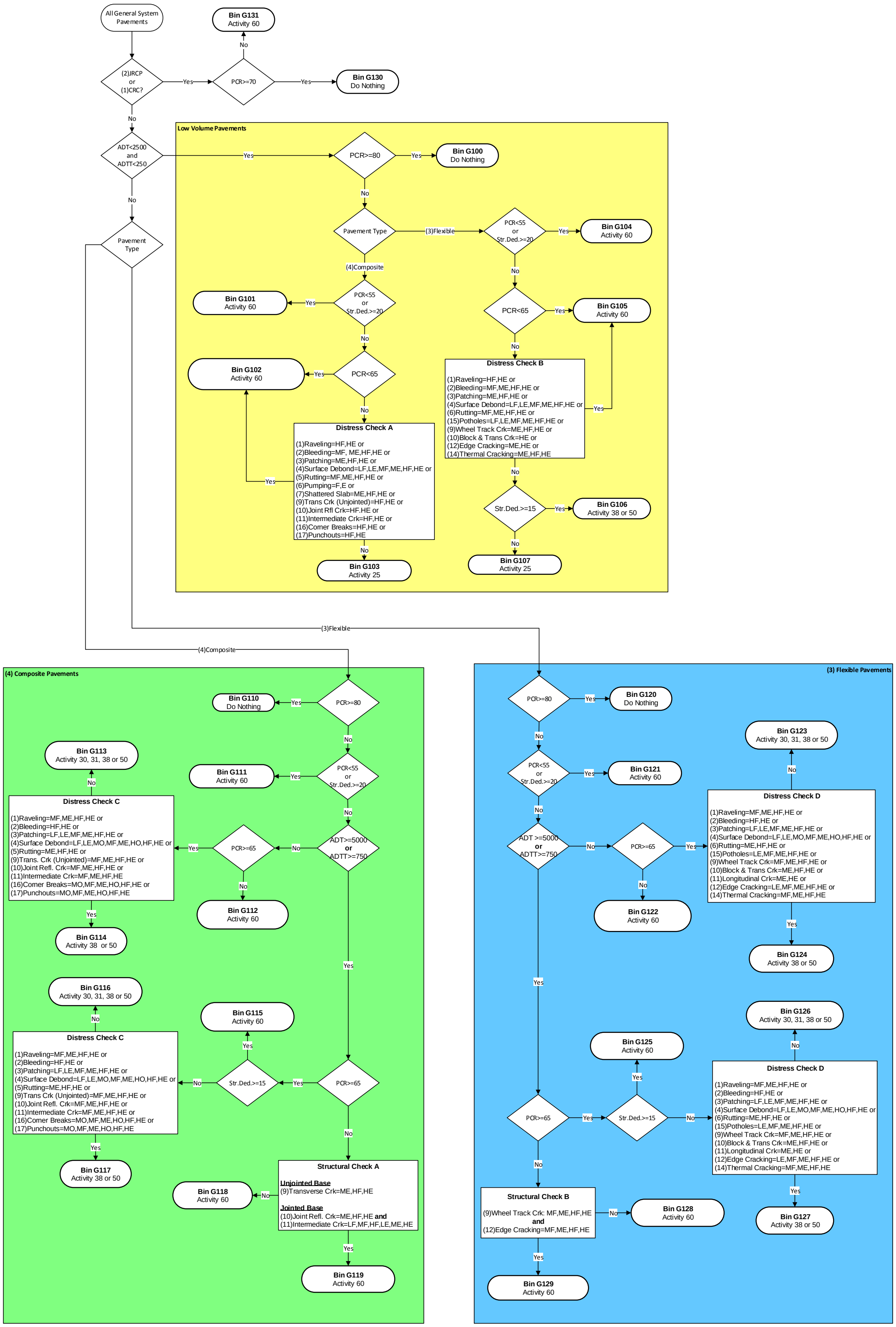
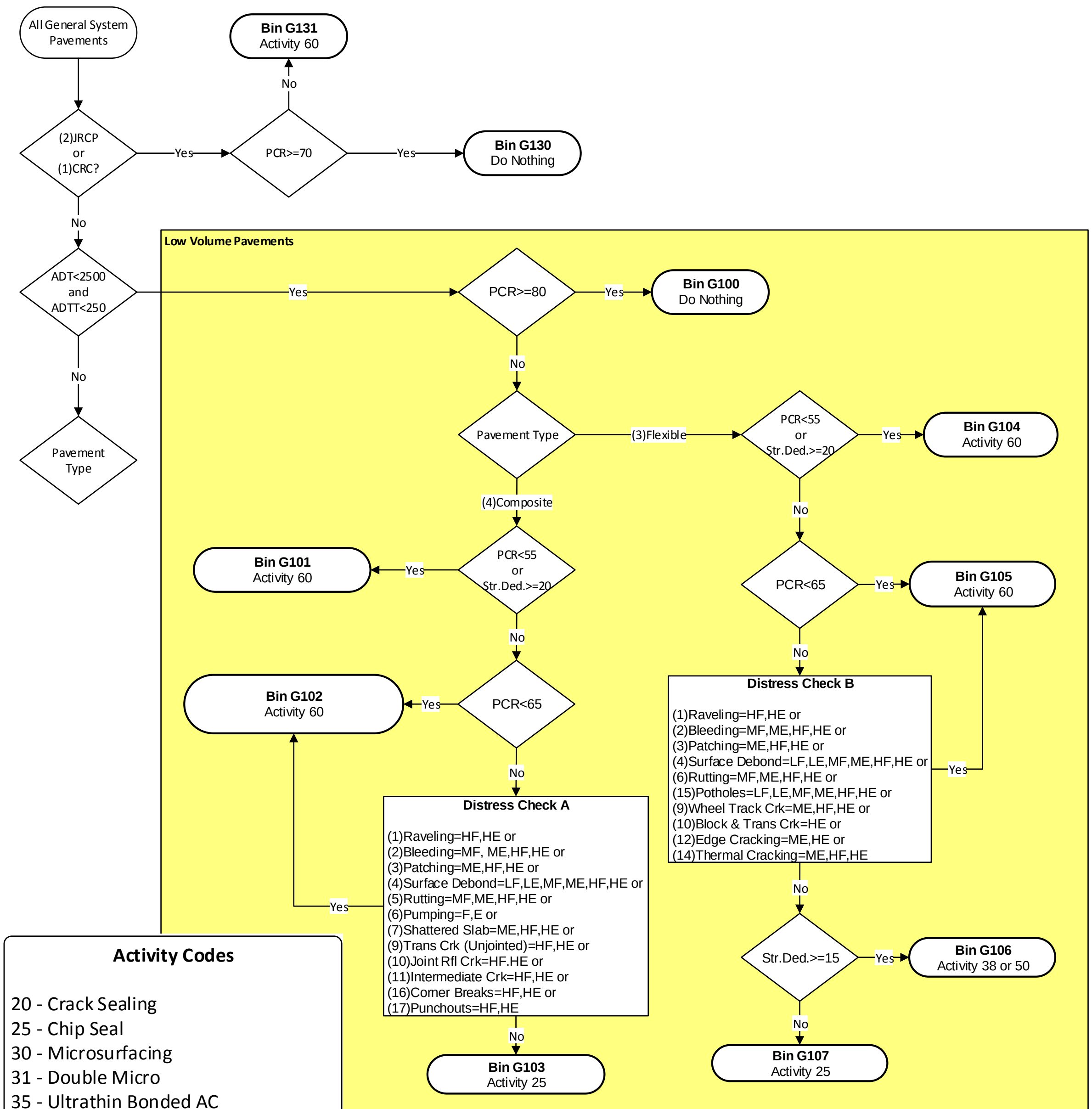


Figure B-2. ODOT's General System Decision Tree.



Activity Codes

20 - Crack Sealing
25 - Chip Seal
30 - Microsurfacing
31 - Double Micro
35 - Ultrathin Bonded AC
38 - Fine Graded Polymer AC
40 - CPR
45 - Intermediate Course Recycled AC
50 - AC Overlay w/o Repairs
52 - AC Inlay
55 - Double Chip Seal
60 - AC Overlay w/Repairs
70 - Crack and Seat
73 - Break and Seat
77 - Rubblize and Roll
80 - Whitetopping
90 - Unbonded Concrete Overlay
95 - Unbonded Composite Overlay
100 - New Flexible Pavement
110 - New Rigid Pavement
120 - New Composite Pavement

05-02-12
Version E

LEGEND

Severity Levels
L Low
M Medium
H High

Extent Levels
O Occasional
F Frequent
E Extensive

Figure B-2. ODOT's General System Decision Tree (continued).

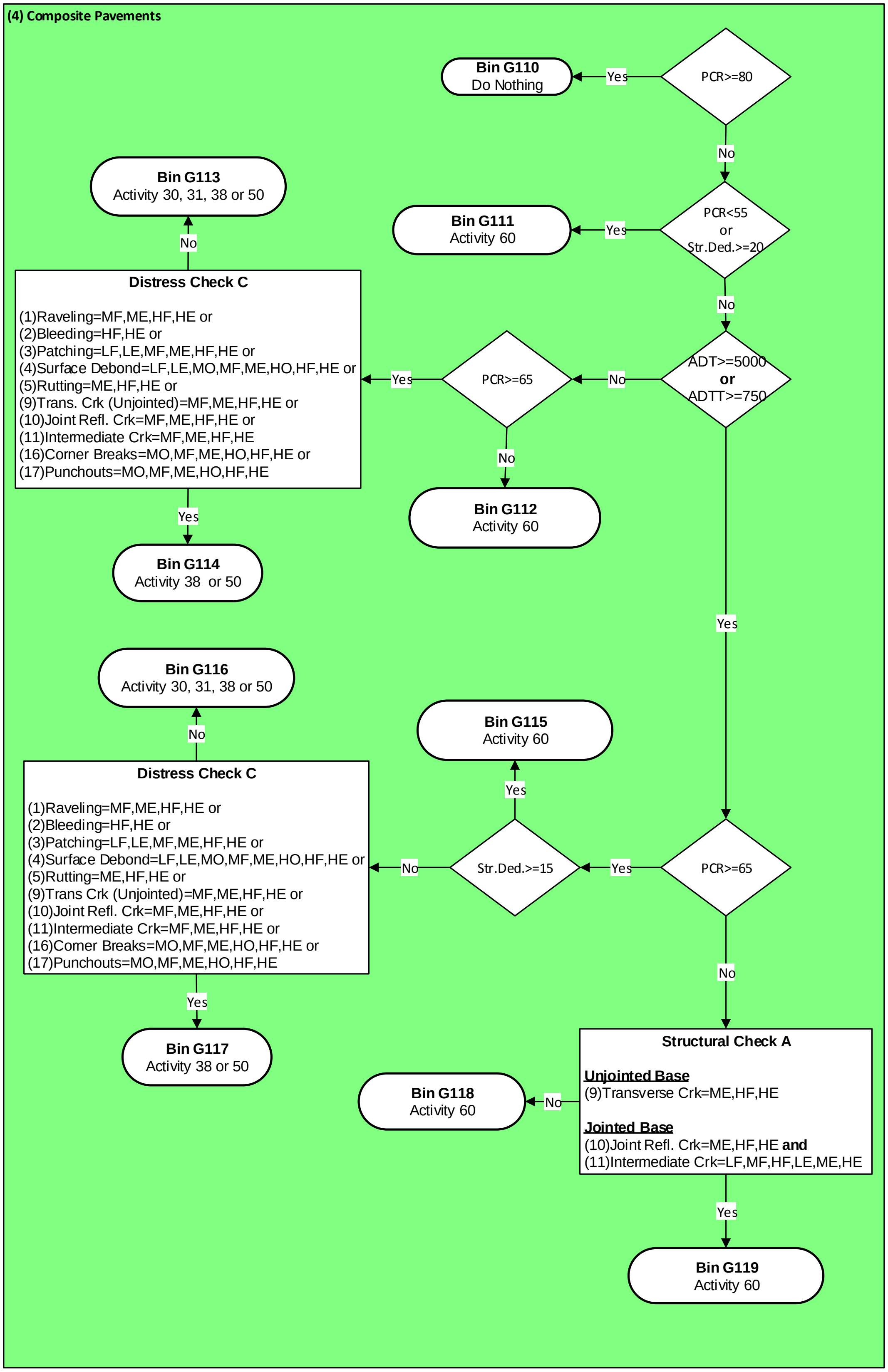


Figure B-2. ODOT’s General System Decision Tree (continued).

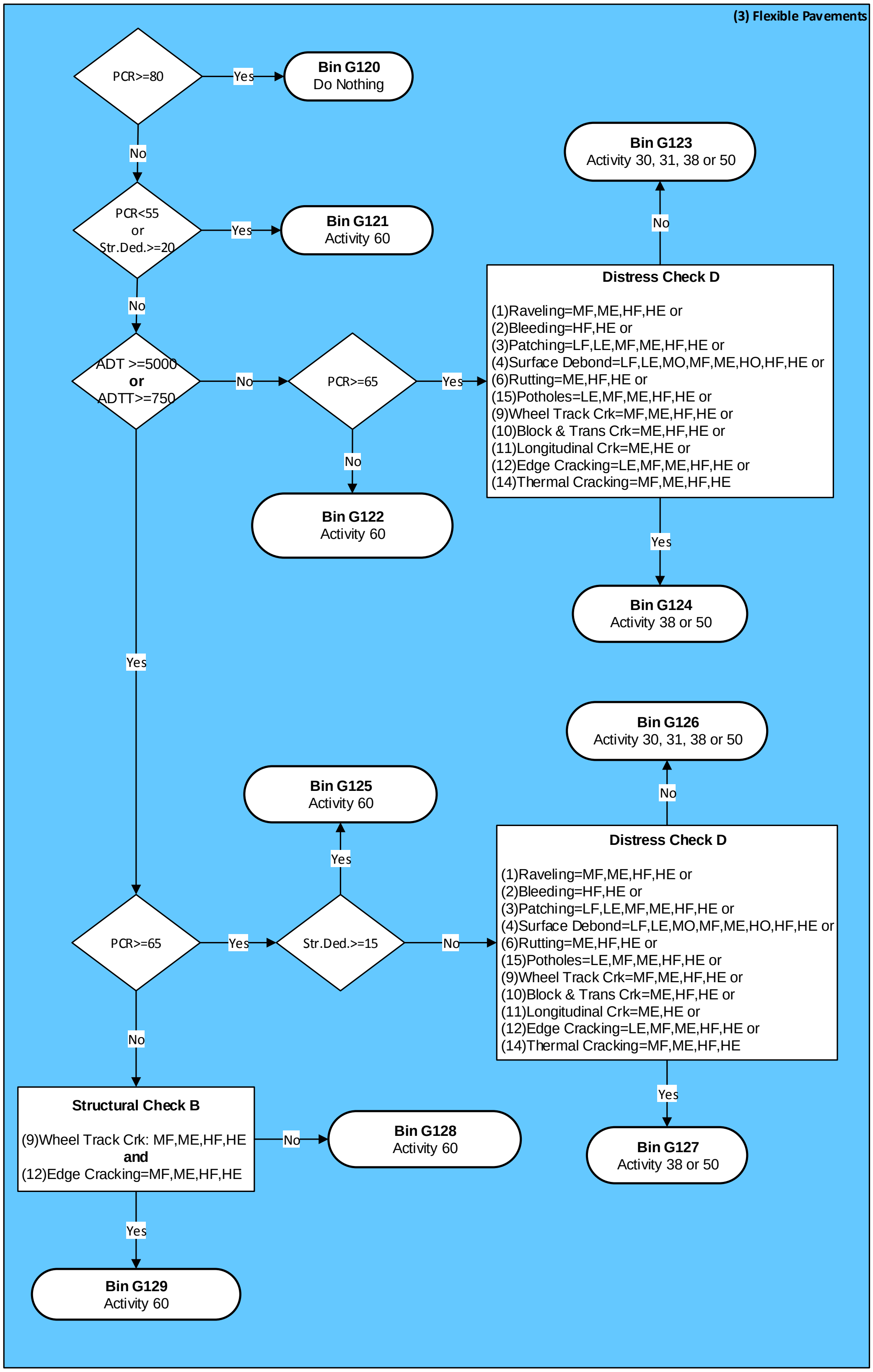
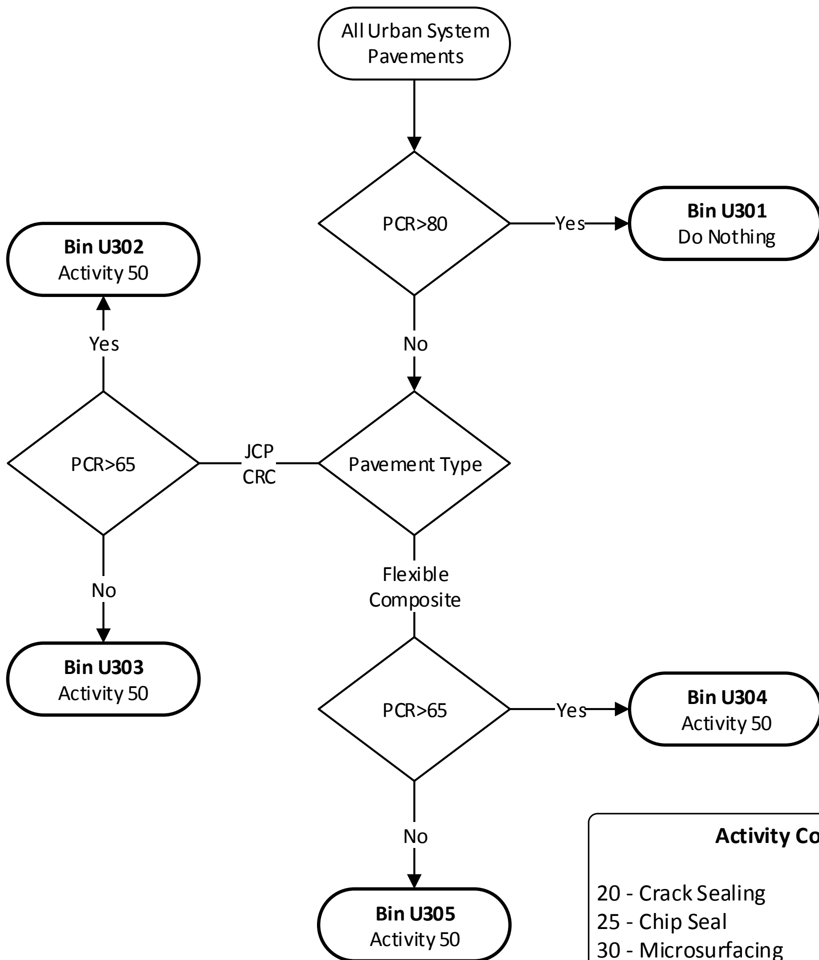


Figure B-2. ODOT's General System Decision Tree (continued).

Urban System Decision Tree

Office of Pavement Engineering



03-05-13

LEGEND

Severity Levels

L	Low
M	Medium
H	High

Extent Levels

O	Occasional
F	Frequent
E	Extensive

Activity Codes

20 - Crack Sealing
25 - Chip Seal
30 - Microsurfacing
31 - Double Micro
35 - Ultrathin Bonded AC
38 - Fine Graded Polymer AC
40 - CPR
45 - Intermediate Course Recycled AC
50 - AC Overlay w/o Repairs
52 - AC Inlay
55 - Double Chip Seal
60 - AC Overlay w/Repairs
70 - Crack and Seat
73 - Break and Seat
77 - Rubblize and Roll
80 - Whitetopping
90 - Unbonded Concrete Overlay
95 - Unbonded Composite Overlay
100 - New Flexible Pavement
110 - New Rigid Pavement
120 - New Composite Pavement

Figure B-3. ODOT’s Urban System Decision Tree.

APPENDIX C—TEST SITE LOCATIONS

Table C-1. Test site location and properties.

Site Number	District	County	Route Code	Route	MP Begin	MP End	Begin lat. (N)	Begin longit. (W)	End lat. (N)	End longit. (W)
1	6	FRA	IR	270	9.63	10.03	39.989977	83.118625	39.995813	83.118404
2	6	DEL	US	23	123.75	123.98	40.424787	83.074407	40.428103	83.073987
3	3	RIC	SR	603	19.13	20.13	40.888	82.43411	40.89394	82.45208
4	3	ASD	SR	96	34.28	33.08	40.869325	82.317918	40.878406	82.33708
5	3	WAY	SR	83	108.80	109.58	40.835649	81.926397	40.841528	81.938715
6	3	WAY	SR	3	212.86	213.96	40.974624	81.899483	40.989102	81.892386
7	3	MED	SR	94	24.05	24.78	41.025438	81.729754	41.035844	81.728823
8	3	MED	SR	94	25.74	26.73	41.050028	81.72872	41.06081	81.73586
9	3	MED	SR	57	25.13	25.60	41.128652	81.857484	41.13426	81.862713
10	3	MED	US	42	216.60	217.43	41.148896	81.863735	41.160889	81.862509
11	3	MED	SR	18	172.86	173.32	41.13916	81.878398	41.139099	81.869793
12	3	LOR	SR	57	43.86	44.09	41.289805	82.06601	41.292943	82.067198
13	3	LOR	SR	301	44.65	45.30	41.488737	82.075732	41.498035	82.075494
14	12	CUY	SR	237	10.53	11.50	41.450143	81.81674	41.464	81.813612
15	12	CUY	SR	237	7.14	7.60	41.408092	81.833997	41.414603	81.829958
16	12	CUY	IR	490	0.40	1.00	41.474374	81.69157	41.476954	81.678388
17	12	CUY	IR	490	1.00	0.40	41.476954	81.678388	41.474374	81.69157
18	12	CUY	SR	283	6.16	6.48	41.574278	81.57519	41.68111	81.57322
19	12	LAK	SR	633	0.00	0.58	41.605246	81.475502	41.61116	81.483109
20	12	LAK	SR	283	16.21	17.24	41.663262	81.436342	41.672213	81.425278
21	12	CUY	SR	91	29.94	30.94	41.459639	81.44042	41.475	81.43817
22	12	CUY	SR	175	6.37	7.30	41.489722	81.49769	41.50111	81.49769
23	12	CUY	SR	43	112.38	113.45	41.430787	81.539124	41.437864	81.556342
24	4	SUM	SR	303	42.13	42.72	41.243262	81.609949	41.244733	81.598478
25	4	SUM	SR	8	7.96	8.96	41.167278	81.47692	41.1795	81.47828
26	4	SUM	SR	8	13.30	14.30	41.179639	81.47856	41.16697	81.47694
27	4	SUM	SR	303	50.04	50.98	41.23605	81.463294	41.239908	81.445741
28	4	POR	SR	303	58.79	59.79	41.242306	81.29844	41.24447	81.28075
29	4	POR	SR	82	46.79	47.79	41.310444	81.19394	41.31022	81.17569
30	12	GEA	SR	44	52.78	53.78	41.387361	81.21628	41.40208	81.21386
31	12	GEA	SR	44	58.80	59.97	41.470417	81.19364	41.48714	81.19361
32	12	GEA	SR	87	34.91	35.91	41.461361	81.06339	41.46	81.04361
33	12	GEA	SR	528	11.48	12.48	41.535028	81.05175	41.54964	81.05179
34	4	ATB	US	6	216.94	217.93	41.60575	80.97272	41.60575	80.95392
35	12	LAK	US	20	218.23	219.23	41.60575	81.24806	41.73525	81.23894
36	12	LAK	SR	84	24.42	25.42	41.726495	81.18689	41.73478	81.17086
37	4	ATB	C	25	0.00	1.00	41.817623	80.75739	41.82953	80.75739
38	4	ATB	SR	534	64.42	65.06	41.796133	80.947355	41.805266	80.947645
39	4	ATB	T	211	0.00	1.08	41.799659	80.97046	41.814596	80.974246
40	4	ATB	SR	46	71.52	72.08	41.73821	80.769529	41.746547	80.769484
42	4	ATB	SR	11	78.61	79.61	41.616361	80.71322	41.63086	80.71322
43	4	TRU	SR	193	26.16	27.16	41.462417	80.6655	41.47647	80.66533
44	4	TRU	SR	46	51.93	52.93	41.462139	80.74661	41.477	80.74675

Table C-1. Test site location and properties (continued).

Site Number	Approach crossroad	Leave crossroad	Pavement Type	Divided	Up (NB/EB)/Dn	Lane No.	Length, mi
1	Trabue Road	Roberts Road	AC/PCC	D	UP	1	0.40
2	Radnor Rd	OH-229	PCC	D	UP	1	0.23
3	OH-96	Mans Adario Rd	AC	U	UP	1	1.00
4	Cottage Street	Mowry Drive	AC	U	DN	1	1.20
5	SR-83/3 split	Friendsville	PCC	U	UP	1	0.78
6	Sterling Rd	Medina St	AC/PCC	U	UP	1	1.10
7	College/Broad St	Franks St	AC/PCC	U	UP	1	0.73
8	Park Center	Edenmore	AC/PCC	U	UP	1	0.99
9	Shaker Rd	South Broadway	AC/PCC	U	UP	1	0.47
10	Highland/Harding St	Stonegate Dr	AC/PCC	U	UP	1	0.83
11	State Rd	North Vine Street	AC/PCC	U	UP	1	0.46
12	Fox Run	Barrington	AC	U	UP	1	0.23
13	Oster Rd	Lake Rd	PCC	U	UP	1	0.65
14	Lorain Avenue	Edgecliff Rd	PCC	U	UP	1	0.97
15	Snow Rd	480 West Exit	PCC	D	UP	1	0.46
16	West 14th St	Quigley Rd	PCC	D	UP	1	0.60
17	Quigley Rd	West 14th St	PCC	D	DN	1	0.60
18	Huntmere Rd	E 156 St	AC/PCC	U	UP	1	0.32
19	US 20	Lakeland Blvd	PCC	U	UP	1	0.58
20	Waban Rd	Forest	AC	U	UP	1	1.03
21	Creekview Circle	Laurel Hill	AC/PCC	U	UP	1	1.00
22	Fairmount Blvd	Cedar St	PCC	U	UP	1	0.93
23	Warrensville Rd	E 175 St.	AC/PCC	U	UP	1	1.07
24	Briarwood Dr.	SR 271	AC	U	UP	1	0.59
25	Hudson Dr	Steels Corners Rd	PCC	D	UP	2	1.00
26	Steels Corners Rd.	Hudson Dr	PCC	D	DN	2	1.00
27	Simon Lane	Atterbury/Millford	AC	U	UP	1	0.94
28	Diagonal Rd	Jerome Rd	AC	U	UP	1	1.00
29	River Beach Rd	CR 276	AC	U	UP	1	1.00
30	Washington St	Edinboro Lane	AC	U	UP	1	1.00
31	Burton Hts Blvd	Butternut Rd	AC	U	UP	1	1.17
32	Hillcrest Avenue	Hayes Rd	AC/PCC	U	UP	1	1.00
33	SR 322	Hwy 13	AC	U	UP	1	1.00
34	Hyde Rd	SR 534	AC/PCC	U	UP	1	0.99
35	Watson/Wood St	Parkview Dr	AC/PCC	U	UP	1	1.00
36	Madison Avenue	Keener Rd	AC/PCC	U	UP	1	1.00
37	SR 11	Garison Rd	AC	U	TBA	1	1.00
38	Commerce Pl	US 20	AC/PCC	U	UP	1	0.64
39	US 20	West Maple Rd	AC	U	TBA	1	1.08
40	E/W Jefferson	W Beech St	AC/PCC	U	UP	1	0.56
42	US 6	Centennial	AC/PCC	D	UP	1	1.00
43	Kinsman SR 87	Wakefield Creek	AC/PCC	U	UP	1	1.00
44	Kinsman SR 87	Wakefield Creek	AC/PCC	U	UP	1	1.00

APPENDIX D—DISTRESS, SEVERITY, EXTENT SUMMARY

Table D-1. AC distress, severity, and extent values.

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
3	1	Raveling			HO	MO	MO	MO	MO
3	2	Bleeding							
3	3	Patching	ME	HO	HO	LO	MO	LO	LO
3	4	Debonding	HO	HF		LO	LO	LO	LO
3	5	Crack seal deficiency	E		E	E	E	E	E
3	6	Rutting	HO	HO	HO	LF	LF	LF	LF
3	9	Wheel track cracking	MO	HF	HO	HO	HO	MF	HO
3	10	Block/transverse cracking	HO	MO	HO	HF	HF	HF	HF
3	11	Longitudinal cracking	HO	HF	HO	HF	HF	HF	HF
3	12	Edge cracking	HO	HO	LO	HO	HO	HO	HO
3	14	Thermal cracking		LE	HO	MO	HO	MO	MF
3	15	Potholes	O	O					
4	1	Raveling		HO	HO	HO	HO	HO	HO
4	2	Bleeding							
4	3	Patching	HF	HE	HO	HO	HO	HO	HO
4	4	Debonding	MO	MO	MO	LO	LO	MO	MO
4	5	Crack seal deficiency	F		E	F	F	E	F
4	6	Rutting	HO	HO	HO	HO	HO	HO	HO
4	9	Wheel track cracking	HO	HF	MO	HF	HF	HF	HF
4	10	Block/transverse cracking	MO	HO	MO	HF	HF	HF	HF
4	11	Longitudinal cracking	MO	HO	HO	HF	HF	HF	HF
4	12	Edge cracking	MO	HO	LO				
4	14	Thermal cracking	LE	HE	MO	HO	HO	MF	HO
4	15	Potholes		E					
12	1	Raveling			LE	MO	MO	MO	MO
12	2	Bleeding							
12	3	Patching	ME	HF	HO	MF	HO	HO	HO
12	4	Debonding							
12	5	Crack seal deficiency	E		E	E	E	E	E
12	6	Rutting	MO	MO	MO	LF	MO	LE	MO
12	9	Wheel track cracking	LO	MO	LF	MO	MO	MO	MO
12	10	Block/transverse cracking	HO	HO	HO	HF	HF	HF	HF
12	11	Longitudinal cracking	LO	HO		HO	HO	HO	HO
12	12	Edge cracking	HF	HF		HF	HF	HF	HF
12	14	Thermal cracking				MO	MO	MO	MO
12	15	Potholes							

Table D-1. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
20	1	Raveling			HO	MF	ME	MF	ME
20	2	Bleeding							
20	3	Patching	HO	HO	HO	MO	MO	MO	MO
20	4	Debonding	MO			LO	LO	LO	LO
20	5	Crack seal deficiency	E		E	F	F	F	F
20	6	Rutting	HO	HO	HO	LF	LF	LF	LF
20	9	Wheel track cracking	MO	HO	HO	LO	LO	LF	LF
20	10	Block/transverse cracking	MO	MO	HO	HO	HO	HO	HO
20	11	Longitudinal cracking	MO	HO	HO	HF	HF	HF	HF
20	12	Edge cracking		LO	MO				
20	14	Thermal cracking	ME	HE	MF	HF	HF	HF	HF
20	15	Potholes		O					
20A	1	Raveling		LO	HO	MF	ME	MF	ME
20A	2	Bleeding							
20A	3	Patching	HO	HO	HO	MO	MO	MO	MO
20A	4	Debonding	MO	LO	MO	LO	LO	LO	LO
20A	5	Crack seal deficiency	E		E	F	F	F	F
20A	6	Rutting	HO	HO	HO	LF	LF	LF	LF
20A	9	Wheel track cracking	MO	HO	HO	LO	LO	LF	LF
20A	10	Block/transverse cracking	MO	MO	MO	HO	HO	HO	HO
20A	11	Longitudinal cracking	MO	MF	HO	HF	HF	HF	HF
20A	12	Edge cracking			MO				
20A	14	Thermal cracking	ME	HE	HO	HF	HF	HF	HF
20A	15	Potholes		O					
24	1	Raveling			HO	MO	MO	MO	MO
24	2	Bleeding							
24	3	Patching	HO	HO	HO	MO	MO	LO	LO
24	4	Debonding							
24	5	Crack seal deficiency	E		E	E	E	E	E
24	6	Rutting	HO	HO	MO	LO	LO	LO	LF
24	9	Wheel track cracking	MO	HO	HO	LO	LO	LO	LO
24	10	Block/transverse cracking	LO	MO	MO	LF	LF	LF	LF
24	11	Longitudinal cracking	MO	MO	HO	HO	HO	HO	HO
24	12	Edge cracking	HO	HO	HO	LE	LE	MO	MO
24	14	Thermal cracking	ME	LE	MO				
24	15	Potholes		E					

Table D-1. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
27	1	Raveling		LO	HO	LF	LF	LF	LF
27	2	Bleeding							
27	3	Patching	HO	HF	HF	MO	MO	MO	MO
27	4	Debonding							
27	5	Crack seal deficiency	F		E	O	O	O	O
27	6	Rutting	HO	HO	HO	LF	LF	LE	LE
27	9	Wheel track cracking	MO	HO	HO	LO	LF	LO	LF
27	10	Block/transverse cracking	HO	MO	MO	LO	LO	LO	LO
27	11	Longitudinal cracking	MO	HO	HO	MF	MF	MF	MF
27	12	Edge cracking		MO					
27	14	Thermal cracking		ME	HO	ME	ME	HF	HF
27	15	Potholes		O					
28	1	Raveling	HO		MO	MF	MF	MF	MF
28	2	Bleeding							
28	3	Patching							
28	4	Debonding							
28	5	Crack seal deficiency	E		E	E	E	E	E
28	6	Rutting	HO	MO	MO	LE	MO	MO	MO
28	9	Wheel track cracking	MO	MO	LO	LO	LO	LO	LO
28	10	Block/transverse cracking	LO	LO	LO	MO	MO	LO	LO
28	11	Longitudinal cracking	HO	HO	LO	HF	HF	HF	HF
28	12	Edge cracking	HO	MO	HO	MO	MO	MO	MF
28	14	Thermal cracking	ME	LE	MO	MO	MO	MO	MO
28	15	Potholes		O					
29	1	Raveling	HO		HO	ME	ME	ME	ME
29	2	Bleeding							
29	3	Patching	MF			MO	MO	LO	LO
29	4	Debonding			LO				
29	5	Crack seal deficiency	F		E	F	F	F	F
29	6	Rutting	MO	HO	MO	LE	LE	LE	LE
29	9	Wheel track cracking	MO	MO	MO	LO	LO	LF	LF
29	10	Block/transverse cracking	HO	HO	HO	HF	HF	HF	HF
29	11	Longitudinal cracking	MO	HO	MO	HF	HF	HF	HF
29	12	Edge cracking	MO	HO		MO	MO	MO	MO
29	14	Thermal cracking		LE	MO	LO			LO
29	15	Potholes		E					

Table D-1. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
30	1	Raveling			LO	MO	MO	LE	LE
30	2	Bleeding							
30	3	Patching	LO						
30	4	Debonding							
30	5	Crack seal deficiency	F		E	F	F	F	F
30	6	Rutting	LE	MO	MO	LF	LF	LO	LO
30	9	Wheel track cracking	MO	MF	MF	LO	LO	LO	LO
30	10	Block/transverse cracking	LO	LO	LO	LO	LO	LO	LO
30	11	Longitudinal cracking	MO	MO	MO	ME	ME	ME	ME
30	12	Edge cracking	MO	LO	MF	MO	MO	MO	MO
30	14	Thermal cracking			MO				
30	15	Potholes		O					
31	1	Raveling			MO	LE	LE	LE	LE
31	2	Bleeding							
31	3	Patching	MO						
31	4	Debonding							
31	5	Crack seal deficiency	F		E	O	O	F	F
31	6	Rutting	MO	HO	HO	LF	LF	LF	LF
31	9	Wheel track cracking	MO	MO	MO	LO	LO	LO	LO
31	10	Block/transverse cracking	LO	LO	LO	LO	LF	LF	LF
31	11	Longitudinal cracking	MO	MO	MO	MO	MO	MO	MO
31	12	Edge cracking	MO	MF	ME	MF	MF	MF	MF
31	14	Thermal cracking	ME	LE	HO	MO	MO	MO	MO
31	15	Potholes							
33	1	Raveling			MO	MF	MF	MF	MF
33	2	Bleeding							
33	3	Patching	HO	HO	HO	LO	LO	MO	MO
33	4	Debonding			MF				
33	5	Crack seal deficiency	E		F			E	E
33	6	Rutting	HO	MO	MO	LF	LF	LO	LF
33	9	Wheel track cracking	MO	HO	LO	LO	LO	LO	LO
33	10	Block/transverse cracking	LO	LO	LO	LO	LO	LO	LO
33	11	Longitudinal cracking	MO	HO	ME	HF	HF	HF	HF
33	12	Edge cracking	LE	HE	ME	HF	HF	HF	HF
33	14	Thermal cracking		HE	MO	MO	MO	LO	LO
33	15	Potholes		O					

Table D-1. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1		ODOT Rater 2	
						Rep 1	Rep 2	Rep 1	Rep 2
37	1	Raveling			HO				
37	2	Bleeding	MF	HF	HE	HF	HF	HE	HE
37	3	Patching	LO	HO	HO	HO	HO	HO	HO
37	4	Debonding							
37	5	Crack seal deficiency	E		E	O	O	O	O
37	6	Rutting	HO	HO	HO	LO	LF	LO	LF
37	9	Wheel track cracking	HO	HO	MO	LO	LO	LO	LO
37	10	Block/transverse cracking							
37	11	Longitudinal cracking	HO	LO	MO				
37	12	Edge cracking	MF	HO	MF	MF	MF	MF	MF
37	14	Thermal cracking			LO				
37	15	Potholes							
39	1	Raveling			HO				
39	2	Bleeding	ME	ME	ME	MF	MF	ME	ME
39	3	Patching	MO	MO					
39	4	Debonding							
39	5	Crack seal deficiency	E		E	E	E	E	E
39	6	Rutting	HO	HO	HO	MF	MF	MF	MF
39	9	Wheel track cracking	MO	HO	HO	MF	MF	MF	MF
39	10	Block/transverse cracking	LO	LO	MO	LO		LO	LO
39	11	Longitudinal cracking	MO		HO	LO	LO	LO	LO
39	12	Edge cracking	HO	HO	HE	ME	ME	ME	ME
39	14	Thermal cracking		HE	HO	LO	MO	LO	LF
39	15	Potholes							

Table D-2. AC/PCC distress, severity, and extent values.

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
1	1	Raveling			HO	LE	LE	LE	LE
1	2	Bleeding							
1	3	Patching	ME	HF	HO	MF	MF	MO	HO
1	4	Disintegration, debonding	LO						
1	5	Rutting	MO	HO	HO	LE	LE	LE	LE
1	6	Pumping				F	F	F	F
1	7	Shattered slab		HF					
1	9	Tvs. Cracking – unjointed							
1	10	Tvs. Cracking – joint reflection	LE	MF	HE	HF	HF	HF	HF
1	11	Tvs. Cracking – intermediate	MO	LO	ME	LO	LO	LO	LO
1	12	Longitudinal cracking	MF	HF	HF	ME	HF	HF	HF
1	13	Pressure damage – upheaval		LO					
1	14	Crack sealing deficiency	E		E	E	E	E	E
1	16	Corner breaks – jointed base	MF					HO	HO
1	17	Punchouts – unjointed base							
6	1	Raveling	HO		HO	HO	HO	HO	HO
6	2	Bleeding							
6	3	Patching	HF	HF	HO	HO	HO	HO	HO
6	4	Disintegration, debonding	LE	LO	MO	LO	LO	MO	MO
6	5	Rutting	HO	HO	HO	MO	MO	MO	MO
6	6	Pumping						O	O
6	7	Shattered slab							
6	9	Tvs. Cracking – unjointed	MO	HO	HO	HO	HO	MF	HO
6	10	Tvs. Cracking – joint reflection							
6	11	Tvs. Cracking – intermediate							
6	12	Longitudinal cracking	HO	HO	HO	HF	HF	HF	HF
6	13	Pressure damage – upheaval							
6	14	Crack sealing deficiency	E		E	E	E	E	E
6	16	Corner breaks – jointed base							
6	17	Punchouts – unjointed base				MO	MO	MO	MO
7	1	Raveling	MO		HO	HO	HO	HO	HO
7	2	Bleeding							
7	3	Patching	ME	HO	HO	MO	MO	LO	LO
7	4	Disintegration, debonding	MO	LO		LO	LO	LO	LO
7	5	Rutting	HO	HO	HO	LF	LF	LE	LE
7	6	Pumping							
7	7	Shattered slab							
7	9	Tvs. Cracking – unjointed	LE	HF	ME	HO	HO	HO	HO
7	10	Tvs. Cracking – joint reflection							
7	11	Tvs. Cracking – intermediate							
7	12	Longitudinal cracking	HE	HO	ME	HF	HO	HF	HF
7	13	Pressure damage – upheaval							
7	14	Crack sealing deficiency	E		E	O	O	O	O
7	16	Corner breaks – jointed base							
7	17	Punchouts – unjointed base							

Table D-2. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
8	1	Raveling	MO		HO	MO	MO	MO	MO
8	2	Bleeding							
8	3	Patching	HO	MO	MO	LO	LO	LO	LO
8	4	Disintegration, debonding	MO	LO					
8	5	Rutting	HO	HO	MO	LO	LO	LF	LF
8	6	Pumping							
8	7	Shattered slab							
8	9	Tvs. Cracking – unjointed							
8	10	Tvs. Cracking – joint reflection	HE	HO	HE	HE	HE	HE	HE
8	11	Tvs. Cracking – intermediate	HO	LE		HF	HF	HE	HE
8	12	Longitudinal cracking	HO	HO	HO	HF	HF	HF	HF
8	13	Pressure damage – upheaval				LO	LO	LO	MO
8	14	Crack sealing deficiency	E		E	O	O	O	O
8	16	Corner breaks – jointed base	LE	LO					
8	17	Punchouts – unjointed base							
9	1	Raveling	HO		HO	ME	ME	HO	HO
9	2	Bleeding							
9	3	Patching	ME	HE		MO	HO	MO	HO
9	4	Disintegration, debonding	MF	LO					
9	5	Rutting	HO	HO	HO	MO	MO	MO	MO
9	6	Pumping							
9	7	Shattered slab	HE						
9	9	Tvs. Cracking – unjointed							
9	10	Tvs. Cracking – joint reflection	HE	HF	LE	ME	ME	ME	ME
9	11	Tvs. Cracking – intermediate	MF	MF		MF	MF	MF	MF
9	12	Longitudinal cracking	MF	HF	MO	HF	HE	HE	HE
9	13	Pressure damage – upheaval							
9	14	Crack sealing deficiency	E		E	E	E	E	E
9	16	Corner breaks – jointed base	LO			MO	MO	HO	HO
9	17	Punchouts – unjointed base							
10	1	Raveling	HO		HO	LE	LE	LE	LE
10	2	Bleeding							
10	3	Patching	HE	HF	HF	HO	HO	MO	HO
10	4	Disintegration, debonding	HO	LF					
10	5	Rutting	HO	HO	HO	HF	HF	ME	ME
10	6	Pumping							
10	7	Shattered slab							
10	9	Tvs. Cracking – unjointed							
10	10	Tvs. Cracking – joint reflection	ME	MF	HE	ME	ME	ME	ME
10	11	Tvs. Cracking – intermediate		HO		ME	ME	MF	ME
10	12	Longitudinal cracking	MF	HO	HO	MF	MF	HO	HO
10	13	Pressure damage – upheaval							
10	14	Crack sealing deficiency	E		E	E	E	E	E
10	16	Corner breaks – jointed base				MF	MO	MO	MO
10	17	Punchouts – unjointed base							

Table D-2. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
11	1	Raveling	HO		HO	HE	HE	HE	HE
11	2	Bleeding							
11	3	Patching	HE	HF	HO	HO	MO	HO	HO
11	4	Disintegration, debonding	ME	MO					
11	5	Rutting	HO	HO	HO	MF	MF	HO	HO
11	6	Pumping						O	O
11	7	Shattered slab							
11	9	Tvs. Cracking – unjointed	HF	HO	MO	HO	HO	HO	HO
11	10	Tvs. Cracking – joint reflection							
11	11	Tvs. Cracking – intermediate							
11	12	Longitudinal cracking	MF	HF	MO	HE	HE	HE	HE
11	13	Pressure damage – upheaval							
11	14	Crack sealing deficiency	E		E	E	E	E	E
11	16	Corner breaks – jointed base							
11	17	Punchouts – unjointed base				MO	MO	HO	HO
18	1	Raveling	HO		HF	HF	HF	HF	HF
18	2	Bleeding							
18	3	Patching	HE	HE	HO	HO	HO	HO	HO
18	4	Disintegration, debonding				MO	MO	MO	MO
18	5	Rutting	HO	HF	HO	HO	HO	HO	HO
18	6	Pumping						O	O
18	7	Shattered slab	HE			HE	HE	HE	HE
18	9	Tvs. Cracking – unjointed							
18	10	Tvs. Cracking – joint reflection	HE	HO		HF	HF	HF	HF
18	11	Tvs. Cracking – intermediate		MO		HF	HF	HE	HE
18	12	Longitudinal cracking	MF	HF		HE	HE	HE	HE
18	13	Pressure damage – upheaval							
18	14	Crack sealing deficiency	E		E	E	E		
18	16	Corner breaks – jointed base	MO			MO	MO	HO	HO
18	17	Punchouts – unjointed base							
21	1	Raveling	HO	LO	HO	HF	HE	HE	HE
21	2	Bleeding							
21	3	Patching	ME	HO	HO	MO	MO	LO	MO
21	4	Disintegration, debonding	HO	MO		LO	LO	LO	LO
21	5	Rutting	HO	MO	HO	MF	MF	MF	MF
21	6	Pumping							
21	7	Shattered slab							
21	9	Tvs. Cracking – unjointed	HO	HO	HO	MF	MF	MF	MF
21	10	Tvs. Cracking – joint reflection							
21	11	Tvs. Cracking – intermediate							
21	12	Longitudinal cracking	MF	HO	MO	HF	HF	HF	HF
21	13	Pressure damage – upheaval				LO	LO	LO	LO
21	14	Crack sealing deficiency	E		E	F	F	F	F
21	16	Corner breaks – jointed base							
21	17	Punchouts – unjointed base							

Table D-2. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
23	1	Raveling	HO		HO	MO	MO	MO	MO
23	2	Bleeding	MO						
23	3	Patching	HE	HF	HO	HO	HO	HO	HO
23	4	Disintegration, debonding	ME	LO		LO	LO	LO	MO
23	5	Rutting	HO	HO	HO	LE	MO	LE	MO
23	6	Pumping							
23	7	Shattered slab							
23	9	Tvs. Cracking – unjointed	HO	HO	HO	HO	HO	HO	HO
23	10	Tvs. Cracking – joint reflection							
23	11	Tvs. Cracking – intermediate							
23	12	Longitudinal cracking	MF	HO	HO	HO	HO	HO	HO
23	13	Pressure damage – upheaval							
23	14	Crack sealing deficiency	E		E	O	F	F	F
23	16	Corner breaks – jointed base							
23	17	Punchouts – unjointed base				MO	MO	MO	MO
32	1	Raveling			HO	MO	MO	MO	MO
32	2	Bleeding			ME				
32	3	Patching	ME	LO		HO	HO	HO	HO
32	4	Disintegration, debonding			HO				
32	5	Rutting	HF	HF	HO	HE	HE	HE	HE
32	6	Pumping							
32	7	Shattered slab							
32	9	Tvs. Cracking – unjointed							
32	10	Tvs. Cracking – joint reflection	ME	HO	ME	HF	HF	HF	HF
32	11	Tvs. Cracking – intermediate	MF	MO		HF	HF	HF	HF
32	12	Longitudinal cracking	HO	HO	LF	HF	HF	HF	HF
32	13	Pressure damage – upheaval							
32	14	Crack sealing deficiency	E		E	E	E	E	E
32	16	Corner breaks – jointed base	MO						
32	17	Punchouts – unjointed base							
34	1	Raveling	HO		HO	HE	HE	HE	HE
34	2	Bleeding							
34	3	Patching	ME	HO		MO	MO	LO	LO
34	4	Disintegration, debonding		LO					LO
34	5	Rutting	HO	HO	MO	LF	LF	LF	LF
34	6	Pumping							
34	7	Shattered slab	HE						
34	9	Tvs. Cracking – unjointed							
34	10	Tvs. Cracking – joint reflection	HE	HF	HE	HF	HF	HE	HE
34	11	Tvs. Cracking – intermediate		HO		HF	HF	HF	HF
34	12	Longitudinal cracking	MF	HF	HF	HE	HE	HE	HE
34	13	Pressure damage – upheaval				LO	MO	MO	MO
34	14	Crack sealing deficiency	E		E	E	E	E	E
34	16	Corner breaks – jointed base	ME						
34	17	Punchouts – unjointed base							

Table D-2. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
35	1	Raveling			HF	HO	HO	HF	HF
35	2	Bleeding							
35	3	Patching	HF	HE		HF	HF	HO	HO
35	4	Disintegration, debonding		HO		LO	LO	LO	LO
35	5	Rutting	HO	HO	HO	MO	MF	MO	MF
35	6	Pumping							
35	7	Shattered slab							
35	9	Tvs. Cracking – unjointed	MO	HO	HO	MO	MO	MO	MO
35	10	Tvs. Cracking – joint reflection							
35	11	Tvs. Cracking – intermediate							
35	12	Longitudinal cracking	MF	MF	HO	HF	HF	HF	HF
35	13	Pressure damage – upheaval		LO					
35	14	Crack sealing deficiency	E		E	F	F	F	F
35	16	Corner breaks – jointed base		LF					
35	17	Punchouts – unjointed base		MO		MF	MF	MF	MF
35A	1	Raveling			HF	HO	HO	HF	HF
35A	2	Bleeding							
35A	3	Patching	HE	HE		HF	HF	HO	HO
35A	4	Disintegration, debonding				LO	LO	LO	LO
35A	5	Rutting	HO	HO	HO	MO	MF	MO	MF
35A	6	Pumping							
35A	7	Shattered slab							
35A	9	Tvs. Cracking – unjointed	MO	HO	HO	MO	MO	MO	MO
35A	10	Tvs. Cracking – joint reflection							
35A	11	Tvs. Cracking – intermediate							
35A	12	Longitudinal cracking	MF	MF	HO	HF	HF	HF	HF
35A	13	Pressure damage – upheaval							
35A	14	Crack sealing deficiency	E		E	F	F	F	F
35A	16	Corner breaks – jointed base							
35A	17	Punchouts – unjointed base				MF	MF	MF	MF
36	1	Raveling	HO		HO	HE	HE	HE	HE
36	2	Bleeding							
36	3	Patching	MF	HO	HF	MO	HO	HO	HO
36	4	Disintegration, debonding		MO		LO	LO	LO	LO
36	5	Rutting	MO	MO	MO	LF	LF	LF	LE
36	6	Pumping							
36	7	Shattered slab							
36	9	Tvs. Cracking – unjointed							
36	10	Tvs. Cracking – joint reflection	ME	HO	HE	HF	HF	HF	HF
36	11	Tvs. Cracking – intermediate	LE	MO	LO	HF	HF	HF	HF
36	12	Longitudinal cracking	MO	HO	HO	HF	HF	HE	HE
36	13	Pressure damage – upheaval				LO	LO	LO	LO
36	14	Crack sealing deficiency	E		E	F	F	F	F
36	16	Corner breaks – jointed base	LE						
36	17	Punchouts – unjointed base							

Table D-2. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
38	1	Raveling			HO	LO	LO	LF	LF
38	2	Bleeding							
38	3	Patching	HO	HO	HO		HO		HO
38	4	Disintegration, debonding		MO					
38	5	Rutting	HO	HO	HO	MO	MO	MO	MO
38	6	Pumping							
38	7	Shattered slab							
38	9	Tvs. Cracking – unjointed	LO	MF	MO	LO	LO	LO	LO
38	10	Tvs. Cracking – joint reflection							
38	11	Tvs. Cracking – intermediate							
38	12	Longitudinal cracking	HO	HO	HO	MO	MO	HO	MO
38	13	Pressure damage – upheaval		LF					
38	14	Crack sealing deficiency	E		E	O	O	O	O
38	16	Corner breaks – jointed base							
38	17	Punchouts – unjointed base		MF					
40	1	Raveling			HO	LO	LO	LO	LO
40	2	Bleeding							
40	3	Patching	HO	HO				LO	LO
40	4	Disintegration, debonding			LO				
40	5	Rutting	HO	HO	HO	LF	LE	LF	LE
40	6	Pumping				O	O	O	O
40	7	Shattered slab							
40	9	Tvs. Cracking – unjointed							
40	10	Tvs. Cracking – joint reflection	ME	HO	HE	MO	MO	HO	HO
40	11	Tvs. Cracking – intermediate		HO		MO	MO	MO	MO
40	12	Longitudinal cracking	MO	HO	HO	MO	MO	MO	MO
40	13	Pressure damage – upheaval		LE					
40	14	Crack sealing deficiency	E		E	E	E	O	O
40	16	Corner breaks – jointed base				MO	MO	MO	MO
40	17	Punchouts – unjointed base							
42	1	Raveling	LO		MO	MO	MO	MO	MO
42	2	Bleeding							
42	3	Patching	MF	HO		MO	MO	LO	LO
42	4	Disintegration, debonding							
42	5	Rutting	MO	LO	LO				
42	6	Pumping					O	O	O
42	7	Shattered slab							
42	9	Tvs. Cracking – unjointed							
42	10	Tvs. Cracking – joint reflection	ME	HO	ME	ME	ME	HF	HF
42	11	Tvs. Cracking – intermediate	LF	HO	ME	MO	MO	MO	MO
42	12	Longitudinal cracking	MO	HO	MO	MF	MF	MF	MF
42	13	Pressure damage – upheaval				LF	LF	LE	LE
42	14	Crack sealing deficiency	E		E	O	O	O	O
42	16	Corner breaks – jointed base	LE			LO	LO	LO	LO
42	17	Punchouts – unjointed base							

Table D-2. AC/PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
43	1	Raveling			MO	LO	LO		
43	2	Bleeding	MF	ME	HE	MF	MF	MF	MF
43	3	Patching							
43	4	Disintegration, debonding							
43	5	Rutting	MO	LO	MO	LO	LO	LO	LO
43	6	Pumping							
43	7	Shattered slab							
43	9	Tvs. Cracking – unjointed							
43	10	Tvs. Cracking – joint reflection	LE	HO	HE	LF	LF	LF	LF
43	11	Tvs. Cracking – intermediate		LE		LE	LE	LE	LE
43	12	Longitudinal cracking	MO	HO	HO	MO	MO	MO	MO
43	13	Pressure damage – upheaval					MO		LO
43	14	Crack sealing deficiency	E		E	O	O	O	O
43	16	Corner breaks – jointed base	LE						
43	17	Punchouts – unjointed base							
44	1	Raveling	HE	MO	HO	HE	HE	HE	HE
44	2	Bleeding							
44	3	Patching	HO	HO		MO	LO	LO	MO
44	4	Disintegration, debonding		LO		LO	LO	LO	LO
44	5	Rutting	MO	HO	HO	LF	LF	LF	LF
44	6	Pumping							
44	7	Shattered slab	HE						
44	9	Tvs. Cracking – unjointed							
44	10	Tvs. Cracking – joint reflection	HE	ME		HF	HF	HF	HF
44	11	Tvs. Cracking – intermediate		MO		ME	ME	MF	ME
44	12	Longitudinal cracking	HO	HF		HE	HE	HE	HE
44	13	Pressure damage – upheaval				LO	LO	LO	LO
44	14	Crack sealing deficiency	E		E	E	E	E	E
44	16	Corner breaks – jointed base	MO						
44	17	Punchouts – unjointed base							

Table D-3. PCC distress, severity, and extent values.

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
2	1	Surface deterioration		HO		LO	LO	LO	LO
2	3	Patching		HE	HE				
2	4	Pumping							
2	5	Faulting	MO	HO	LE	LO	LO	LO	LO
2	6	Settlement							
2	7	Transverse joint spalling	LO	LE	LE	LO	LO	LO	LO
2	9	Pressure damage – upheaval							
2	10	Tvs. Cracking - > 20 ft slabs							
2	11	Longitudinal cracking							
2	12	Corner breaks							
2	13	Longitudinal joint spalling	LO	MO	HO	LO	LO		LO
2	14	Tvs. Cracking - < 20 ft slabs	LO	LF	LO	MF	MF	HF	HF
5	1	Surface deterioration				LF	LE	LE	LE
5	3	Patching	HF	HF	HE	HE	HE	HF	HF
5	4	Pumping				O	O	O	O
5	5	Faulting	MO	HO	LE	MO	MO	LF	LF
5	6	Settlement					LO		LO
5	7	Transverse joint spalling	HO	LE	MF	LF	LF	LO	LF
5	9	Pressure damage – upheaval	LE			F	F	F	F
5	10	Tvs. Cracking - > 20 ft slabs	HF	MO	HF	HF	HF	HF	HF
5	11	Longitudinal cracking	HO	MO	LO	MO	MO	MO	MO
5	12	Corner breaks	MO	LO	HO				
5	13	Longitudinal joint spalling	ME	HO	ME	HO	HO	HF	HF
5	14	Tvs. Cracking - < 20 ft slabs							
13	1	Surface deterioration		LO		LF	LF	MO	MO
13	3	Patching	HE	HE	HE	HE	HE	HE	HE
13	4	Pumping							
13	5	Faulting	MO	HO	HO	HF	HF	HF	HF
13	6	Settlement							
13	7	Transverse joint spalling	MF	HO	ME	HO	HO	HF	HF
13	9	Pressure damage – upheaval				F	F	O	O
13	10	Tvs. Cracking - > 20 ft slabs							
13	11	Longitudinal cracking	HO	LF	LF	MO	MO	MO	MO
13	12	Corner breaks	HF	MF		HO	HO	HO	HO
13	13	Longitudinal joint spalling	HF	MF	ME	HO	HF	HO	HF
13	14	Tvs. Cracking - < 20 ft slabs	LO	LF	LF	HF	HF	HF	HO

Table D-3. PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1		ODOT Rater 2	
						Rep 1	Rep 2	Rep 1	Rep 2
14	1	Surface deterioration	LO			LO	LO	LF	LF
14	3	Patching	HO	HO	HO	HE	HE	HE	HE
14	4	Pumping							
14	5	Faulting	MO	LE	LE				
14	6	Settlement							
14	7	Transverse joint spalling	HO	LE	MF	MO	MO	HO	HO
14	9	Pressure damage – upheaval					O		O
14	10	Tvs. Cracking - > 20 ft slabs	LO	LO	LO	LF	LF	LF	LF
14	11	Longitudinal cracking	MO		MF				
14	12	Corner breaks	MO	LE	MO				
14	13	Longitudinal joint spalling	MO	LO	LO	HO	HF	HO	HF
14	14	Tvs. Cracking - < 20 ft slabs							
15	1	Surface deterioration		HO		LF	LF	LF	LF
15	3	Patching	HO	HF	HO	HO	HO	MO	MO
15	4	Pumping							
15	5	Faulting	MO	HO	LE	LO	LO	LO	LO
15	6	Settlement				LO	LO	LO	LO
15	7	Transverse joint spalling	HO	LE	LE	LO	LF	LO	LF
15	9	Pressure damage – upheaval							
15	10	Tvs. Cracking - > 20 ft slabs	ME	LF	MF	ME	ME	ME	ME
15	11	Longitudinal cracking							
15	12	Corner breaks	HO		HO				
15	13	Longitudinal joint spalling	ME	HO	HE	MF	MF	HO	HO
15	14	Tvs. Cracking - < 20 ft slabs							
16	1	Surface deterioration		HO		LO	LO	LO	LF
16	3	Patching	HF	HF	HO	HO	HO	MO	MO
16	4	Pumping							
16	5	Faulting	MF	HO	LE	MF	MF	MF	MF
16	6	Settlement							
16	7	Transverse joint spalling	MO	MF	MF	LO	LO	LO	LO
16	9	Pressure damage – upheaval				F	F	F	F
16	10	Tvs. Cracking - > 20 ft slabs	ME	ME	ME	ME	ME	HF	HF
16	11	Longitudinal cracking			LO	LO			
16	12	Corner breaks	LO						
16	13	Longitudinal joint spalling	MO		MO	LE	LE	LF	LF
16	14	Tvs. Cracking - < 20 ft slabs							

Table D-3. PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
17	1	Surface deterioration		LO		LF	LF	LO	LF
17	3	Patching	HO	HO	HF	HO	HO	HO	HO
17	4	Pumping							
17	5	Faulting	MO	HO	LE	MO	MO	MO	MO
17	6	Settlement					LO		
17	7	Transverse joint spalling	HO	HF	LE	LO	LO	LO	LO
17	9	Pressure damage – upheaval				F	F	F	F
17	10	Tvs. Cracking - > 20 ft slabs	ME	ME	ME	ME	ME	HF	HF
17	11	Longitudinal cracking	LO		LF				
17	12	Corner breaks	HO				MO		HO
17	13	Longitudinal joint spalling	HO	MO	HO	MO	MO	MO	MO
17	14	Tvs. Cracking - < 20 ft slabs							
19	1	Surface deterioration				LO	LO	LO	LO
19	3	Patching	HO	HO		HO	HO	LO	LO
19	4	Pumping							
19	5	Faulting	MO	MF	LE				
19	6	Settlement							
19	7	Transverse joint spalling	HO	LE	ME	LO	LO	LO	LO
19	9	Pressure damage – upheaval				F	F	F	F
19	10	Tvs. Cracking - > 20 ft slabs							
19	11	Longitudinal cracking	MF	LO	LF	LE	LE	LF	LE
19	12	Corner breaks							
19	13	Longitudinal joint spalling		LO					
19	14	Tvs. Cracking - < 20 ft slabs	LF	LO	LO	LE	LE	LE	LE
19A	1	Surface deterioration				LO	LO	LO	LO
19A	3	Patching	HO	MO		HO	HO	LO	LO
19A	4	Pumping							
19A	5	Faulting	MO	MF	LE				
19A	6	Settlement							
19A	7	Transverse joint spalling	HO	LE	ME	LO	LO	LO	LO
19A	9	Pressure damage – upheaval				F	F	F	F
19A	10	Tvs. Cracking - > 20 ft slabs							
19A	11	Longitudinal cracking	MF	LO	LF	LE	LE	LF	LE
19A	12	Corner breaks							
19A	13	Longitudinal joint spalling		LO					
19A	14	Tvs. Cracking - < 20 ft slabs	LF	LO	LO	LE	LE	LE	LE

Table D-3. PCC distress, severity, and extent values (continued).

Site	ODOT Dist No	Distress Name	Pathway	Fugro	Mandli	ODOT Rater 1 Rep 1	ODOT Rater 1 Rep 2	ODOT Rater 2 Rep 1	ODOT Rater 2 Rep 2
22	1	Surface deterioration		LO		LE	LE	LE	LE
22	3	Patching	HO	HF	HF	MO	MO	LO	MO
22	4	Pumping							
22	5	Faulting	MO	HO	LE	LO	LO	LO	LO
22	6	Settlement							
22	7	Transverse joint spalling	HO	LE	MF	LO	LO	LO	LO
22	9	Pressure damage – upheaval	LF			F	F	E	E
22	10	Tvs. Cracking - > 20 ft slabs	MF	LO	ME	ME	ME	ME	ME
22	11	Longitudinal cracking	MF		HF	MF	HO	HO	HO
22	12	Corner breaks	HO		HO				
22	13	Longitudinal joint spalling	MO		MO	LO	LO	LO	LO
22	14	Tvs. Cracking - < 20 ft slabs							
25	1	Surface deterioration				LF	LE	LE	LE
25	3	Patching	HF	HF	HF	MO	HO	MO	MO
25	4	Pumping							
25	5	Faulting	MO	HO	LE	LF	LF	LO	LF
25	6	Settlement							
25	7	Transverse joint spalling	HO	HO	MF	LO	LO	LO	LO
25	9	Pressure damage – upheaval	LE			O	O	O	O
25	10	Tvs. Cracking - > 20 ft slabs	HF	MF	MF	HF	HF	HF	HF
25	11	Longitudinal cracking			MO				
25	12	Corner breaks	MO		MO				
25	13	Longitudinal joint spalling	HO	HO	HO	LO	LO	LO	LO
25	14	Tvs. Cracking - < 20 ft slabs							
26	1	Surface deterioration				LF	LE	LE	LE
26	3	Patching	HE	HE	HF	HE	HE	HE	HE
26	4	Pumping			O				
26	5	Faulting	MO	MO	LE	LO	LO	LO	LO
26	6	Settlement							
26	7	Transverse joint spalling	HO	LE	ME	LO	LO	LO	LO
26	9	Pressure damage – upheaval							
26	10	Tvs. Cracking - > 20 ft slabs	MO	MO	ME	HF	HF	HF	HF
26	11	Longitudinal cracking							
26	12	Corner breaks							
26	13	Longitudinal joint spalling	HF	HO	ME	MO	MO	MO	MO
26	14	Tvs. Cracking - < 20 ft slabs							

APPENDIX E—PCR RATING SUMMARY

Table E-1. Project PCR rating values.

Site No	Pvt Type	ODOT R1 Rep 1	ODOT R1 Rep 2	ODOT R2 Rep 1	ODOT R2 Rep 2	ODOT Avg.	Fugro	Mandli	Pathway
1	APC	66.4	65.4	61.0	59.8	63.1	73.8	78.6	60.2
2	PCC	80.4	80.4	81.6	80.4	80.7			
3	AC	61.2	58.8	61.4	59.8	60.3	61.8	55.5	59.0
4	AC	59.0	55.0	53.4	54.3	55.4	64.0	45.3	62.5
5	PCC	53.8	53.0	55.5	54.3	54.2	55.0	70.4	57.9
6	APC	63.9	63.9	58.4	60.0	61.6	61.7	79.1	69.2
7	APC	75.4	77.4	75.7	75.7	76.1	56.4	72.1	66.0
8	APC	68.4	68.4	66.2	65.7	67.2	61.0	80.9	70.0
9	APC	64.0	63.8	63.0	61.8	63.1	48.4	70.7	80.4
10	APC	60.2	64.6	66.2	64.0	63.7	66.4	77.8	66.0
11	APC	57.4	58.6	52.5	52.5	55.3	49.6	76.2	75.0
12	AC	62.0	59.6	60.8	59.6	60.5	71.8	72.1	75.6
13	PCC	47.0	46.0	44.5	48.0	46.4	58.4	51.9	58.0
14	PCC	79.9	76.4	77.6	74.1	77.0	74.6	81.2	73.3
15	PCC	73.0	71.8	74.3	73.1	73.1	66.0	72.8	67.4
16	PCC	65.0	67.0	68.9	68.1	67.3	66.8	63.4	69.3
17	PCC	68.2	64.2	69.0	63.2	66.2	64.5	65.5	64.5
18	APC	41.2	43.2	40.6	40.6	41.4	50.6	76.3	63.4
19	PCC	66.6	66.6	70.1	69.6	68.2	68.2	74.7	77.0
19A	PCC	66.6	66.6	70.1	69.6	68.2	68.2	76.2	77.0
20	AC	67.5	66.3	66.3	65.1	66.3	66.8	63.5	57.6
20A	AC	67.5	66.3	66.3	65.1	66.3	66.8	63.1	57.3
21	APC	65.1	63.1	64.0	63.1	63.8	52.2	79.5	71.8
22	PCC	65.0	67.3	67.8	66.3	66.6	59.5	80.0	54.3
23	APC	71.6	68.9	70.1	68.0	69.7	49.6	79.1	71.0
24	AC	76.1	76.1	77.5	76.9	76.7	65.0	65.3	60.8
25	PCC	72.4	70.1	72.8	71.6	71.7	59.5	69.4	63.0
26	PCC	68.7	67.9	67.9	67.9	68.1	73.7	74.7	61.0
27	AC	76.5	75.3	75.9	74.7	75.6	79.0	60.5	61.5
28	AC	70.2	69.0	70.5	69.1	69.7	62.3	76.6	73.3
29	AC	68.2	68.2	67.9	65.9	67.6	67.9	68.3	69.3
30	AC	78.6	78.6	79.2	79.2	78.9	83.6	80.7	69.8
31	AC	77.0	76.2	74.7	74.7	75.6	74.5	76.1	65.0
32	APC	59.0	59.0	59.0	59.0	59.0	67.0	82.4	69.0
33	AC	72.9	72.9	69.1	68.5	70.9	73.0	56.8	64.0
34	APC	58.8	58.3	56.8	55.9	57.5	48.6	73.3	69.8
35	APC	63.5	62.1	61.5	60.1	61.8	72.3	74.6	71.0
35A	APC	63.5	62.1	61.5	60.1	61.8	71.3	78.6	71.0
36	APC	59.9	58.7	57.7	57.1	58.4	69.4	82.3	67.2
37	AC	80.3	79.7	79.8	79.2	79.8	69.6	73.0	62.1
38	APC	89.0	86.0	87.3	85.1	86.9	80.4	76.0	74.2
39	AC	68.5	67.0	66.1	65.3	66.7	69.2	63.7	51.5
40	APC	78.1	79.5	77.8	77.2	78.1	77.6	79.0	69.1
42	APC	77.6	74.6	72.7	72.7	74.4	73.2	85.2	77.0
43	APC	85.9	84.4	87.4	86.4	86.0	79.6	85.8	68.8
44	APC	59.5	60.4	61.4	59.5	60.2	49.8	74.0	69.4

APPENDIX F—VENDOR COST ESTIMATE SUMMARY (AVERAGE OF ALL VENDORS)

Ohio DOT is considering transitioning from manual to automated collection methods for pavement surface distress data. The following questions are designed to assist in that evaluation. Please complete them in this electronic document to the best of your ability and return it to Lynn Evans at ARA (levans@ara.com).

Your responses will be kept in strict confidence. The detailed information from this survey will not be published or made available to any other vendor. The terms of any Nondisclosure Agreement can be applied to the provided data.

Please use the following information as you prepare your responses.

Annual lane miles of data collection:
22,942 mi (Interstate – 3,128 mi, State – 14,827 mi, US – 4,987 mi).

Collection Procedures:
Two lane roads: one lane collected in the same direction each year.
Divided 4+ lane roads: one lane collected in each direction.

Data Quality:
Average PCR initially confirmed within 10 percent of manual ODOT ratings.
Industry standard Quality Control processes.
Agency standard Quality Assurance processes.

Vendor Contact Information

Name: ______________________________

Company: ______________________________

Current position/title: ______________________________

Address: ______________________________

City, State, ZIP: ______________________________

Phone: ______________________________

Email: ______________________________

ODOT is considering each of the following options. To assist in their decision processes, please note below an approximate price (US dollars) for providing ODOT with the equipment, technical support, and services described in the following scenarios. These estimates are not considered an official cost proposal.

Option 1. ODOT purchases equipment in 2013 from Vendor for Agency data collection, processing, QC and QA.

Collection System (CS) as described in table 1	$/CS	1,040,000
Workstation (WS) as described in table 1	$/WS	38,000
Web hosting instance	$	50,000
3-year warranty on collection system (not including vehicle)	$	153,000
5-year warranty on collection system (not including vehicle)	$ (US)	302,000
Initial collection system training & 1st year tech support	$/CS	17,000
Initial workstation training & 1st year tech support	$/WS	6,700
Ongoing collection system technical support (not including vehicle)	$ /yr	28,600
Ongoing workstation technical support	$ /yr	4,200
Estimated annual ODOT collection person-hours	hours/yr	6,500
Estimated annual ODOT processing person-hours	hours/yr	7,000

Comments: (Please include any additional anticipated costs or services.)

Table 1. Collection System, Workstation, and Web Posting Properties. (Please describe the costs and properties of the system you believe would best fit ODOT's needs.)

Summary Specification	Explanation of Details/Exceptions
1. VEHICLE: Contractor shall supply a current model full-size van adequate to provide safe, comfortable, efficient, effective data collection.	
2. SUBSYSTEM SAFETY: The vehicle and all installed subsystems shall provide safety for operators, pedestrians, and other drivers. This includes but is not limited to interior noise dampening (OSHA 1910.95), laser shields, eyewear, and shutoffs, a backup camera, and light bars.	
3. VEHICLE DISTANCE MEASUREMENT INSTRUMENT: The vehicle shall be equipped with a Distance Measuring Instrument (DMI) to reference all images, data, and information to the Ohio state highway system by highway number, mileage reference marker (MRM), and displacement from the MRM.	
4. LINEAR REFERENCING: All collected images, data, and other information shall be referenced to the Ohio state highway system by highway number, Mileage Reference Marker (MRM), displacement from the MRM, and lane number.	
5. GLOBAL POSITIONING: The system shall include a high quality Global Positioning System capable of receiving and applying satellite-based or beacon-based real-time differential corrections.	
6. ROADWAY DIGITAL IMAGING: The system shall collect, process, store, and display on the operator's terminal high quality digital images of the roadway using camera(s) activated at regular, operator-defined intervals as the vehicle travels at normal highway speeds.	
7. LONGITUDINAL PROFILE MEASUREMENT: The system shall measure and record longitudinal profile continuously between operator-triggered start and end points. The system shall meet all Class 1 requirements of ASTM E 950-09, AASHTO MP 328-10, and ASSHTO R56-10.	

Table 1. Collection System, Workstation, and Web Posting Properties. (Please describe the costs and properties of the system you believe would best fit ODOT's needs.) (continued)

Summary Specification	Explanation of Details/Exceptions
8. SLAB FAULTING MEASUREMENT: The system shall independently detect slab faulting, including at skewed joints, in the left and right wheel paths using non-contact sensors, meeting all requirements of AASHTO R 36-12.	
9. TRANSVERSE PROFILE AND RUTTING MEASUREMENT: The system shall measure and record the transverse profile of the pavement surface (at 4-m minimum width), including at least 1280 profile points.	
10. AUTOMATED CRACK DETECTION: The system shall acquire 4-m (minimum width) continuous intensity images and three-dimensional surface elevations of the pavement surface providing ability to measure 2-mm (0.08-in) cracks.	
11. PAVEMENT MACROTEXTURE MEASUREMENT: The system shall estimate macrotexture in the left wheel path using a non-contact sensor following the requirements of ASTM E 1845-09.	
12. ONBOARD COMPUTER SYSTEM: The system shall include computers and software with adequate speed, capacity, and power to control onboard data acquisition subsystems at speeds up to 70 mph.	
13. DEDICATED WORKSTATION SOFTWARE: The Contractor shall supply dedicated workstation software for processing all images and data acquired by the mobile equipment, to be installed on workstation(s) supplied by ODOT.	
14. WEB-BASED VIEWING SOFTWARE: The Contractor shall supply a web-based application, to be hosted on servers operated by ODOT.	

Option 2. ODOT purchases equipment in 2013 from Vendor for Agency data collection, Vendor processes data, and Agency conducts QA.

Collection system(CS) as described in table 1	$/CS	1,040,000
Web hosting instance	$	50,000
3-year warranty on collection system (not including vehicle)	$	153,000
5-year warranty on collection system (not including vehicle)	$	302,000
Initial collection system training & 1st year tech support	$	20,000
Ongoing collection system technical support (not including vehicle)	$	28,600
Annual processing of ODOT-collected data	$/ln mi	49
Estimated ODOT data collection person-hours	hours/yr	6,500

Comments: (Please include any additional anticipated costs or services.)

Estimated Annual Equipment Cost Information

Please provide an estimated value or range ODOT may encounter for the following items, based on your experience:

Vehicle miles requiring vehicle replacement*	miles	320,000
Years to past warranty software upgrade	years	6
Years to right of way camera(s) replacement*	years	6
Years to downward image camera replacement*	years	6
Years to computer hardware replacement*	years	6
Years to longitudinal profile sensor replacement*	years	7
Years to GPS system replacement*	years	7
Years to inertial navigation system replacement*	years	7
Estimated ODOT annualized operating cost (not including vehicle purchase and maintenance)	$/year	10,000

**Consider only replacement due to equipment failure rather than obsolescence.*

Comments: (Please include any additional related information or explanations.)

Option 3. Vendor collects data using standard QC procedures and ODOT processes the data in-house and completes QA.

Annual collection of ODOT data	$/ln mi	45
Workstation (WS) as described in table 1	$/WS	38,000
Web hosting instance	$	50,000
Initial workstation training & 1st year tech support	$/WS	10,000
Ongoing ODOT workstation technical support	$/year	5,800
Estimated ODOT data processing person-hours	hours/yr	7,000

Comments: (Please include any additional anticipated costs or services.)

Option 4. Vendor collects and processes ODOT data following standard vendor QC and ODOT QA requirements.

Annual collection of ODOT data	$/ln mi	40
Annual processing of ODOT data	$/ln mi	49

Comments: (Please include any additional anticipated costs or services.)

Contribution and Production Estimates

Additionally, as we discussed early in the project, please provide the following contribution and production estimates for this project and for full-scale testing and evaluation.

To-date ODOT PCR Research Project Contributions (your approximate efforts toward this research):

Activity	Avg. Hours of Effort
Software development	68
Manual distress identification:	See below…
• AC pavement sites	110
• AC/PCC pavement sites	95
• PCC pavement sites	60
Quality Control/Quality Assurance	50
Correspondence, management, demonstration, and other activities	490

We thank you for your "above and beyond" effort!

First Year's Full Scale Production Estimates (scenario 4 – You complete data collection and processing):

Activity	Avg. Time, weeks
Time required after award for mobilization	3
Time required for data collection	20
Time required for initial data processing and QC	16
Time required for initial fine tuning of distress ID procedures	5
Total time from mobilization to completed project delivery	30

Subsequent Year's Full Scale Production Estimates (scenario 4):

Activity	Avg. Time, weeks

Time required for vendor data collection	20
Time required for initial vendor data processing and QC	15
Total time from mobilization to completed project delivery	28

Additional Comments:

____

____

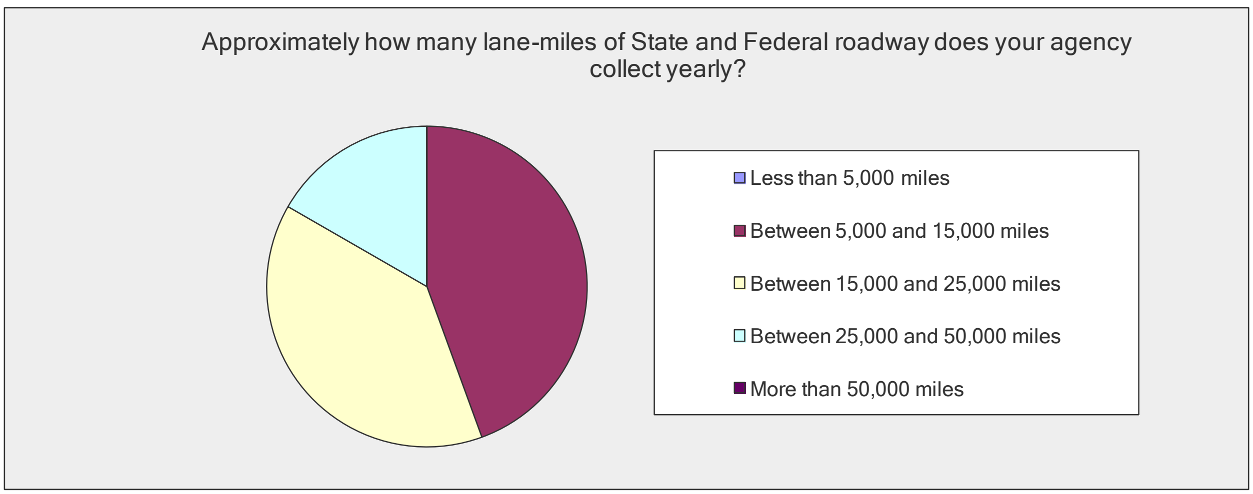
____

Thank you for completing the survey!

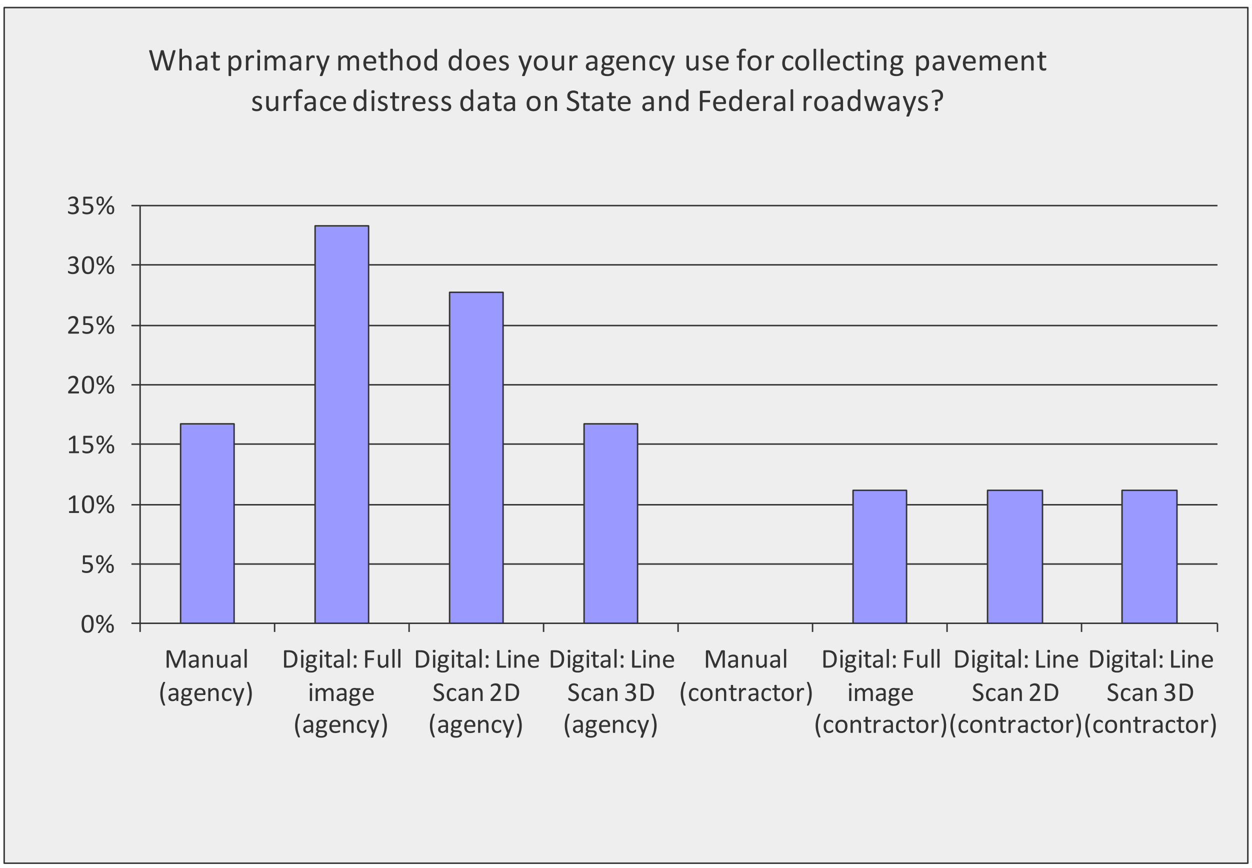
Please send any additional information or documents that you think might be of use for this project to Mr. Lynn Evans, email: levans@ara.com, 100 Trade Centre Drive, Suite 200, Champaign, IL 61820, Tel: 217-356-4500, Fax: 217-356-3088.

APPENDIX G—AASHTO SURVEY RESULTS

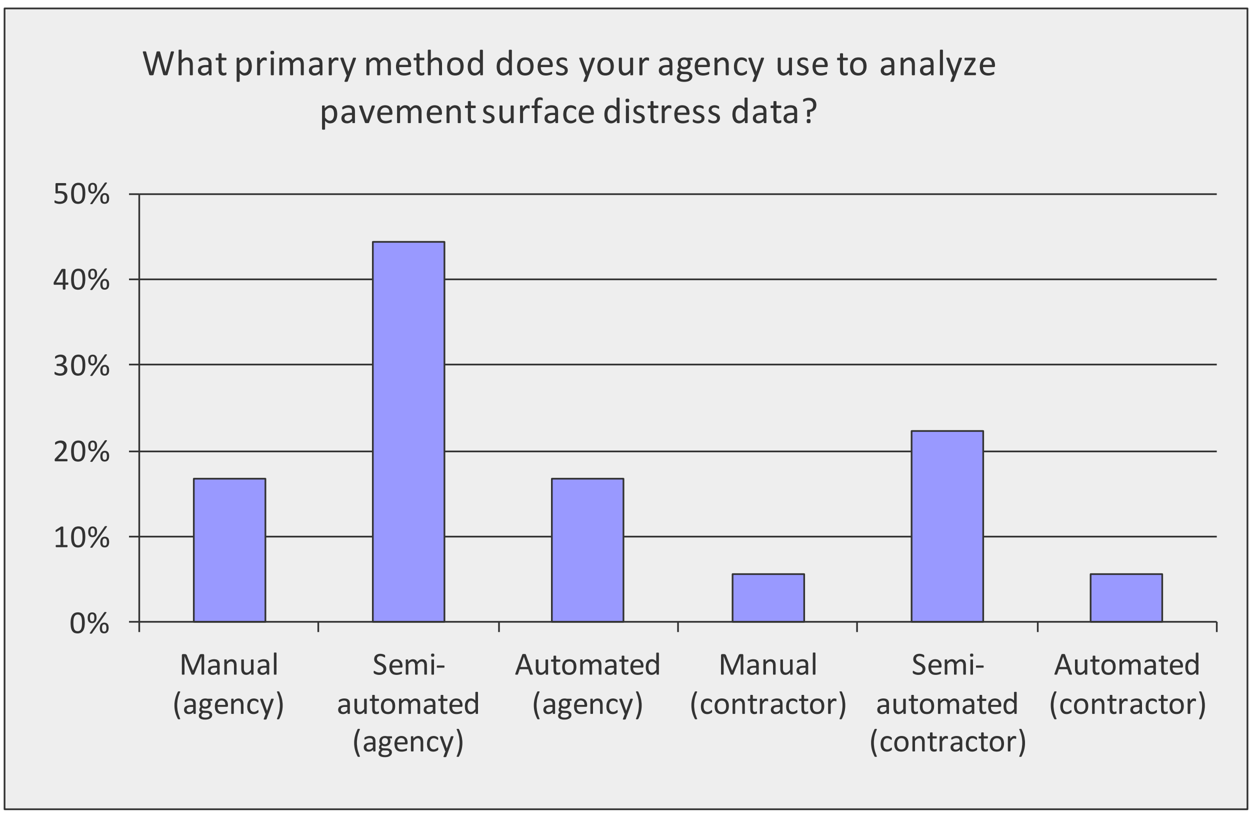
Approximately how many lane-miles of State and Federal roadway does your agency collect yearly?		
Answer Options	**Response Percent**	**Response Count**
Less than 5,000 miles	0.0%	0
Between 5,000 and 15,000 miles	44.4%	8
Between 15,000 and 25,000 miles	38.9%	7
Between 25,000 and 50,000 miles	16.7%	3
More than 50,000 miles	0.0%	0
	Total Responses	**18**



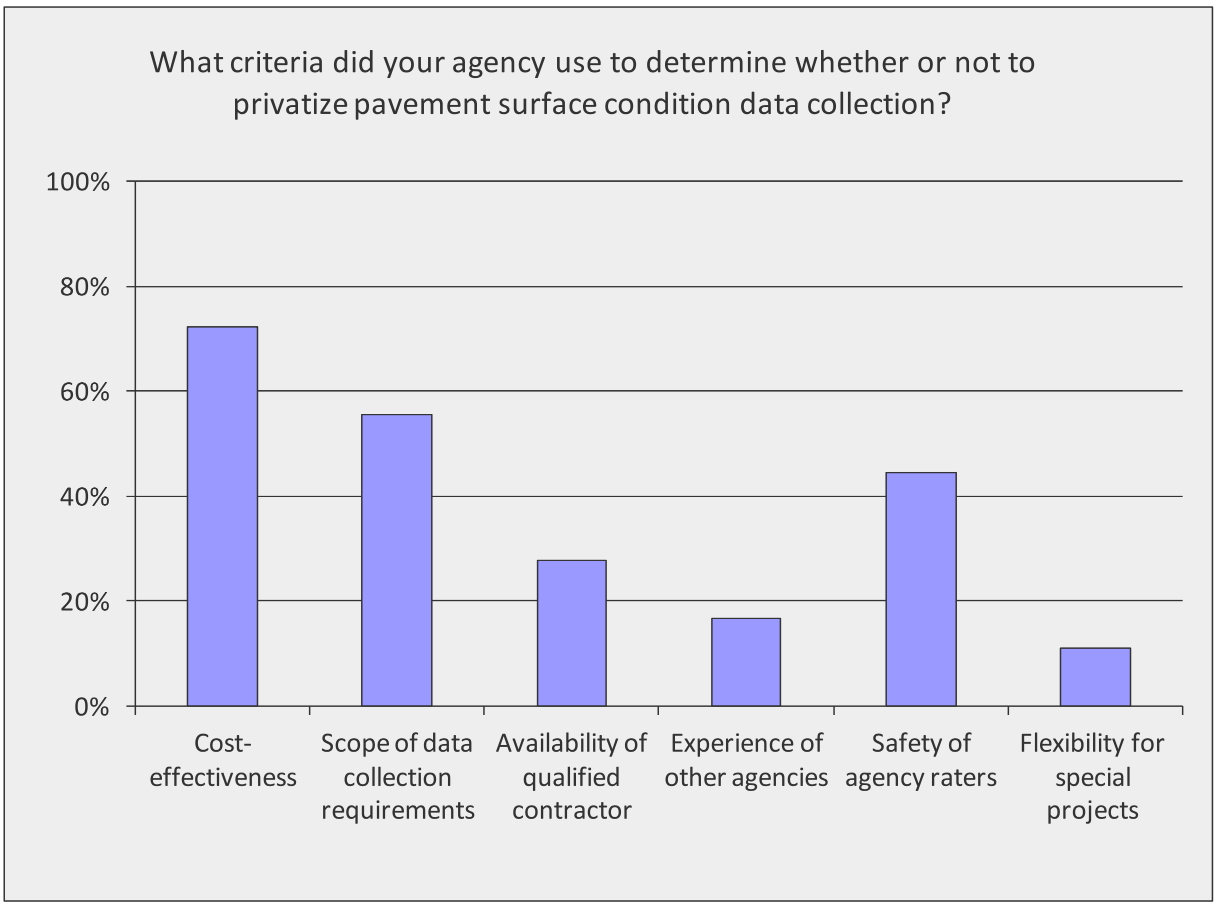
What primary method does your agency use for collecting pavement surface distress data on State and Federal roadways?		
Answer Options	**Method Percent**	**Method Count**
Manual (agency)	16.7%	3
Digital: Full image (agency)	33.3%	6
Digital: Line Scan 2D (agency)	27.8%	5
Digital: Line Scan 3D (agency)	16.7%	3
Manual (contractor)	0.0%	0
Digital: Full image (contractor)	11.1%	2
Digital: Line Scan 2D (contractor)	11.1%	2
Digital: Line Scan 3D (contractor)	11.1%	2
Other (please specify)	5.6%	1
	Agency Responses	**18**



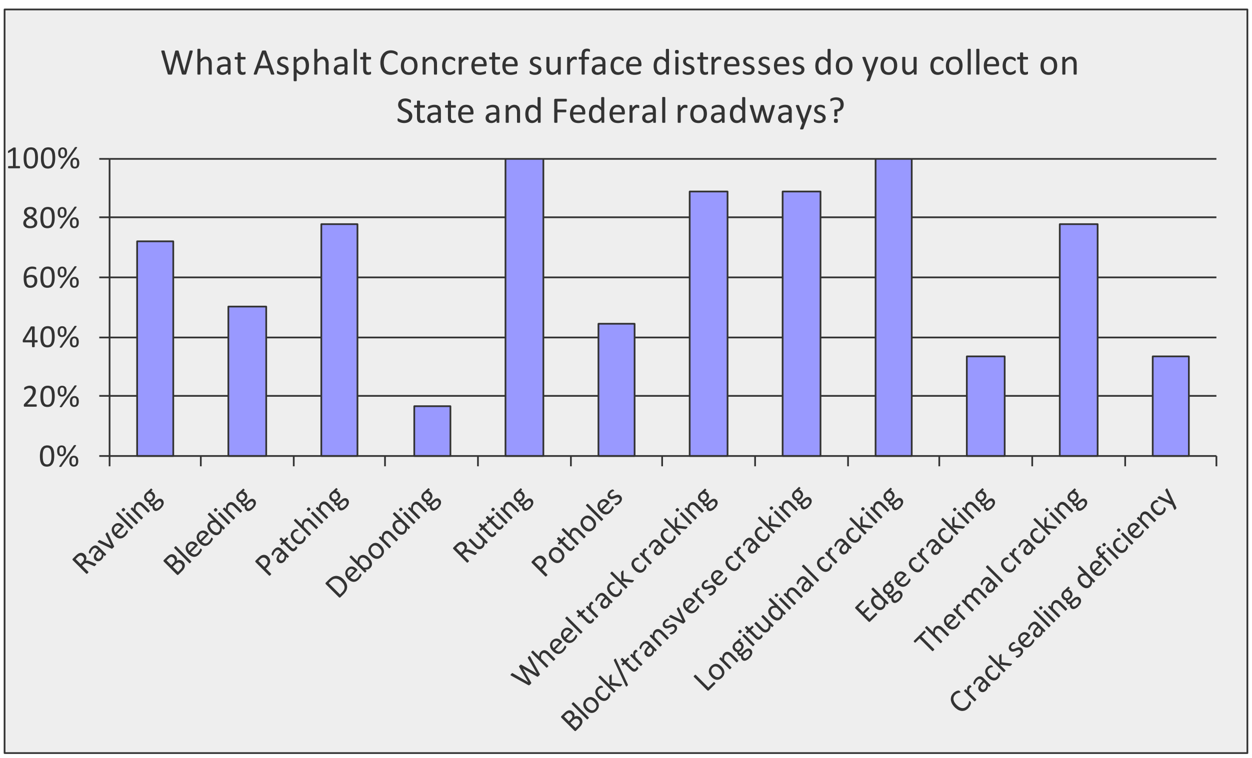
What primary method does your agency use to analyze pavement surface distress data?		
Answer Options	**Method Percent**	**Method Count**
Manual (agency)	16.7%	3
Semi-automated (agency)	44.4%	8
Automated (agency)	16.7%	3
Manual (contractor)	5.6%	1
Semi-automated (contractor)	22.2%	4
Automated (contractor)	5.6%	1
	Agency Responses	**18**



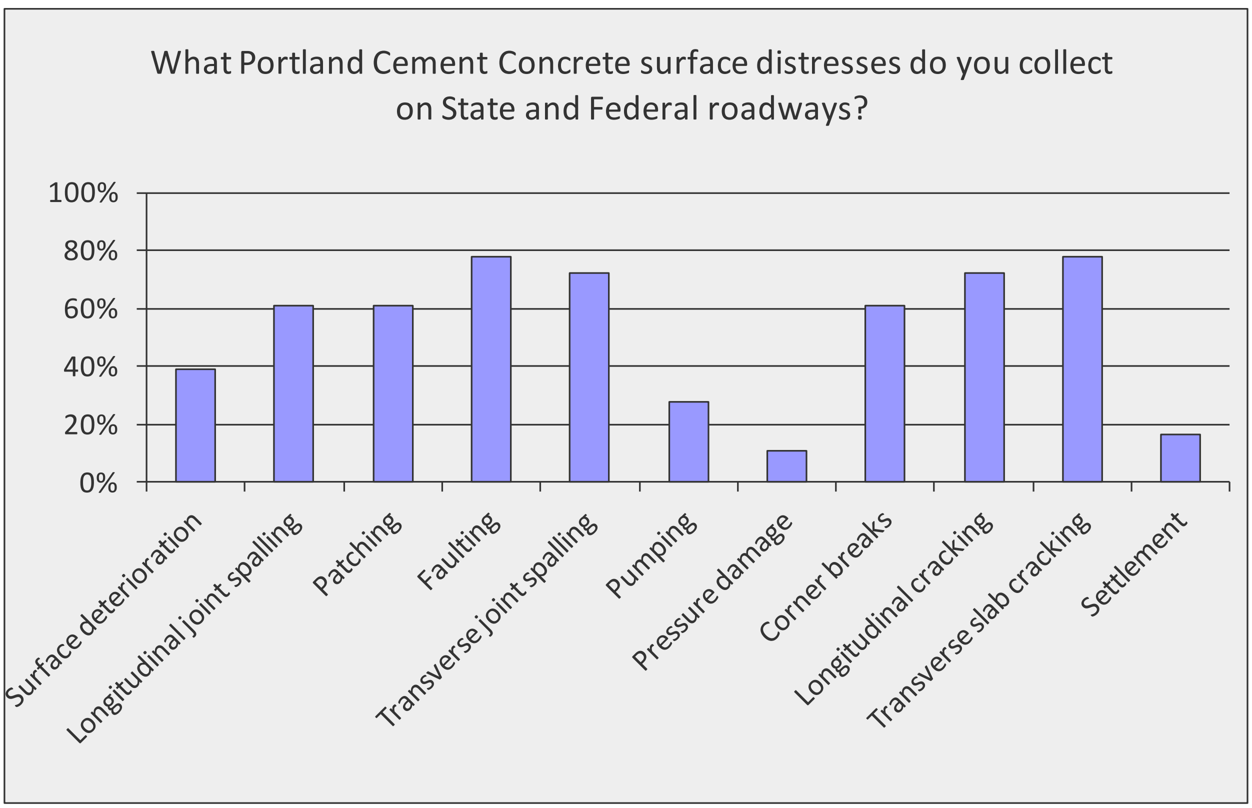
What criteria did your agency use to determine whether or not to privatize pavement surface condition data collection? (Check all that apply.)		
Answer Options	**Response Percent**	**Response Count**
Cost-effectiveness	72.2%	13
Scope of data collection requirements	55.6%	10
Availability of qualified contractor	27.8%	5
Experience of other agencies	16.7%	3
Safety of agency raters	44.4%	8
Flexibility for special projects	11.1%	2
Other (please specify)	55.6%	10
	Agency Responses	**18**



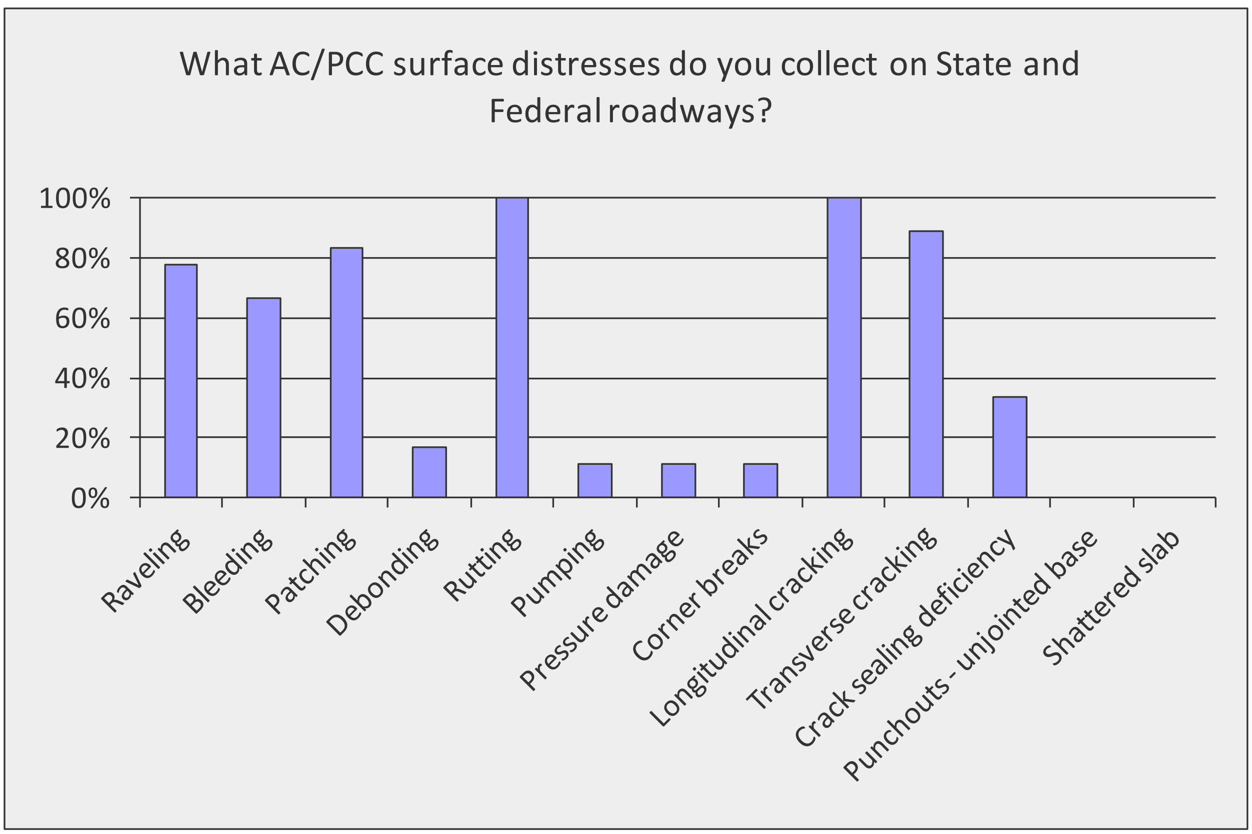
What ASPHALT (AC) surface distresses do you collect on State and Federal roadways? (Check all that apply.)		
Answer Options	**Response Percent**	**Response Count**
Raveling	72.2%	13
Bleeding	50.0%	9
Patching	77.8%	14
Debonding	16.7%	3
Rutting	100.0%	18
Potholes	44.4%	8
Wheel track cracking	88.9%	16
Block/transverse cracking	88.9%	16
Longitudinal cracking	100.0%	18
Edge cracking	33.3%	6
Thermal cracking	77.8%	14
Crack sealing deficiency	33.3%	6
Other (please specify)	44.4%	8
	Agency Responses	**18**



What Portland Cement Concrete (PCC) surface distresses do you collect on State and Federal roadways? (Check all that apply.)		
Answer Options	**Response Percent**	**Response Count**
Surface deterioration	38.9%	7
Longitudinal joint spalling	61.1%	11
Patching	61.1%	11
Faulting	77.8%	14
Transverse joint spalling	72.2%	13
Pumping	27.8%	5
Pressure damage	11.1%	2
Corner breaks	61.1%	11
Longitudinal cracking	72.2%	13
Transverse slab cracking	77.8%	14
Settlement	16.7%	3
Other (please specify)	61.1%	11
	Agency Responses	**18**



What AC/PCC surface distresses do you collect on State and Federal roadways? (Check all that apply.)		
Answer Options	**Response Percent**	**Response Count**
Raveling	77.8%	14
Bleeding	66.7%	12
Patching	83.3%	15
Debonding	16.7%	3
Rutting	100.0%	18
Pumping	11.1%	2
Pressure damage	11.1%	2
Corner breaks	11.1%	2
Longitudinal cracking	100.0%	18
Transverse cracking	88.9%	16
Crack sealing deficiency	33.3%	6
Punchouts - unjointed base	0.0%	0
Shattered slab	0.0%	0
Other (please specify)	61.1%	11
	Agency Responses	**18**



What type of quality checks are applied to pavement data collection as part of your quality management program? *Note that Quality Control is conducted by the data collection provider (vendor or agency) and Quality Assurance by the owner agency.			
Quality Control*			
Answer Options	**Yes**	**No**	**Response Count**
Calibration of equipment and/or analysis criteria before the data collection	17	1	18
Testing of known "control" segments before data collection	16	2	18
Periodic testing of known "control" segments during production	13	5	18
Periodic testing of blind "control" segments during production	4	14	18
Verification of sample data by an independent consultant	4	14	18
Verification of the post-survey processing software/procedures	13	5	18
Cross-measurements; i.e. random assignment of repeated segments to different	5	13	18

What type of quality checks are applied to pavement data collection as part of your quality management program? *Note that Quality Control is conducted by the data collection provider (vendor or agency) and Quality Assurance by the owner agency.			
Quality Assurance*			
Answer Options	**Yes**	**No**	**Response Count**
Calibration of equipment and/or analysis criteria before the data collection	11	7	18
Testing of known "control" segments before data collection	14	4	18
Periodic testing of known "control" segments during production	10	8	18
Periodic testing of blind "control" segments during production	4	14	18
Verification of sample data by an independent consultant	5	13	18
Verification of the post-survey processing software/procedures	12	6	18
Cross-measurements; i.e. random assignment of repeated segments to different	4	14	18

Overall, have you been satisfied with the effectiveness of your agency's pavement distress data collection/processing (in-house or contractor)?		
Answer Options	**Response Percent**	**Response Count**
Completely satisfied	38.9%	7
Mainly satisfied	50.0%	9
Partially satisfied	11.1%	2
Not satisfied	0.0%	0
	Agency Responses	**18**

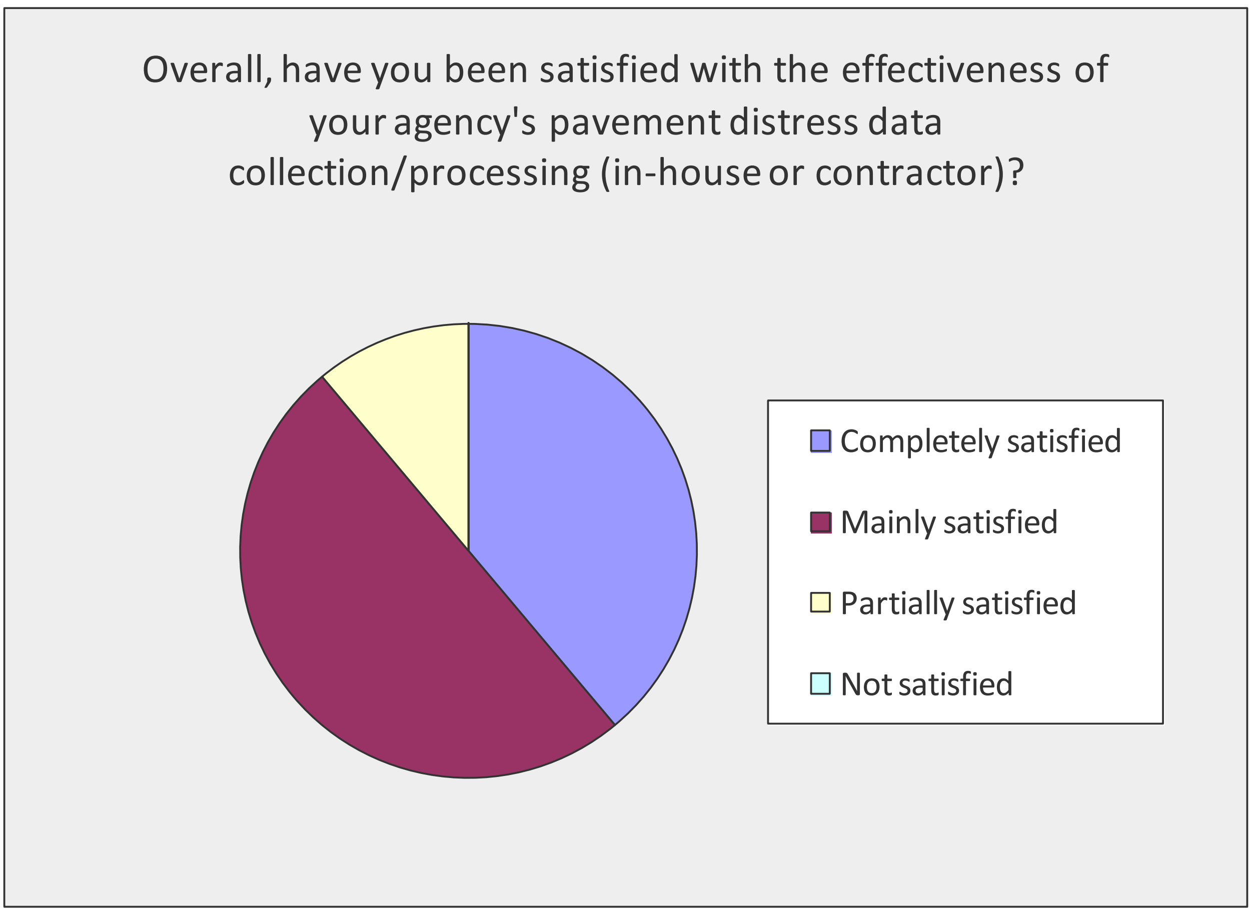


Table G-1. Additional Agency distresses.

State	Other AC Distresses	Other PCC Distresses	Other AC/PCC Distressed
FL			This is considered as asphalt pavement surface distress (see 6)
ND			
NH	sealed cracks	Do not have PCC pavements	Sealed cracks
MN			Same as AC pavements
NV		we are currently in the process of moving toward PCC distress collection, but haven't collected any data yet	we are currently in the process of moving toward PCC distress collection, but haven't collected any data yet
IA	Alligator cracking	D-cracking at joints	Alligator cracking
MD	IRI, friction	IRI, friction	IRI, friction
ID			
ME		Maine has no concrete pavements	The few spots where asphalt over concrete may exist are treated as asphalt.
WA	Alligator cracking		We rate AC and PCC separately (as in question # 5 and #6)
SC	patching / trans cracks	punch outs	fatique crack .
UT			Utah does not have AC/PCC roads unless one includes "crack and seat". If so UDOT collects all the distress associated with traditional asphalt pavements
NC		Shattered slabs	
MT			N/A we don't analyze this type. PCC that is now AC (crack and seat) is now analyzed as AC
OR		shattered slabs, punchouts	Use same distress as AC pavement
WI	Patching, potholes	diagonal cracking, D-cracking, shrinkage cracks	Would do AC only survey
NE	Shoulder condition	Shoulder condition	Shoulder condition
IL	IRI (roughness)	D-Cracking, punchouts (CRCP), high steel spalling, IRI (roughness)	IRI (roughness), reflective D-cracking

Table G-2. Additional Agency comments and recommendations.

State	Comment or Recommendation
ND	NDDOT is currently in the process of procuring equipment/software to move towards automated crack analysis detection and scoring
NH	
MN	We will be implementing fully automated distress analysis this summer.
NV	We are currently in the process of moving into a automated data collection contract. We currently collect IRI and rutting through automated procedures. We hope to collect PCC as well as AC surface distresses through this contract. If the data is acceptable, we plan to continue forward with automated distress collection.
IA	We are currently working through a process for the DOT to review a sample of the processed pavement images (with distresses identified) for evaluation of the accuracy of the vendor's distress identification.
ME	#9 above: Difficult to assess. Our state-owned ARAN is run by a technician and a laborer/driver who operate the vehicle 6 months of the year as weather permits, including ride-spec work. We do half the system per year. The vehicle cost $1M, but you'd have to pro-rate that over the life of the vehicle, plus the cost of fuel, maintenance, and licensing fees. Post processing is done by the 2 ARAN operators the other 6 months plus a full-time technician and further analysis through dTIMS CT is done part of the time by a Senior Engineer.
WA	We are looking forward to improvements in technology with 3D systems. This should eventually reduce labor costs involved with analyzing pavement images. We collect in one direction only on simple 2-lane roads, and in outside lane only in both directions on divided highway.
SC	Please provide us with a copy of the results
UT	Question 8 QC/QA - Comments box was not included: We provide IRI incentives/disincentives for accuracy
NC	In addition to automated data collection, we still collect manual data on 60,000 miles on secondary roads. Highly recommend using a third party contractor for data QA/QC.
MT	We verify data by comparing to previous years in the pavement management system and independent windshield audits by office staff. The automated distress identification is an ongoing learning process. The first year took longer since we were teaching the program through interactions of correcting and rerunning. The second season was much better and the items to address in our upcoming third season are greatly reduced to two areas of concern both minimal issues on MT roads.
OR	I answered to 8 for QC of known control segements for distress. However, contractor does do known control segments for IRI weekly. Please send results of survey.
WI	We establish consistent and reliable protocols for dta collection and analysis, Then we adhere to these protocols
IL	Illinois DOT has been using a vendor to collect data since 2008. From 2008 through 2012 we used Pathway Services and the responses above are based on that collection process. Starting in 2013 IL DOT will be using Mandli for data collection and processing.
IL	Illinois DOT has been using a vendor to collect data since 2008. From 2008 through 2012 we used Pathway Services and the responses above are based on that collection process. Starting in 2013 IL DOT will be using Mandli for data collection and processing. If you have additional questions on the information above or our collection efforts, please contact Travis Lobmaster.

Table G-3. Agencies participating in survey.

Name	Agency	Title	City	State
Bouzid Choubane	Florida DOT	Pavement Materials Engineer	Gainesville	FL
Karen A. Strauss	Idaho Transp. Dept.	Pavement Management Engineer	Boise	ID
LaDonna Rowden	Illinois DOT	Materials & Physical Research Engineer	Springfield	IL
Chris Brakke	Iowa DOT	Pavement Engineer	Ames	IA
Daniel Robbins, PE	Maine DOT	Highway Management Engineer	Augusta	ME
Geoff Hall	Maryland SHA	Pavement & Geotechnical Division Chief	Hanover	MD
David Janisch	Minnesota DOT		Maplewood	MN
Mary Gayle Padmos	Montana DOT	Pavement Management Supervisor	Helena	MT
Dan Nichols	Nebraska DOR	Asset Management Engineer	Lincoln	NE
Anna R Dapra, PE	Nevada DOT	Senior Materials Supervisor	Carson City	NV
Eric Thibodeau	New Hampshire DOT	Pavement Management Chief	Concord	NH
Neil Mastin	North Carolina DOT		Raleigh	NC
Stephanie Weigel	North Dakota DOT	Pavement Management Engineer	Bismarck	ND
John Coplantz	Oregon DOT	Pavement Management Engineer	Salem	OR
Thomas Shea	South Carolina DOT		Columbia	SC
Stan Burns	Utah DOT		Salt Lake City	UT
David Luhr	Washington DOT	Pavement Management Engineer	Olympia	WA
Bill Dukert	Wisconsin DOT	Engineer	Madison	WI

APPENDIX H—EXAMPLE SERVICES PROCUREMENT SPECIFICATIONS

OVERVIEW

If ODOT selects an option to procure services, a detailed Request for Proposals (RFP) must be prepared that allows ODOT to eliminate vendors that will not meet their needs. The RFP must also provide sufficient information to allow ODOT to clearly understand the options and properties of each vendor's offering. Critical portions of this type of specification include compliance testing, proposal acceptance criteria contract characteristics, data acceptance criteria, and semi-automated distress collection guides, for which examples are provided below.

COMPLIANCE TESTING

Pennsylvania DOT Automated Data Collection, Inventory and Analysis – 2012

Test Project Submittal. The information requested in this Part II, Section II-12 shall constitute the Test Project Results Submittal. The objective of this requirement is to assist PennDOT in evaluating Offeror proposals for collecting and reporting pavement distress data. Each Offeror must contact the Issuing Officer to arrange a data collection schedule for the Test Project as specified in the Calendar of Events. The Issuing Officer will schedule three (3) consecutive calendar days for each Offeror to collect all data. PennDOT may grant an exception to three (3) consecutive calendar days for data collection if the following occurs:

- Offeror submits written request to the Issuing Officer at least forty-eight (48) hours in advance of the scheduled three (3) consecutive calendar days for the Offeror to collect all data.
- The written request from the Offeror must describe the unique circumstances that require the Offeror to collect all data outside the required three (3) consecutive calendar days.
- The request must be approved by the Issuing Officer prior to the Offeror beginning collection of data for the Test Project.

A PennDOT observer will accompany each Offeror during the Test Project while data is collected to ensure that all data collection procedures, as described in this Section II-12, are followed. A PennDOT observer will note the location, date, time, and number of passes over a test section. The need for multiple passes due to equipment malfunction will also be recorded by the PennDOT observer.

The purpose of the Test Project is to simulate a network-level survey on a small scale. Each Offeror must collect Test Project data using the same procedures for network level surveys, as described in Part IV-1, of this RFP. PennDOT requests that all data be collected in one pass per segment. If multiple passes are required to collect "quality" data, the Offeror must describe the techniques in their Test Project Submittal.

In the event the Offeror's equipment malfunctions during the Test Project, the Offeror shall immediately notify the PennDOT observer of the problem. The Offeror must also provide to the observer a determination as to whether testing can continue or if the testing must temporarily cease until the equipment is operating and functioning properly. If the Offeror must temporarily cease testing due to an equipment malfunction, the Offeror must:

1. Immediately notify the Issuing Officer, as found in Section I-2., *Issuing Office*, of this RFP, in writing, describing the reason to temporarily cease testing and when the Offeror expects to resume testing.
2. The Issuing Officer will respond to the Offeror in writing of PennDOT's approval or rejection of the request. Once approved, the Issuing Officer will establish the dates the Offeror may resume testing.

Once the Offeror resumes testing, PennDOT expects the Offeror to complete the testing in one pass. If multiple passes are required to complete the Test Project, the Offeror is required to provide only the last "quality" data set in the Test Project Submittal.

All data to be submitted from the Test Project must be enclosed in a separate, sealed envelope. The Test Project will be conducted to evaluate the acceptability of all Offeror-supplied pavement distress measurements and image quality.

The Test Project is scheduled to be held in the Harrisburg, Pennsylvania, area. PennDOT will schedule dates and times for Offerors to participate in the Test Project. All testing will be done between July 25 and September. PennDOT reserves the right to change dates, times, and/or destination. Any change in date, time, and/or destination will be identified through an addendum to the RFP and will be posted on the DGS website.

There will be 250 100-ft segments and 200 ½-mile segments surveyed and analyzed in the Test Project. A complete Test Project will consist of two (2) studies:

Study 1: Concentrates on the ability of machine-based pavement ratings to discern individual condition types. This test will be conducted on short 100-ft segments in 500-ft sections.

Study 2: Concentrates on the influence the condition ratings have on treatments and costs associated with the condition data. It will also simulate each Offeror's ability to gather, reduce, and report network-level condition data based upon the distress definitions and data analysis reporting requirements of this proposal.

Two (2) pavement surface types are involved in the evaluation:

1. Bituminous hot mix.
2. Jointed portland cement concrete pavements.

Each Offeror must:

1. Participate in a roughness and surface distress test survey of 200 ½-mile Systematic Technique to Analyze and Manage Pennsylvania Pavements (STAMPP) segments.
2. Provide detailed descriptions of their data collection and analysis procedures for the test project.
3. Provide panoramic digital images, delivered on hard drive or DVD in the format described in this RFP, of the 200 ½-mile STAMPP segments.
4. Provide condition data, delivered on hard drive, CD or DVD in the format described in this RFP, for the 100-ft and ½-mile STAMPP segments.

Caltrans Automated Pavement Condition Survey – 2010

Caltrans APCS Demonstration and Evaluation

Each Proposer passing the minimum requirement evaluation will demonstrate its ability to meet the requirements for the annual Automated Pavement Condition Survey (APCS) service by performing an APCS on a set of pavement sections identified by the Department, and analyzing and delivering required results in a safe, efficient, and accurate manner. The performance of each Proposer will be evaluated and scored by the Department's Evaluation Committee following the relevant criteria and scoring system included in the Attachment 8**,** APCS Demonstration and APCS Oral Presentation Evaluation Criteria Form.

The Proposer must demonstrate to the Department that the technologies and personnel employed can satisfactorily meet the requirements of the APCS. This may include the disclosure of equipment and software specifications, details, or other proprietary information needed to support the requirements. The burden of proof for this requirement will be on the Consultant.

Eight to twelve short Sacramento Common Verification (SCV) sections (180 m long) and one long SCV section (approximately 10 km long) will be identified by the Department. The Proposers will be informed of locations of these sections within five days prior to the planned APCS Demonstration date.

Caltrans Data Collection, Analysis and Reporting

Each Proposer will collect, analyze, and report data on all the selected SCV sections, following the requirements of the Annual Start Up Process (see Attachment 12, Section 22 in the Exhibit A), except that pavement surface profile measurement (Attachment 12, Exhibit A Section E.b.v) will only need to be performed once.

Referenced sections of the APCS Manual, Attachment 5 and Standard Proposed Agreement, Attachment 12 must be followed. Attachment 12 contains provisions regarding data collection, data analysis, data format, data reporting, and other important aspects of the APCS. The

Proposer's success in the APCS Demonstration is dependent upon a thorough understanding of the APCS Manual and Attachment 12, Proposed Standard Agreement.

The Department will collect data on the SCV sections and analyze them to establish the analyzed data determined by the Department of the georeference, distresses, and conditions of these sections. The accuracy and quality of the data collected and reported by the Proposers will be evaluated against the analyzed data determined by the Department.

Caltrans APCS Demonstration Schedule

One day of field work will be assigned to each Proposer to collect raw data on all the SCV sections. Multiple Proposers will potentially be scheduled on the same day, but they will perform data collection independently. The Department will notify all Proposers of their scheduled APCS Demonstration dates in a timely manner.

Each Proposer will prepare a list showing the order in which the SCV sites will be surveyed and deliver the list to the Department's Project Manager two working days prior to the scheduled APCS Demonstration date. Each Proposer will coordinate with the Department to set up necessary triggering mechanisms at all the sections to be surveyed.

Each Proposer will provide a short tour of its data collection vehicle and the equipment it contains on the scheduled APCS Demonstration day at the following address (Transportation Material Laboratory, California Department of Transportation, 5900 Folsom Blvd, Sacramento, CA 95819) before leaving for the field work. The Department may determine that if the Proposer does not have the equipment necessary to perform the APCS Demonstration, the Department has the authority to terminate the APCS Demonstration. The Proposers proposal at that point will be considered non-responsive.

A Caltrans escort vehicle will accompany each Proposer during the scheduled APCS Demonstration day to observe the Proposer's data collection. The Proposer will only be allowed during the scheduled day and time to collect data on the test sections unless delays or stoppage of work are encountered, which are beyond the Proposer's control (i.e. road closures, inclement weather).

Each Proposer will deliver the collected raw data in the specified format to the Department by 5:00 PM two (2) working days after the scheduled data collection date. Raw data to be delivered include all the Right-of-Way (ROW) images, all the downwards perspective images, and all the pavement surface profiles as identified in the APCS and this RFP.

A complete analyzed data set, including the synchronized raw data and analyzed pavement distress/condition data per data segment specified in this RFP will be delivered to the Department by each Proposer by 5:00 PM five (5) working days after the scheduled data collection date.

Each Proposer will prepare a brief report summarizing the work performed for the APCS Demonstration, following the reporting requirements specified in Attachment 12, Proposed Standard Agreement. This report will be delivered with the complete analyzed data set. The report should not include any data or extra information beyond that required as stated in the attachment 12, Proposed Standard Agreement.

All the relevant requirements for file naming, file labeling, and file organization specified by Attachment 12, Standard Proposed Agreement must be observed. The Proposer's ability to provide logically organized and correctly named/labeled data, and necessary documents to assist the Department staff in handling and analysis of the data will be evaluated by the Evaluation Committee as part of Item 2 of Attachment 8, APCS Demonstration and APCS Oral Presentation Criteria Evaluation Form. Acceptable media for the electronic data include CD-ROM, DVD-ROM, and removable hard drives. The media will not be returned to the Proposer.

Iowa DOT Automated Pavement Distress Collection Services – 2010

As part of the selection process, the DOT will conduct an evaluation of the proposing vendor's data collection, data reduction, and reporting systems. Each vendor will collect data on a maximum of 50 miles of pavements representing a cross section of Iowa pavement types. The test sections will be manually rated according to the new SHRP manual to provide a baseline with which to compare the automated results. Each test section will be collected three (3) times by the vendor following the "Data Collection Requirements" above.

Vendors will have between June 23 and July 23 in which to arrive in Iowa and collect data on the test sections. During the time they are in Iowa they will also give a brief presentation of their system to DOT staff. Once the data is collected, the vendors will have 15 business days to process the data and provide it to the DOT. The vendors will provide a 2-week license for use of the analysis software. After the processed data is received, the DOT will evaluate the results based on completeness of data, consistency of data, and accuracy of distress data.

PROPOSAL ACCEPTANCE CRITERIA

Pennsylvania DOT Automated Data Collection, Inventory and Analysis – 2012

Evaluation Criteria. The following criteria will be used in evaluating each proposal:

A. **Technical:** The Issuing Office has established the weight for the Technical criterion for this RFP as 50 percent of the total points. Evaluation will be based upon the following in order of importance:

   i. Test Project. This requirement is to assist PennDOT in evaluating Offerors for collecting and reporting pavement distress data. Emphasis here is on data collection and analysis.

   ii. Contractor Qualifications. This refers to the ability of the selected Offeror to meet the terms of the RFP, especially the time constraint and the quality, relevancy, and recency of studies and projects completed by the selected Offeror. This also includes the selected Offeror’s financial ability to undertake a project of this size.

iii. Personnel Qualifications. This refers to the competence of professional personnel who would be assigned to the project by the selected Offeror. Qualifications of professional personnel will be measured by experience and education, with particular reference to experience on studies/services similar to that described in the RFP. Particular emphasis is placed on the qualifications of the project manager.

iv. Soundness of Approach. Emphasis here is on the techniques for collecting and analyzing data, sequence, and relationship of major steps, and methods for managing the study/service. Of equal importance is whether the technical approach is completely responsive to all written specifications and requirements contained in the RFP and if it appears to meet PennDOT’s objectives.

v. Understanding the Problem. This refers to the selected Offeror’s understanding of PennDOT’s objectives in asking for the services or undertaking the study, and of the nature and scope of the work involved. This also includes the Offeror’s responsiveness to the RFP, including quality criteria.

B. **Cost:** The Issuing Office has established the weight for the Cost criterion for this RFP as 30 percent of the total points.

C. **Disadvantaged Business Participation:** BMWBO has established the weight for the Disadvantaged Business (DB) Participation criterion for this RFP as 20 percent of the total points. Evaluation will be based upon the following in order of priority:

- Priority Rank 1 Proposals submitted by Small Disadvantaged Businesses.
- Priority Rank 2 Proposals submitted from a joint venture with a Small Disadvantaged Business as a joint venture partner.
- Priority Rank 3 Proposals submitted with subcontracting commitments to Small Disadvantaged Businesses.
- Priority Rank 4 Proposals submitted by Socially Disadvantaged Businesses.

Each DB Participation Submittal will be rated for its approach to enhancing the utilization of Small Disadvantaged Businesses and/or Socially Disadvantaged Businesses. Each approach will be evaluated, with Priority Rank 1 receiving the highest score and the succeeding options receiving scores in accordance with the above-listed priority ranking. To the extent that there are multiple DB Participation submittals that offer subcontracting commitments to Small Disadvantaged Businesses, the proposal offering the highest total percentage commitment shall receive the highest score in the Priority Rank 3 category and the other proposal(s) in that category shall be scored in proportion to the highest total percentage commitment offered.

To qualify as a Small Disadvantaged Business or a Socially Disadvantaged Business, the Small Disadvantaged Business or Socially Disadvantaged Business cannot enter into subcontract arrangements for more than 40 percent of the total estimated dollar amount of the contract. If a Small Disadvantaged Business or a Socially Disadvantaged Business subcontracts more than 40 percent of the total estimated dollar amount of the contract to other contractors, the Disadvantaged Business Participation scoring shall be proportionally lower for that proposal.

D. **Enterprise Zone Small Business Participation:** In accordance with the priority ranks listed below, bonus points in addition to the total points for this RFP will be given for the Enterprise Zone Small Business Participation criterion. The maximum bonus points for this criterion is 3 percent of the total points for this RFP. The following options will be considered as part of the final criteria for selection:

- Priority Rank 1 Proposals submitted by an Enterprise Zone Small Business will receive 3 percent bonus for this criterion.
- Priority Rank 2 Proposals submitted by a joint venture with an Enterprise Zone Small Business as a joint venture partner will receive 2 percent bonus for this criterion.
- Priority Rank 3 Proposals submitted with a subcontracting commitment to an Enterprise Zone Small Business will receive the 1 percent bonus for this criterion.
- Priority Rank 4 Proposals with no Enterprise Zone Small Business Utilization shall receive no points under this criterion.

To the extent that an Offeror is an Enterprise Zone Small Business, the Offeror cannot enter into contract or subcontract arrangements for more than **40 percent** of the total estimated dollar amount of the contract in order to qualify as an Enterprise Zone Small Business for purposes of this RFP.

E. **Domestic Workforce Utilization:** Any points received for the Domestic Workforce Utilization criterion are bonus points in addition to the total points for this RFP. The maximum bonus points for this criterion is **3 percent** of the total points for this RFP. To the extent permitted by the laws and treaties of the United States, each proposal will be scored for its commitment to use domestic workforce in the fulfillment of the contract. Maximum consideration will be given to those Offerors who will perform the contracted direct labor exclusively within the geographical boundaries of the United States or within the geographical boundaries of a country that is a party to the World Trade Organization Government Procurement Agreement. Those who propose to perform a portion of the direct labor outside of the United States and not within the geographical boundaries of a party to the World Trade Organization Government Procurement Agreement will receive a correspondingly smaller score for this criterion. Offerors who seek consideration for this criterion must submit in hardcopy the signed Domestic Workforce Utilization Certification Form in the same sealed envelope with the Technical Submittal. The certification will be included as a contractual obligation when the contract is executed.

Caltrans Automated Pavement Condition Survey – 2010

Evaluation Process

A. Format Review

1. At the time of proposal opening, each proposal will be checked for the presence and/or absence of required information in conformance with the submission requirements of this RFP. Proposers that do not provide requested information will be rejected as non-responsive.
2. Proposals that contain false or misleading statements, or which provide references, which do not support an attribute or condition claimed by the Proposer, shall be rejected.

B. Evaluation of Proposal

1. The State will evaluate each proposal to determine its responsiveness to the State's needs. APCS Technical Proposals, APCS Demonstration and APSC Oral Presentations and Cost proposals will be rated by an evaluation committee using a consensus process (DOT's RFP Evaluation Standards and Procedures) for determining final scores.
2. An evaluation committee will evaluate those APCS Technical Proposals that meet the proposal submission requirements. The evaluation will be based on the criteria shown on the Attachment 7, APCS Technical Proposal Evaluation Criteria.
3. Proposers will be contacted to schedule a date and time for the APCS Demonstration and the APCS Oral Presentation. The evaluation will be based on the criteria shown on the APCS Demonstration and APCS Oral Presentation, Attachment 8. It is anticipated that the APCS Demonstration and the APCS Oral Presentation will be held in the City of Sacramento.
4. The final proposal score will be combined evaluation of the APCS Technical Proposal, APCS Demonstration and APCS Oral Presentation, and Cost Proposal. The Agreement will be awarded to the Proposer with the highest combined score who meets the requirements outlined in this RFP.
5. The cost will be evaluated on a sliding scale. The other proposals will be scored in relation to the lowest price proposal using the following formula: Low Bid Proposal / Other Proposer's Bid) x 30 = Points Awarded.

C. Small Business Preference

1. Small business (SB) or Microbusiness (MB) proposers certified by the Department of General Services, Office of Small Business and DVBE Services (OSDS), for evaluation purposes, shall be granted a five percent preference from the highest scored proposal (total score) if the highest scored proposal is from a non-certified small business or microbusiness.

2. Non-Small Business proposers who commit to subcontracting a minimum of 25 percent of their net bid price, in the categories most appropriate to accomplish the prescribed services, may also be granted this preference. Proposers must complete.
3. In the event of a precise tie, lots will be drawn, or if applicable, the tie will be broken in accordance with Government Code 14838 (f).

D. Miscellaneous Award Issues

1. If no proposals are received containing a price, which in the opinion of the Department is a reasonable price, the Department is not required to award an Agreement (Public Contract Code 10344 (d)).
2. The prospective Contractor is advised that should this RFP result in an award of an Agreement, the Agreement will not be in force and no work shall be performed until the Agreement is fully approved by the State and the Contractor is notified by the Contract Manager to begin work.

Iowa DOT Automated Pavement Distress Collection Services – 2010

The selection committee will review and evaluate the proposals submitted based on the following criteria and the weighted value assigned to each. The weighted value of each criterion is indicated.

- 50 percent—Results of data collection field evaluations.
- 15 percent—Project approach and data reduction methods.
- 20 percent—Recent experience with similar projects for DOTs.
- 15 percent—Project schedule and availability to meet schedule.

CONTRACT CHARACTERISTICS

Three contract characteristics are of particular interest – the letting cost basis, the contract period, and the price adjustment clauses. The 2009 NCHRP Synthesis 401 reports that agency contracts "are typically let based on a cost per mile (58 percent), with some having a lump-sum fixed price (31 percent) and a few agencies citing other contracting modes." The contract lengths reported in this document (shown in Figure 3) vary from one to more than three years. The authors suggest that longer contract periods may result in increased consistency from year to year. Some agencies provide options for extended contracts, based on contractor performance.

A 2003 report, cited in NCHRP 401 indicates that "most data collection service contracts included a quality assurance provision and approximately half had price adjustment clauses…" The 2009 survey indicated that 39 percent of contracts linked payment to data quality, while 32 percent did not. Below are several examples of RFP contract characteristic requirements.

Question: How long is the contracting period?

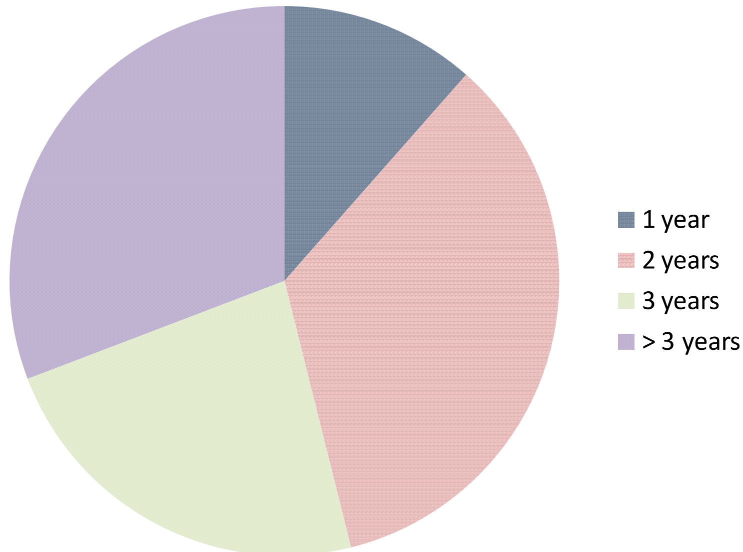


Figure H-1. Length of contract period for outsourced data collection services.

Pennsylvania DOT Automated Data Collection, Inventory and Analysis – 2012

Term of Contract. The term of the contract will commence on the Effective Date and will be in effect for a period of twenty-four (24) months following the date of the Notice to Proceed. The Issuing Office will fix the Effective Date after the contract has been fully executed by the selected Offeror and by the Commonwealth and all approvals required by Commonwealth contracting procedures have been obtained. The selected Offeror shall not start the performance of any work prior to the Effective Date of the contract and the Commonwealth shall not be liable to pay the selected Offeror for any service or work performed or expenses incurred before the Effective Date of the contract.

The Commonwealth's Contracting Officer may renew this contract incrementally or in one step by mutual agreement of the Commonwealth and the selected Offeror, for a period of up to forty-eight (48) months by written notification provided to the selected Offeror by the Commonwealth's Contracting Officer. Renewal of this contract may require review and approval as required by Commonwealth contracting procedures. Any renewal will be under the same terms and conditions.

Unit prices submitted by the selected Offeror on Appendix E, Cost Proposal Template, Cost Proposal Template, under the contract may be negotiated for an increase up to a maximum of 3.00 percent during each renewal term. Upon receipt of the unit prices for the renewal, the Commonwealth's Contracting Officer will provide a determination as to the acceptance or rejection of the unit prices for the renewal period by issuing written notification to the selected Offeror. After negotiations have concluded, the Commonwealth's Contracting Officer will issue a final determination letter to the selected Offeror.

The Commonwealth reserves the right, upon notice to selected Offeror, to extend the term of the Contract for up to three (3) months at the current pricing with the same terms and conditions. This may be utilized to prevent a lapse in Contract coverage.

Deliverable costs quoted in Appendix E, Cost Proposal Template shall be an individual unit price based on estimated quantities. Quantities listed in Appendix E, Cost Proposal Template are estimated based on historical data and are not guaranteed.

Caltrans Automated Pavement Condition Survey – 2010

The services to be performed by the Consultant in this Project are divided into two Task Orders. In each Task Order, the entire California state highway network, totaling 50,733 lane-miles will be surveyed. Each data segment of the highway network will be surveyed two times in the two Task Orders. The lag between the two surveys on each data segment should be not shorter than 9 months and not longer than 15 months. Each Task Order must not take the Consultant more than nine months to complete, from the Department's annual startup process to the Department's acceptance of all data. The retention payment noted in the Exhibit B is dependent on the overall accuracy of the Consultant's data on the FUV sections as stated in this Agreement.

Iowa DOT Automated Pavement Distress Collection Services – 2010

The project will include collection of pavement distress data on a two-year cycle. The contract period will be for four years (two collection cycles) plus an option for DOT to extend the contract for two more years (a third collection cycle). The number of miles to be tested is approximately between 9,500 and 12,500 miles each year with a four-year average of 10,500 miles/year. Data is collected in one direction on two-lane highways and in both directions on multi-lane divided highways. There are approximately 6,550 miles of two-lane highways and 2,875 directional miles of four-lane divided highways.

DATA ACCEPTANCE CRITERIA

Pennsylvania DOT Automated Data Collection, Inventory and Analysis – 2012

Table 1 – Expected Accuracy of Data Collection Elements:

A. PennDOT has developed accuracy and repeatability guidelines for the selected Offeror to meet for this project. Table H-1 lists the data collection elements and the expected accuracy for each element.
B. PennDOT encourages the selected Offeror to carefully review their data collection capabilities for each of the conditions that will be reported. The selected Offeror must be capable of collecting data according to PUB 336, and analyzing and reporting within the tolerances of the guidelines listed in Tables H-2 and H-3 below.

Table H-1. PennDOT pavement distress data acceptance criteria.

Element	Accuracy	Repeatability
Roughness (IRI)	± 10 percent compared to rod and level, Dipstick, ARRP Walking Profiler or other Class 1 profiler	± 5 percent run to run for three repeat runs
Wheelpath rut depth	± 10 percent compared to PennDOT's survey of each wheelpath	± 5 percent run to run for three repeat runs
JPC faulted joints	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
JPC broken slabs	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
JPC transverse joint spalls	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
JPC transverse cracking	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
JPC bituminous patching	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
Fatigue cracking	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
Transverse cracking	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
Miscellaneous cracking	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
Edge deterioration	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
Left edge joint	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs
Bituminous patching	± 10 percent compared to PennDOT's survey	± 5 percent run to run for three repeat runs

Caltrans Automated Pavement Condition Survey – 2010

The retention payment noted in Exhibit B is dependent on the overall accuracy of the Consultant's data on the Follow-up Verification (FUV) sections as stated in this Agreement.

- The Consultant's data from the relevant FUV sections will be compared to the pooled set of by the Department's baseline data on those sections. At least 85 percent of all the quantitative distress measurement and condition indicator values must be within the allowed tolerance. For example, if there are 18 FUV sections and 15 data items are evaluated for each section, there will be 18×15=270 data items to evaluate. At least 270×85 percent=230 data items must be within their tolerances.

- On each distress measurement or condition indicator, at least 80 percent of the applicable FUV sections must meet the tolerance requirements for that item. For example, if there are ten flexible surfaced FUV sections, at least eight sections must have crack length ratio on the left wheelpath within the tolerance. If the number of FUV sections of any pavement surface type (flexible, JPCP, or CRCP) is less than five, then one FUV section is allowed to have a failing value for each distress measurement or condition indicator.

Table H-2. Quality acceptance criteria for distress/condition measurements of AC surfaced pavement.

Data Item[1]	Section in APCS Manual	Tolerance for Annual Startup		Tolerance for APCS Demonstration and FUV Section QA	
		Abs. Diff.	Rela. Diff.	Abs. Diff.	Rela. Diff.
Longitudinal profiles[2]	6.1	Average accuracy score of 85 or greater for each wheelpath in each SCV section.		N/A	
IRI[2]	6.1	8.0 cm/km	5%	32 cm/km	20%
MPD	6.2	0.1 mm	10%	0.2 mm	20%
Mean rut depth[2]	6.3	2 mm	10%	3 mm	20%
Number of sealed transverse cracks per data segment	3.3	0.15	10%	0.2	20%
Number of unsealed narrow transverse cracks per data segment	3.3	0.15	10%	0.2	20%
Number of unsealed wide transverse cracks per data segment	3.3	0.15	10%	0.2	20%
Length ratio of sealed longitudinal cracks	3.4	0.1	10%	0.2	20%
Length ratio of unsealed narrow longitudinal cracks	3.4	0.1	10%	0.2	20%
Length ratio of unsealed wide longitudinal cracks	3.4	0.1	10%	0.2	20%
Wheelpath crack length ratio[2]	3.5	0.2	10%	0.4	20%
XF-crack length ratio	3.6	0.4	10%	0.8	20%
Average number of potholes per data segment	3.7	0.2	10%	0.4	20%
Patch area ratio	3.8	1%	10%	1%	20%

Note: [1] If not stated otherwise, the value subjected to compare is the mean value across each 180 m long section.
[2] Evaluate for the two wheelpaths separately and count as two data items.

Table H-3. Quality acceptance criteria for distress/condition measurements of JPCP.

Data Item[1]	Section in APCS Manual	Tolerance for Annual Start-Up Abs. Diff.	Tolerance for Annual Start-Up Rela. Diff.	Tolerance for APCS demonstration and FUV section QA Abs. Diff.	Tolerance for APCS demonstration and FUV section QA Rela. Diff.
Longitudinal profiles[2]	6.1	Average accuracy score of 85 or greater for each wheelpath in each SCV section.		N/A	
IRI[2]	6.1	8.0 cm/km	5%	32 cm/km	20%
MPD	6.2	0.1 mm	10%	0.2 mm	20%
Mean rut depth[2]	6.3	2 mm	10%	3 mm	20%
Average joint fault height	6.4	1 mm	10%	2 mm	20%
Number of joints per PDS	6.4	0.1	10%	0.2	20%
Average spall area	6.5	100 mm^2	10%	200 mm^2	20%
Number of spalls per PDS	6.5	0.1	10%	0.2	20%
Number of longitudinal cracks per slab	4.4	0.1	10%	0.2	20%
Number of transverse cracks per slab	4.5	0.1	10%	0.2	20%
Number of corner cracks per slab	4.6	0.1	10%	0.2	20%
Number of XJ-cracks per slab	4.7	0.1	10%	0.2	20%
Asphalt patch area ratio	4.8	0.05	10%	0.1	20%
Percentage slabs with 1st stage cracking[3]	4.9	6%	10%	10%	20%
Percentage slabs with 3rd stage cracking[3]	4.10	6%	10%	10%	20%

Note: [1] If not stated otherwise, the value subjected to compare is the mean value across each 180 m long section.
[2] Evaluate for the two wheelpaths separately and count as two data items.
[3] Calculated from data segment-based data; not an average value.

Iowa DOT Automated Pavement Distress Collection Services – 2010

1. Data Completeness
    a. Of the total network miles contracted, a minimum of 98 percent of the collectable miles will be delivered to the DOT. Areas closed off for construction are not considered collectable miles.
    b. Of the delivered data, 100 percent of the description items will be populated and accurate. Description items include: system, route, direction, and location (begin and end latitude/longitude).
    c. Of the delivered data, 98 percent of the sections will be completely populated with data values, not including any expected limitations. For example, IRI in low-speed areas.

2. Data Accuracy
   a. Of the delivered miles there should not be more than 10 consecutive fixed segments missing (500 ft total). Re-collection will be required if more than 10 consecutive fixed segments are missing.
      i. Of the remaining 2 percent of sections, a section will be recollected if it is missing more than 2% of the length of the section.
   b. Of the delivered data, 95 percent of the values will be within the required minimum accuracy.
      i. IRI – must not deviate more than +/- 5 percent from DOT measured values.
      ii. Pavement Distresses – must not deviate more than +/- 10 % from the DOT manual survey.

SEMI-AUTOMATED DISTRESS COLLECTION GUIDE

In transitioning from manual to semi-automated distress data collection, modifications are inevitably necessary for the ODOT Pavement Condition Rating System manual. These changes will include quantifying distress properties and reporting statistics that coordinate with the more complete data collection methods and results employed by these systems. Examples of distress collection guides adjusted for this purpose can be reviewed from the following sources:

- Caltrans Automated Pavement Condition Survey – 2010. (http://www.emarketplace.state.pa.us/Solicitations.aspx?SID=3511R03 document 45a00022f.pdf).
- Pennsylvania DOT Automated Pavement Condition Survey Field Manual Publication 336, April 2013 (ftp://ftp.dot.state.pa.us/public/PubsForms/Publications/Pub%20336.pdf).

EXAMPLE PROCUREMENT SPECIFICATIONS

Because of the many recent RFPs and contracts awarded for semi-automated distress data collection, several examples of procurement specifications are available, including the following:

- Pennsylvania DOT Automated Data Collection, Inventory and Analysis – 2012 (http://www.emarketplace.state.pa.us/Solicitations.aspx?SID=3511R03).
- Caltrans Automated Pavement Condition Survey – 2010 (http://www.emarketplace.state.pa.us/Solicitations.aspx?SID=3511R03).
- Iowa DOT Automated Pavement Distress Collection Services – 2010 (http://www.prof-tech-consultant.dot.state.ia.us/uploads/RFP.pdf).
- Oklahoma DOT RFP for Pavement Management System Data Collection – 2007 (NCHRP Synthesis 401, pp. 133-138) (4).
- Louisiana DOT&D RFP for Pavement Distress Data Collection Statewide – 2006 (NCHRP Synthesis 401, pp. 105-132.) (4).

APPENDIX I—EQUIPMENT PROCUREMENT SPECIFICATIONS

OVERVIEW

If ODOT selects an option to procure equipment, a detailed RFP must be prepared that allows ODOT to eliminate systems that will not meet their needs. The RFP must also provide sufficient information to allow ODOT to clearly understand the options and properties of each vendors offering. This appendix includes major portions of a high-quality equipment RFP prepared by the South Dakota DOT for the 2012 purchase of a 3D Roadway Data Collection and Analysis System.

SCOPE OF WORK

Mandatory Elements

Mandatory elements of the Roadway Data Collection and Analysis System include:

a. Vehicle suitable for data acquisition at normal highway speeds.
b. Vehicle distance measurement.
c. Linear referencing.
d. Global positioning.
e. Roadway digital imaging.
f. Longitudinal profile and roughness measurement.
g. Slab faulting measurement.
h. Transverse profile and rutting measurement.
i. Onboard computer system.
j. Dedicated workstation software.
k. Web-based viewing software.

Optional Elements

Optional elements of the Roadway Data Collection and Analysis System include:

a. Automated crack detection and classification.
b. Edge drop-off measurement.
c. Pavement texture measurement.
d. Roadway geometry measurement.
e. LiDAR roadway feature measurement.

PROPOSAL EVALUATION AND AWARD PROCESS

Evaluation Criteria

After determining that a proposal satisfies the mandatory requirements stated in the RFP, a committee of State personnel will evaluate these responses and select the best-qualified proposal in consideration of the following criteria:

a. Cost.
b. Degree of compliance with specifications.
c. Specialized expertise, capabilities, and technical competence as demonstrated by the proposed approach and methodology to meet the project requirements.
d. Resources available to perform the work, including any specialized services, within the specified time limits for the project.
e. Record of past performance, including price and cost data from previous projects, quality of work, ability to meet schedules, cost control, and contract administration.
f. Proposed project management techniques.
g. Quality of project delivery plan and ability to meet it.
h. Ability and proven history in handling special project constraints.
i. Ability to provide support for installation and warranty period.

Experience and Reliability

Experience and reliability of the Offeror's organization are considered subjectively in the evaluation process. Therefore, the Offeror is advised to submit any information which documents successful and reliable experience in past performances, especially those performances related to the requirements of this RFP.

Qualifications

The qualifications of the personnel proposed by the Offeror to perform the requirements of this RFP, whether from the Offeror's organization or from a proposed subcontractor, will be subjectively evaluated. Therefore, the Offeror should submit detailed information related to the experience and qualifications, including education and training, of proposed personnel.

Right to Reject

The State reserves the right to reject any or all proposals, waive technicalities, and make award(s) as deemed to be in the best interest of the State of South Dakota.

Award

The requesting agency and the highest ranked Offeror shall mutually discuss and refine the scope of services for the project and shall negotiate terms, including compensation and performance schedule.

If the agency and the highest ranked Offeror are unable for any reason to negotiate a contract at a compensation level that is reasonable and fair to the agency, the agency shall, either orally or in writing, terminate negotiations with the contractor. The agency may then negotiate with the next highest ranked contractor.

The negotiation process may continue through successive Offerors, according to agency ranking, until an agreement is reached or the agency terminates the contracting process.

Contractual Requirements

After the purchase order is issued, any changes or modifications shall require written approval from DOT's Office of Transportation Inventory Management.

The Contractor shall send delivery status reports on alternate Wednesdays to the primary and alternate contacts identified by DOT. The delivery status reports shall include a specific statement of schedule status and list specific accomplishments and remaining tasks with projected completion dates.

If the Contractor falls behind schedule, a recovery plan or revised delivery schedule shall be submitted for approval by DOT. The reports, plans, and revisions shall not affect any contracted dates unless specifically approved by DOT.

Terms of Payment

Payment will be authorized in up to four parts, each as a portion of the contracted amount.

The first payment, equal to one-third of the full purchase price, will be authorized when the vehicle including all subsystems, the dedicated workstation software, and the web-based viewing software are delivered to DOT.

The second payment, equal to one-third of the full purchase price, will be authorized upon successful completion of acceptance testing to validate the performance of the vehicle including all subsystems, the dedicated workstation software, and the web-based viewing software. System testing shall be completed by contractor-trained DOT personnel and will verify that all vendor-supplied products that subsystems meet specifications cited in the Technical Specification Responses form (Section 0, beginning page 188).

The third payment, equal to one-third of the full purchase price excluding the cost of the automatic crack detection and classification subsystem (if purchased), will be authorized after the completion of 20 workdays of successful operation of the vehicle including all subsystems, the dedicated workstation software, and the web-based viewing software by contractor-trained DOT personnel.

The fourth payment, equal to the remaining one-third of the cost of the automated crack detection and classification subsystem (if purchased), will be authorized upon completion of calibrating the automated crack detection and classification subsystem to DOT's distress classification method.

No payment except the first payment will be authorized prior to July 1, 2013, regardless of the status of delivery or acceptance.

Authorization of the final payment will constitute final acceptance of the system by DOT.

Technical specifications

Definitions

- BIT: South Dakota Bureau of Information and Telecommunications
- Contractor: the company, corporation, or individual awarded a contract
- Macrotexture: pavement surface texture with wavelengths from 0.5 mm to 50mm (0.02 to 2 inches) and peak-to-peak amplitude of 0.1 mm to 20 mm (0.005 to 0.8 inches)
- May: the word "may" is used with advisory or optional requirements
- MRM: Mileage Reference Marker is the DOT reference location system
- Must: the word "must" is used with mandatory requirements
- Offeror: a company, corporation, or individual responding a Request for Proposal (RFP)
- OPM: South Dakota Office of Procurement Management
- DOT: South Dakota Department of Transportation
- Shall: the word "shall" is used with mandatory requirements
- Should: the word "should" is used with advisory or optional requirements
- TIM: Transportation Inventory Management Program of the DOT
- Vehicle: the complete vehicle and all subsystems transported by it

Technical Specification Responses

A response to each specification statement is required and is to be entered on the lines provided in the Offeror's Response column. If the equipment fully conforms to the specification, enter the word "CONFORMS." If the equipment does not fully conform to the specification, enter the word "EXCEPTION" and state the deviation from the specification in the rightmost column of the table. Failure to conform to the specification may result in bid rejection.

	Offeror's Response	Explanation of Exception
T1. Vehicle (Mandatory)		
T1.1 Contractor shall supply a vehicle including the following factory-equipped features:		
T1.1.1 current model full-size van from an authorized dealer licensed by the State of South Dakota in accordance with 5-18D-25		
T1.1.2 maximum vehicle height of 8 feet, 6 inches including all externally mounted systems		
T1.1.3 V8 engine		
T1.1.4 air conditioning – front and rear		
T1.1.5 alternator: maximum amperage		

	Offeror's Response	Explanation of Exception
T1.1.6 battery: heavy duty and auxiliary		
T1.1.7 bumper: rear		
T1.1.8 cooling: auxiliary transmission		
T1.1.9 fuel tank: maximum capacity		
T1.1.10 heating: front and rear		
T1.1.11 interior insulation package		
T1.1.12 paint: exterior, solid color, manufacturer's standard white preferred		
T1.1.13 power steering		
T1.1.14 radio: am-fm with cd player		
T1.1.15 running boards		
T1.1.16 two (2) captain chairs with additional seating for at least one person.		
T1.1.16.1 power seat adjustment		
T1.1.16.2 lumbar support		
T1.1.16.3 heavy duty tubular steel seat frame		
T1.1.16.4 durable stain-resistant covering		
T1.1.16.5 seating system tested and certified to meet or exceed DOT safety standard FMVSS #207 per section S 4.2 and S 4.3		
T1.1.16.6 all materials tested and certified to meet or exceed DOT safety standard FMVSS per section #302 per section S 4.2 and S 4.3		
T1.1.16.7 minimum dimensions of 35 inches total height from base to top of head rest, 30 inches high from top of seat cushion to top of head rest by 21 inch wide backrest, 24 inches depth from front to back, and 19 inches from front of seat cushion to backrest		
T1.1.17 cruise control		
T1.1.18 tilt steering wheel		
T1.1.19 all-season tires including spare		
T1.1.20 full size spare tire mounted inside vehicle		
T1.1.21 automatic transmission		
T1.1.22 windows in rear and side door(s) will be tinted.		
T1.1.23 power remote mirrors		
T1.1.24 power windows		
T1.1.25 power door locks		
T1.1.26 two (2) remote vehicle entries		
T1.1.27 two (2) vehicle keys		
T1.2 Contractor shall install additions and modifications to the vehicle as follow:		
T1.2.1 Modifications to the interior and exterior of the vehicle will securely mount all data collection subsystems.		
T1.2.2 Interior insulation, finished walls and ceiling, covered floor, interior lighting, storage compartments, equipment racks, and work surfaces		
T1.2.3 All contractor-installed locking compartments shall be keyed alike. All padlocks shall be keyed alike.		

	Offeror's Response	Explanation of Exception
T1.2.4 Two auxiliary interior 12 volt electrical connections protected by resettable circuit breakers.		
T1.2.5 Mud flaps front and back		
T1.2.6 All contractor-installed controls, gauges, indicators, pilot lamps, and switches shall be mounted in one control panel and permanently labeled to indicate function and on-off positions.		
T1.2.7 The control panel shall be ergonomically located for the operators and positioned to avoid creating nuisance reflections.		
T1.2.8 Interior-mounted cameras shall not interfere with the sun visors.		
T1.2.9 All contractor-installed wiring and subsystem wiring shall be color-coded or permanently labeled for identification and correspond to the contractor supplied wiring diagrams.		
T1.2.10 The vehicle shall be free of decals, emblems, identification, logos and advertising by the Contractor, subcontractors, and dealers. Standard brand and model identification of the vehicle manufacturer is acceptable.		
T1.2.11 The Contractor shall not include the DOT in any advertising, photographs, illustrations, or references. Inclusion on a list of customers as a statement of fact is acceptable.		
T1.3 Vehicle Warranty		
T1.3.1 The vehicle shall be covered by the manufacturer's standard warranty.		
T1.3.2 Work performed by the Contractor shall not diminish the manufacturer's warranty coverage or adversely affect any emission control system.		
T1.3.3 The Contractor will not be responsible for maintenance and repair of the vehicle.		
T1.4 Auxiliary Power Unit to Power Data Collection Subsystems		
T1.4.1 The Contractor shall supply and install an auxiliary power unit (APU) large enough to supply continuous electrical power to all onboard computer, electrical, and related subsystems.		
T1.4.2 Auxiliary power shall include a power inverter with breaker box and battery backup supply to power subsystems in the event of APU failure.		
T1.4.3 Total power consumption of installed equipment shall not exceed APU capacity.		
T1.4.4 APU failure shall not disable the vehicle electrical system.		
T1.4.5 The APU shall include surge protection to prevent damage to the vehicle and all data collection subsystems.		

	Offeror's Response	Explanation of Exception
T1.4.6 APU installation shall comply with the manufacturer's recommendations and standards.		
T1.4.7 APU installation shall not adversely affect the vehicle including all subsystems, compliance with emission standards, and warranty coverage.		
T1.4.8 Preferred APU: The APU shall be an auxiliary alternator powered by the vehicle's engine.		
T1.4.9 Alternate APU: The APU shall be a gasoline-powered generator:		
T1.4.9.1 Manufacturer-approved to run on gasoline containing up to 10% ethanol by volume		
T1.4.9.2 Remote on/off/start switch accessible to vehicle driver and passenger		
T1.4.9.3 Power status indicator visible to vehicle driver and passenger		
T1.4.9.4 USFS-approved spark arrestor muffler		
T1.4.9.5 Sound-attenuating enclosure		
T1.4.9.6 Vibration isolating mounts		
T1.4.9.7 Low oil level shutdown		
T1.4.9.8 High engine temperature shutdown		
T1.4.9.9 An interior 120VAC outlet receptacle		
T1.4.9.10 Ground-Fault Circuit Interrupters on all receptacles		
T1.4.9.11 Protection of individual circuits by resettable circuit breakers or fuses		
T1.4.9.12 Start and Stop Controls		
T1.4.9.13 Pilot Lamp: On only while the APU engine is running		
T1.4.9.14 Hour meter: Running only while the APU engine is running		
T1.4.9.15 Spare Parts: air filter (1), fuel filter (1), oil filter (1), fuses (5 of each capacity), and spark plugs (1 set).		
T1.4.10 External Power: The Contractor shall install an external, weatherproof, electrical hookup to allow common house current to power the subsystems for an indefinite period. The hookup shall totally preclude the possibility of back-feed to utility lines.		
T1.5 Operating Conditions		
T1.5.1 The vehicle including all subsystems shall remain fully operational in ambient air temperature ranging from 0°F to 120°F.		
T1.5.2 The vehicle including all subsystems shall remain fully operational in relative humidity ranging up to 90% (non-condensing).		

	Offeror's Response	Explanation of Exception
T1.5.3 The vehicle including all subsystems shall withstand storage at ambient air temperatures ranging from -30°F to 150°F.		
T1.5.4 The vehicle including all subsystems shall withstand storage at relative humidity ranging up to 100% (non-condensing).		
T1.5.5 The vehicle including all subsystems shall remain fully operational at elevations ranging up to 7000 feet above sea level.		
T1.5.6 The vehicle and all subsystems shall be weather proof.		
T1.5.7 The vehicle and all subsystems shall be protected from theft.		
T1.6 Safety		
T1.6.1 The vehicle and all installed subsystems shall comply with provisions of OSHA regulation 1910.95 for occupational noise level exposure without hearing protection.		
T1.6.2 While in full operation noise levels for the driver and operator shall never exceed 85 decibels.		
T1.6.3 All safety hazards on vehicle shall be appropriately labeled.		
T1.6.4 All laser light sources shall be shielded or equipped with safety interlock to prevent excessive exposure to operators and bystanders.		
T1.6.5 The Contractor shall supply four sets of safety eyewear to protect operators from exposure to laser devices installed on the vehicle.		
T1.6.5.1 Eyewear shall be recommended by the manufacturer of the laser system.		
T1.6.5.2 Eyewear shall be certified to ANSI Z136.1.		
T1.6.5.3 Eyewear shall fit over prescription eyewear.		
T1.6.5.4 Eyewear shall provide wrap-around protection.		
T1.6.6 Fire Extinguishers: 3, eleven pound Halotron I fire extinguishers in quick-release brackets and installed in DOT-approved locations.		
T1.6.7 Two (2) vertical heavy duty 36 inch fluorescent orange marker guides to mark the limits of sensors mounted on the front of the vehicle		
T1.6.8 Safety Partition behind driver and operator to arrest shift of loads and reduce noise		
T1.6.9 Audible alarm that sounds when vehicle is backing		
T1.6.10 Wired back-up camera		
T1.6.10.1 7 inch minimum high resolution monitor		
T1.6.10.2 120° minimum wide angle rear view		

	Offeror's Response	Explanation of Exception
T1.6.10.3 The back-up camera system shall be standalone not affecting any other system.		
T1.6.11 Light Bars: Front and Rear, Code 3, LED X 2100 Mini Bar or equal		
T1.6.11.1 Front and rear light bars shall be controlled separately		
T1.6.11.2 Light bars shall not interfere electrically with any subsystem		
T1.6.11.3 Light bars shall not interfere with roadway image collection while on or off.		
T2. Vehicle Distance Measurement (Mandatory)		
T2.1 The vehicle shall be equipped with a Distance Measuring Instrument (DMI) to reference all images, data, and information to the South Dakota state trunk highway system by highway number, Mileage Reference Marker (MRM), and displacement from the MRM.		
T2.2 The system shall allow continuous real time viewing of DMI, speed, and selected profile index at 0.10 mile intervals		
T2.3 The system shall include automated calibration and validation for the DMI.		
T2.3.1 Calibration constants shall be computed automatically.		
T2.3.2 The operator shall have the option to accept or decline calibration change.		
T2.3.3 The system shall include any physical objects needed accomplish the calibration.		
T2.4 The measured distance shall be accurate to 0.1% for speeds to 70 mph		
T2.5 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum:_________mph Maximum:_________mph		
T2.6 Testing for acceptance by DOT will include the DMI Check Test described in AASHTO R 56-10.		
T3. Linear Referencing (Mandatory)		
T3.1 All collected images, data, and other information shall be referenced to the South Dakota state trunk highway system by highway number, Mileage Reference Marker (MRM), displacement from the MRM, and lane number.		
T3.2 The system shall carry an onboard database of South Dakota state trunk highways including the beginning and ending MRMs of every continuous highway segment and every uniform (integer-valued) MRM.		
T3.3 The data collection menu shall allow the operator to select routes and MRMs from a list.		
T3.4 The operator shall be able to enter descriptive comments and attach them to collected data files for later retrieval, display, and processing.		

	Offeror's Response	Explanation of Exception
T3.5 The system shall accept and validate operator key entry to identify the beginning and ending MRMs of any continuous highway segment and any uniform (integer-valued) MRM		
T3.6 The system shall prompt the operator audibly and visually in advance of any uniform MRM being approached.		
T3.7 The system shall provide an operator-selected option of automatic initiation of data collection using reflective pavement marking tape. The system shall be capable of being armed by the operator at any distance prior to the marking.		
T3.8 The system shall allow continuous recording through divided and undivided sections of a single state highway. Changes in divided and undivided highway designations at these transitions shall occur automatically without operator intervention.		
T3.9 The system shall allow the operator to simultaneously or independently mark the all data streams with "event marks" for certain highway features such as bridges, railroad crossings, etc.		
T4. Global Positioning (Mandatory)		
T4.1 The system shall include a Global Positioning System capable of receiving and applying satellite-based or beacon-based real-time differential corrections.		
T4.2 The system shall be able to associate all collected data with latitude, longitude, and elevation		
T4.3 System shall provide accuracy as stated by Offerer:		
T4.3.1 latitude accuracy: ±________degrees		
T4.3.2 longitude accuracy: ±________degrees		
T4.3.3 elevation accuracy: ±________feet		
T4.4 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum:________mph Maximum:________mph		
T5. Roadway Digital Imaging (Mandatory)		
T5.1 The system shall collect, process, store, and display on the operator's terminal digital images of the roadway using camera(s) activated at regular, operator-defined intervals as the vehicle travels at normal highway speeds.		
T5.2 Three (3) 2500x2000 pixels minimum, 24-bit color digital cameras shall be installed, one aimed straight forward, one aimed nominally 45° to the right, and one aimed nominally 45° to the left to provide a nominal horizontal field-of view of at least 135°.		
T5.3 One (1) 2500x2000 pixels minimum, 24-bit color digital camera shall be installed and aimed right at 90° from forward.		
T5.4 Cameras shall be identical with power focus, power zoom, and auto iris.		
T5.5 Camera mounts shall provide power pan and tilt.		
T5.6 The system shall allow the operator to select distance between images, including intervals of 17.6', 26.4', and 52.8'.		

		Offeror's Response	Explanation of Exception
T5.7	Images shall be compressed and stored in real time using the standardized Joint Photographic Experts Group (JPEG) compression method.		
T5.8	The level of image compression shall be operator selectable.		
T5.9	Images shall be clear and unobstructed views		
T5.10	Images from the cameras shall be acquired simultaneously.		
T5.11	Steps shall be taken to minimize effects of the sun light and position on image quality.		
T5.12	Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T6. Longitudinal Profile and Roughness Measurement (Mandatory)			
T6.1	The system shall measure and record longitudinal profile continuously between operator-triggered start and end points.		
T6.2	The system shall meet the Class 1 requirements of ASTM E 950-09 for measuring longitudinal profile.		
T6.3	Profile shall be measured independently and simultaneously in the left and right wheel paths using non-contact sensors spaced 66 inches apart and centered transversely on the vehicle.		
T6.4	Each non-contact height sensor shall have a resolution of at least 0.001" and sufficient linear measurement range to cover the vehicle suspension motion and variation in pavement elevation.		
T6.5	Each non-contact sensor shall provide a minimum of 100mm scan width oriented at 45° to the direction of travel.		
T6.6	Accelerometers shall be biased to compensate for the acceleration of gravity, shall include anti-alias filtering, and shall fully accommodate the range of vertical motions experienced by the vehicle.		
T6.7	The system shall be capable of measuring profile on pavement with an IRI range of 5 inches per mile to 300 inches per mile.		
T6.8	The system shall have an undistorted response (profile amplitude error of less than 5 percent and location error of less than 17 percent) for all wavelengths between 1.0 and 120 feet over its entire range of operating speeds.		
T6.9	The system shall have a minimum of a 30 percent reduction in profile amplitude for wavelengths shorter than 0.5 feet and longer than 300 feet, and a minimum of a 70% reduction for wavelengths shorter than 0.3 feet and longer than 450 feet.		
T6.10	The system shall measure and store profile elevation data spaced at operator selected intervals as short as 0.75 inches.		
T6.11	The system shall be capable of exporting profile data in the University of Michigan's Transportation Research Institute Engineering Research Division .erd format		

	Offeror's Response	Explanation of Exception
T6.12 The system shall be capable of exporting profile data in the FHWA ProVal software .pff format for upload to ProVAL without manipulation.		
T6.13 As the profiles are being measured, the system shall calculate, report, and record the International Roughness Index (IRI) as described in ASTM E 1926 for each wheel path based on a simulated vehicle speed of 80 km/hr (50 mph).		
T6.14 The system shall store International Roughness Index (IRI) at operator-selectable, preset intervals.		
T6.15 The system shall display summary IRI measurements while traveling at highway speeds to allow the operator to monitor the system's performance.		
T6.16 The system shall have automated calibration and validation procedures, including a bounce test to ensure the measured profile is unaffected by vehicle motion and a block test to ensure profile amplitudes are accurately measured.		
T6.16.1 Calibration constants shall be computed automatically.		
T6.16.2 The operator shall have the option to accept or decline calibration change.		
T6.16.3 The system shall include any physical objects needed accomplish the calibration.		
T6.17 Prior to delivery, the Contractor shall obtain certification of the longitudinal profile and roughness measurement subsystem at an independent testing facility in accordance with AASHTO Standard R 56-10, "Standard Practice for Certification of Inertial Profiling Systems". Certification shall not relieve the Contractor of full responsibility for system performance. The Contractor shall provide the equipment operator. All certification expenses shall be the responsibility of the Contractor.		
T6.18 Testing for acceptance by DOT shall include applicable tests to ensure compliance with AASHTO M 328-10, AASHTO R 56-10, and ASTM E950-09		
T6.19 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T7. Slab Faulting Measurement (Mandatory)		
T7.1 The system shall independently detect slab faulting, including at skewed joints, in the left and right wheel paths using non-contact sensors.		
T7.2 The sensors may be the same sensors used to measure longitudinal profile.		
T7.3 The system shall record the location and height of each fault detected in the left and right wheel paths.		
T7.4 At operator-defined intervals, the system shall calculate and store average fault height and the number of fault height measurements within operator-defined height ranges in each wheel path.		

	Offeror's Response	Explanation of Exception
T7.5 The system shall include automated calibration and validation procedures.		
T7.5.1 Calibration constants shall be computed automatically.		
T7.5.2 The operator shall have the option to accept or decline calibration change.		
T7.5.3 The system shall include any physical objects needed accomplish the calibration.		
T7.6 The bias of average fault height measurements in each wheel path shall not exceed 0.025" as compared to slab height determined by Georgia Fault meter measurements in the same 0.1 mile section of pavement. The system must successfully locate at least 90% of all faults exceeding 0.1" in height.		
T7.7 The system shall collect, process, and report slab faulting measurements described for automated survey methods in AASHTO R 36-12.		
T7.8 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T8. Transverse Profile and Rutting Measurement (Mandatory)		
T8.1 The system shall measure and record the transverse profile of the pavement surface as follows:		
T8.1.1 sampling rate: 30 profiles/second minimum		
T8.1.2 profile spacing: adjustable, operator-controlled, 1.3 meters (4') maximum		
T8.1.3 transverse resolution: 1280 points/profile minimum		
T8.1.4 transverse field of view: 4 meters (13 feet) minimum		
T8.1.5 transverse accuracy: ±3 mm (0.12 in)		
T8.1.6 depth range of operation: 500 mm (20 in)		
T8.1.7 depth resolution: 0.5 mm (0.02 in)		
T8.1.8 depth accuracy: ±1 mm (0.04 in)		
T8.2 The system shall report average rut depths in 0.2 mile sections within ±0.040" of values obtained manually per ASTM E1703 -10.		
T8.3 The accuracy and reliability of the data shall not be adversely affected by paint stripes or other roadway coatings.		
T8.4 The system shall calculate maximum rut depth in the left and right wheelpaths using straightedge and string-line estimation techniques		
T8.5 The system shall record maximum, minimum, average, and standard deviation rut depth for each wheel path at operator-defined intervals		
T8.6 The system shall identify road segments with rut depth exceeding user-specified thresholds.		

	Offeror’s Response	Explanation of Exception
T8.7 The system shall incorporate automated calibration and validation procedures, including a straightedge or string line surface test to ensure that the measured rut depth of a flat surface is zero and block tests to ensure that rut depth amplitudes are accurately measured.		
T8.7.1 Calibration constants shall be computed automatically.		
T8.7.2 The operator shall have the option to accept or decline calibration change.		
T8.7.3 The system shall include any physical objects needed accomplish the calibration.		
T8.8 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T9. Automated Crack Detection and Classification (Optional)		
T9.1 The system shall acquire continuous black and white intensity images and three-dimensional surface elevations of the pavement surface as follows:		
T9.1.1 sampling rate: 5600 profiles/s, minimum		
T9.1.2 profile spacing: adjustable, operator-controlled, 5mm (0.19 in) maximum		
T9.1.3 transverse resolution: 4096 points/profile		
T9.1.4 transverse field-of-view: 4 meters (13 feet) minimum		
T9.1.5 transverse accuracy: ±1 mm (0.04 in)		
T9.1.6 depth range of operation: 500 mm (20 in)		
T9.1.7 depth resolution: 0.5 mm (0.02 in)		
T9.1.8 depth accuracy: ±0.5 mm (0.04 in)		
T9.2 The system shall resolve cracks 2 mm (0.08 in) wide from the acquired intensity images and pavement surface elevations.		
T9.3 The system shall measure and report crack depth, crack width, crack roughness, and crack faulting.		
T9.4 The system shall acquire and compress data in real time to minimize on-board storage needs.		
T9.5 The system shall capture images unaffected by adverse lighting conditions.		
T9.6 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T9.7 The system shall include automated calibration and validation procedures for acquisition of intensity images and surface elevations.		
T9.7.1 Calibration constants shall be computed automatically.		
T9.7.2 The operator shall have the option to accept or decline calibration change.		
T9.7.3 The system shall include any physical objects needed accomplish the calibration.		

	Offeror's Response	Explanation of Exception
T9.8 The system shall analyze collected intensity and surface elevation data to detect, classify, and quantify pavement distress according to the DOT Distress Manual classification method outlined in the Pavement distress tables (Section 0 on page 222).		
T9.9 The system may use data supplied by DOT identifying the linear-referenced beginnings and endings of roadway sections paved with asphalt concrete and Portland cement concrete to improve distress classification.		
T9.10 The system shall operate in automatic mode to detect, analyze, and report pavement distress type, severity, and extent.		
T9.10.1 The software shall perform continuous survey providing 100 percent sampling over segments defined by highway, MRM, and displacement.		
T9.10.2 The system shall automatically detect lane markings and determine wheel path location.		
T9.11 The system shall operate in operator-assisted mode to detect, analyze, and report pavement distress type, severity, and extent.		
T9.11.1 The system shall simultaneously display high-resolution intensity images and three-dimensional digital surface profiles of the same road segment.		
T9.11.2 The system shall provide a help screen displaying distress severity and extent levels defined in Tables 1 and 2 sample distress severity rating images provided by DOT.		
T9.11.3 The system shall permit the pavement image length to match the interval length of the roadway images selected by the operator.		
T9.12 The system shall export distress ratings in a format be determined in coordination with DOT in one of the following file types:		
T9.12.1 Comma Separated Variables (*.csv)		
T9.12.2 dBase (*.dbf)		
T9.12.3 Microsoft Access (*.mdb)		
T9.12.4 Microsoft Excel (*.xls)		
T10. Edge Drop-Off Measurement (Optional)		
T10.1 The system shall measure and record a transverse profile that spans the edge of pavement and extends a minimum of 8 feet from the right edge of the vehicle.		
T10.2 The system shall use a non-contact sensor.		
T10.3 The system shall collect, process, display and store edge drop-off data in operator-selected intervals.		
T10.4 The system shall include automated calibration and validation procedures.		
T10.4.1 Calibration constants shall be computed automatically.		
T10.4.2 The operator shall have the option to accept or decline calibration change.		

	Offeror's Response	Explanation of Exception
T10.4.3 The system shall include any physical objects needed to accomplish the calibration.		
T10.5 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T10.6 The system shall create custom reports measuring and identifying the drop-off from pavement to shoulder within user defined thresholds.	ANALYSIS	
T11. Pavement Texture Measurement (Optional)		
T11.1 The system shall estimate macrotexture in the left wheel path using a non-contact sensor.		
T11.2 At operator-defined intervals, the system shall calculate, report, and store texture as average mean profile depth according to ASTM E1845-09 and as average root-mean-square profile depth.		
T11.3 The system shall measure macrotexture wavelengths over the range of 0.02 to 2.00 inches. State the range of pavement surface texture wavelengths detected. Minimum:_________in. Maximum:_________in.		
T11.4 The system shall include automated calibration and validation procedures including tests to measure the texture of standard surfaces.		
T11.5 Calibration constants shall be computed automatically.		
T11.6 The operator shall have the option to accept or decline calibration change.		
T11.7 The system shall include any physical objects needed accomplish the calibration.		
T11.8 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T12. LiDAR Roadway Feature Measurement (Optional)		
T12.1 The system shall acquire three-dimensional LiDAR point cloud data out to 300 feet from the vehicle in a single pass		
T12.2 The system shall provide ±2in accuracy within point cloud within 100 feet of vehicle centerline in both directions		
T12.3 The point cloud accuracy and location shall be unaffected by vehicle movement.		
T12.4 The system shall collect, process, display and store data in operator-selected intervals and measure and identify road segments.		
T12.5 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T12.6 The system shall include automated calibration and validation procedures.		

	Offeror's Response	Explanation of Exception
T12.6.1 Calibration constants shall be computed automatically.		
T12.6.2 The operator shall have the option to accept or decline calibration change.		
T12.6.3 The system shall include any physical objects needed accomplish the calibration.		
T12.7 The system shall be able to export files in a .LAS format.		
T12.8 The system shall have options to filter out redundant data points		
T12.9 The system shall identify and recognize shapes and surfaces for user to identify roadway assets from standard lists and report dimensions of objects.		
T12.10 The system shall automatically report bridge clearances defined as National Bridge Inventory Items 10, 47, 54, 56, and 57.		
T12.11 The system shall allow manually-assisted identification and measurement of horizontal and vertical dimensions and clearances of roadway features.		
T13. Roadway Geometry Measurement (Optional)		
T13.1 The system shall measure the horizontal curvature of the lane driven by the vehicle.		
T13.1.1 horizontal curvature accuracy: ________degrees		
T13.2 The system shall measure the vertical curvature of the lane driven by the vehicle.		
T13.2.1 vertical curvature accuracy: ________degrees		
T13.3 The system shall measure cross-slope of the lane driven by the vehicle.		
T13.3.1 cross-slope accuracy: ________degrees		
T13.4 The system shall measure the grade of the lane driven by the vehicle.		
T13.4.1 grade state accuracy:_________%		
T13.5 Vehicle speed shall range to 70 mph without affecting subsystem integrity and measurement quality. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T14. Onboard Computer System (Mandatory)		
T14.1 The system shall include computers and software with adequate speed, capacity, and power to control onboard data acquisition subsystems at speeds up to 70 mph. State minimum and maximum highway speeds allowed: Minimum: ________mph Maximum: ________mph		
T14.2 The system shall include keyboards and monitors for the operator in the front passenger seat and in the back of the vehicle.		
T14.3 The system shall be fully operable by a single operator located at either position—in the front passenger seat or in the back of the vehicle.		

	Offeror's Response	Explanation of Exception
T14.4 The system shall monitor all measurement and imaging subsystems, display their operational status, and report malfunctions and out-of-range measurement errors in real time.		
T14.5 The system shall include diagnostics for each installed measurement and imaging subsystem.		
T14.6 The system shall provide a function simulating vehicle travel to support subsystem diagnostics.		
T14.7 The system shall be remotely operable by the Contractor to support system diagnostics.		
T14.8 The system shall allow inoperable subsystems to be disabled so data collection can continue with operable subsystems.		
T14.9 The system shall be able to graphically and textually display raw and processed measurements and images from any subsystem in real time.		
T14.10 The system shall display vehicle positions by linear referencing and global positioning, textually and by map:		
T14.10.1 current vehicle position		
T14.10.2 data collection starting and ending points		
T14.11 The system shall include multiple identical removable hard drives to be used for transfer at least 2,000 miles of data weekly from the vehicle to an office-based workstation.		
T14.12 The system shall simultaneously store all acquired image and sensor data on fixed internal hard drives and removable hard drives.		
T14.13 The internal hard drives shall have a minimum of storage for 2,000 miles of data collection.		
T14.14 The system shall preclude the overwriting of data files and provide a warning when storage is approaching maximum capacity.		
T14.15 The system shall be able to recover data saved on internal hard drives in the event of power failure.		
T14.16 The system shall provide efficient file management functions including copy, backup, erase, and export.		
T14.17 The system shall generate reports summarizing data collection activity over operator-specified date ranges.		
T14.18 The system shall display a statewide map identifying were data collection has and has not been accomplished.		
T15. Dedicated Workstation Software (Mandatory)		
T15.1 The Contractor shall supply dedicated workstation software for processing all images and data acquired by the mobile equipment, to be installed on workstation(s) supplied by DOT,		
T15.2 The Offeror's proposal shall supply complete hardware and software specifications for workstation(s) to be purchased by DOT in compliance with the SD Bureau of Information and Telecommunications (BIT) standards http://bit.sd.gov/standards/.		

	Offeror's Response	Explanation of Exception
T15.3 In addition to general purpose viewing, the software shall provide for user viewing of images, data, and information on ordinary networked and stand-alone DOT workstations with concurrent licensing for pavement distress analysis by a minimum of ten users throughout the DOT.		
T15.4 For the user viewing the images, reversing directions on divided roadways shall respond the same as reversing directions on undivided highways; e.g., if the user is observing images along west bound I-90 and elects to reverse viewing directions, the system shall present images along east bound I-90 starting from the point of reversal.		
T15.5 The workstation software shall include all of the following features:		
T15.5.1 Display all raw and processed measurements and images in tabular and graphical format		
T15.5.2 Depict all measurements and images on maps of South Dakota highways		
T15.5.3 Ability to zoom in on roadway and right of way features in images		
T15.5.4 Ability to identify roadway assets and measure their location and dimensions		
T15.5.5 Use of digital images without degradation of the images		
T15.5.6 Play digitized images forward and backward		
T15.5.7 Synchronize measurements and digital images to display at the same highway location		
T15.5.8 Simultaneously display data recorded in opposing directions at the same highway location		
T15.5.9 Display the location of measurements and images by frame number, database record, highway, MRM, displacement, lane, direction, latitude, and longitude		
T15.5.10 Select road segments by pointing and clicking on a map of South Dakota highways, by MRM and displacement, and by latitude and longitude		
T15.5.11 Navigate road segments by "turning" at intersections		
T15.5.12 Provide user-definable query and filtering functions		
T15.5.13 Allow user-configurable windows for processing and viewing measurements and images		
T15.5.14 Manage storage of measurement and image data on DOT database servers		
T15.5.15 System shall allow user to configure reports of data and images.		
T15.5.16 Process and export measurement data to DOT information systems		
T15.5.17 Export measurement data to geographic data sets		

	Offeror's Response	Explanation of Exception
T15.5.18 Import and display other geographical data sets		
T15.5.19 Print or save selected images		
T15.5.20 An online user's manual and a help section to assist the viewer in using the software.		
T16. Web-Based Viewing Software (Mandatory)		
T16.1 The Contractor shall supply a web-based application, to be hosted on servers operated by the SD Bureau of Information & Telecommunications and provided to users throughout DOT via the DOT Intranet.		
T16.2 The web-based application shall operate in the environment described by SD Bureau of Information and Telecommunications (BIT) standards http://bit.sd.gov/standards/.		
T16.3 The web-based viewing software shall provide general purpose viewing of images, data, and information.		
T16.4 The Contractor shall allow concurrent licensing throughout multiple South Dakota governmental entities.		
T16.5 The web-based viewing software shall include the following features:		
T16.5.1 Display measurements and images in tabular and graphical format		
T16.5.2 Depict all measurements and images on maps of South Dakota highways		
T16.5.3 Ability to zoom in on roadway and right of way features in images		
T16.5.4 Ability to identify roadway assets and measure their location and dimensions		
T16.5.5 Use of digital images without degradation of the images		
T16.5.6 Play digitized images forward and backward		
T16.5.7 Synchronize measurements and digital images to display at the same highway location		
T16.5.8 Simultaneously display data recorded in opposing directions at the same highway location		
T16.5.9 Display the location of measurements and images by frame number, database record, highway, MRM, displacement, lane, direction, latitude, and longitude		
T16.5.10 Select road segments by pointing and clicking on a map of South Dakota highways, by MRM and displacement, and by latitude and longitude		
T16.5.11 Navigate road segments by "turning" at intersections		
T16.5.12 Provide user-definable query and filtering functions		
T16.5.13 Allow user-configurable windows for processing and viewing measurements and images		

	Offeror's Response	Explanation of Exception
T16.5.14 Manage storage of measurement and image data on DOT database servers		
T16.5.15 System shall allow user to configure reports of data and images.		
T16.5.16 Process and export measurement data to DOT information systems		
T16.5.17 Export measurement data to geographic data sets		
T16.5.18 Import and display other geographical data sets		
T16.5.19 Print or save selected images		
T16.5.20 An online user's manual and a help section to assist the viewer in using the software.		
T17. Delivery		
T17.1 All deliveries shall be F.O.B. to: Rocky Hook South Dakota Department of Transportation Office of Transportation Inventory Management Becker-Hansen Building 700 Easy Broadway Avenue Pierre, SD 57501-2586 (605) 773-3278		
T17.2 The Contractor shall deliver the vehicle and all installed subsystems within 90 days after receipt of order.		
T17.2.1 The Contractor shall provide a minimum one week advance delivery notice		
T17.2.2 The Contractor shall present the following upon delivery of the vehicle:		
T17.2.2.1 the vehicle, including all subsystems, in a ready-for-use, fully fueled and fully operational condition.		
T17.2.2.2 certified weight slips for the vehicle delivered documenting compliance with the vehicle manufacturer's ratings.		
T17.2.2.3 original documentation of certification according to AASHTO R 56-10		
T17.2.2.4 two sets and an electronic copy of operator, calibration, service, repair, parts, and procedure manuals and schematics and wiring diagrams for the vehicle including the APU and all other subsystems. Material for the vehicle as supplied by DOT is excluded.		
T17.2.3 The Contractor shall be responsible for all cost and liability associated with transport of the vehicle.		
T17.2.4 The vehicle shall have driven no more than 3000 miles prior to delivery.		

	Offeror’s Response	Explanation of Exception
T17.3 The Contractor shall install dedicated workstation software on workstations at DOT offices within 60 days of receipt of order.		
T17.3.1 The Contractor shall provide a minimum one week advance delivery notice.		
T17.3.2 The Contractor shall supply two copies of operator and user manuals upon installation of workstation software.		
T17.3.3 The Contractor shall supply updated documentation for all measurement, detection, estimation, and filtering algorithms and for the format of all image and data files.		
T17.3.4 They Contractor shall supply comprehensive, updated calculations of computer memory storage requirements per lane mile for the vehicle delivered.		
T17.3.5 The Contractor will develop, demonstrate, and rules and algorithms to detect, classify, and quantify pavement distress according to the DOT Distress Manual classification method outlined in the Pavement distress tables (Section 0 on page 222) (if automated crack detection and classification is purchased) within 90 days of delivery of the vehicle.		
T17.3.6 The Contractor shall install the fully functional web-based application within 60 days of receipt of order.		
T18. Technical Standards The vehicle and all subsystems shall conform to the following standards.		
T18.1 AASHTO MP 328-10 “Standard Equipment Specification for Inertial Profiler”		
T18.2 AASHTO R 36-12 “Standard Practice for Evaluating Faulting of Concrete Pavements”		
T18.3 AASHTO R 56-10 “Standard Practice for Certification of Inertial Profiling Systems”		
T18.4 ASTM E950-09 “Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference”		
T18.5 ASTM E1703-10 “Standard Test Method for Measuring Rut-Depth of Pavement Surfaces Using a Straightedge”		
T18.6 ASTM E1845-09 “Standard Practice for Calculating Pavement Macrotexture Mean Profile Depth”		
T18.7 OSHA 1910.95 “Occupational Noise Exposure”		
T19. Units of Measurement		
T19.1 All systems shall use U.S. customary units with an option to use SI units(metric).		
T20. Training		
T20.1 The Contractor shall provide at least 5 days of on-site training by qualified and technically knowledgeable personnel at a DOT-selected location.		

	Offeror's Response	Explanation of Exception
T20.2 Training shall thoroughly address operation, maintenance, trouble-shooting, and calibration of all vehicle subsystems.		
T20.3 Training shall thoroughly address operation of the dedicated workstation software and the web-based viewing software.		
T20.4 The Contractor shall supply printed manuals to each trainee.		
T20.5 The Contractor shall permit DOT to record the training sessions for subsequent training purposes.		
T21. Workmanship and Materials		
T21.1 All equipment, parts, and materials shall be new and unused current production models.		
T21.2 All equipment shall be fit for the intended purpose.		
T21.3 All equipment shall be free from defects in design, materials, and workmanship.		
T21.4 Design and installation shall provide ease of calibration, maintenance, repair, and serviceability.		
T21.5 Design considerations shall include safety and ergonomics.		
T21.6 All equipment and installation shall comply with all applicable regulations.		
T21.7 All Contractor work shall be performed by qualified personnel in accordance with the highest professional standards and according to the recommended practices of the equipment manufacturers.		
T21.8 Workmanship and parts installation shall not adversely affect warranty coverage of vehicle or system components.		
T21.9 Installation shall preclude electromagnetic interference (EMI) and shielding shall be installed if necessary.		
T22. Technical Support, Warranty, and Annual Service Agreements		
T22.1 The Contractor shall provide two years of full warranty, beginning upon final acceptance by DOT, for all hardware and software supplied by Contractor, including:		
T22.1.1 100% of parts, labor, service, travel		
T22.1.2 software updates		
T22.1.3 technical support including response to technical questions, advice concerning system additions and enhancements, and assistance in evaluating system changes.		
T22.1.4 unlimited technical support via email, fax, and telephone during the work week between the hours of 10:00 am and 5:00 pm, Central time.		
T22.1.5 Fifty (50) hours per year of incidental programming to enhance or customize software.		
T22.2 Warranty and any annual service contract parts and workmanship shall be of the same or better quality as the original contractor-installed equipment		

	Offeror's Response	Explanation of Exception
T22.3 During the warranty and any annual service contract, the Contractor shall commence physical repair within forty-eight hours of being notified of the situation.		
T22.4 The requirement for a minimum of two years coverage shall not limit the warranty coverage provided by any component manufacturer in excess of two years.		
T22.5 The Offeror shall identify the name(s) and qualifications of the individual(s) assigned to carry out this support.		
T22.6 The Contractor shall provide an option for annual service contract renewals beyond the initial two year warranty for the vehicle, all subsystems, the dedicated workstation software, and the web-based viewing software.		
T22.7 The Contractor shall not be responsible for warranty of computers and computer components provided by DOT.		

Information Technology Requirements

Vendor Systems Questions—Commercial Off-the-Shelf (COTS) Software

The Offerer must include this table, with answers to each of the COTS Vendor Systems Questions, in the proposal. For questions requiring an explanation, the Offerer should include suitable narrative, identified by question number, immediately following the table.

Group	COTS Vendor System Question	Response
Infrastructure	1. Typically the State of South Dakota prefers to host all systems. In the event that the State decides that it would be preferable for the vendor to host the system, is this an option?	☐ Yes ☐ No
	If you answered Yes to the previous question:	
	Are there planned disruption periods? If yes, then the proposal should include the planned disruption schedule.	☐ Yes ☐ No
	Is there a strategy for mitigating unplanned disruptions? If yes, then the proposal should include the strategy and maximum disruption time frames.	☐ Yes ☐ No
	Is there a documented disaster recovery plan? If yes, then your proposal should include your disaster recovery plan.	☐ Yes ☐ No
	2. Is the User Interface tier server based?	☐ Yes ☐ No
	If yes, which configuration is recommended?	
	Non-Microsoft Web server? If yes, then specify in your proposal.	☐ Yes ☐ No
	Microsoft Web IIS? If yes, versions should be specified in the proposal.	☐ Yes ☐ No
	Citrix Metaframe? If yes, versions should be specified in the proposal.	☐ Yes ☐ No
	Other? If yes, then specify in your proposal.	☐ Yes ☐ No
	Operating System (OS)_____________	
	OS Version _____________	
	CPU requirement: _____________	
	RAM requirement: _____________	

Group	COTS Vendor System Question	Response
	3. Is there a workstation install requirement? If yes, then specify in your proposal.	☐ Yes ☐No
	4. Is this a browser based User Interface? If yes, then specify required make and versions in your proposal.	☐ Yes ☐No
	5. What are the development technologies used for this system? ASP Version: _____ NET Version: _____ Java/JSP Version: _____ Other? Describe: _______________________ Version: _____	
	6. Will the system support authentication? If yes, specify in your proposal. For example, Windows Authentication, SQL Server Login, etc.	☐ Yes ☐No
	7. Will the system infrastructure require an email interface? If yes, specify in your proposal.	☐ Yes ☐No
	8. Will the system require a database? If so please specify the vendor and version and license requirements in your proposal. Indicate if the database is proprietary.	☐ Yes ☐No
	9. Will the system infrastructure require database replication? If yes, specify in your proposal.	☐ Yes ☐No
	10. Will the system require transaction logging for database recovery?	☐ Yes ☐No
	11. Will the system infrastructure have a special backup requirement? If yes, then specify in your proposal.	☐ Yes ☐No
	12. Will the system provide an archival solution? If yes, provide a detailed description in your proposal.	☐ Yes ☐No
	13. Will the system infrastructure have any processes that require scheduling? If yes, then specify in your proposal.	☐ Yes ☐No
	14. Will the system infrastructure include a separate OLTP or Data Warehouse Implementation? If yes, then specify in your proposal.	☐ Yes ☐No
	15. Will the system infrastructure require a Business Intelligence solution? If yes, provide a detailed description in your proposal.	☐ Yes ☐No
	16. Will the system have any workflow requirements? If yes, then specify in your proposal.	☐ Yes ☐No
	17. Explain the software licensing model, including the number of concurrent users, ownership of the product, and license duration and renewal.	☐ Yes ☐No
	18. Can the system be implemented via Citrix? If so, please include 3 client names/contact numbers of those who have implemented your proposed system under Citrix.	☐ Yes ☐No
	19. Will the system implement its own level of security or can it integrate with our enterprise Active Directory to ensure access is controlled?	☐ Yes ☐No
	20. Will the system print to a Citrix compatible networked printer?	☐ Yes ☐No
	21. Will the network communications meet IEEE standard TCP/IP and use either standard ports or State defined ports as the State determines?	☐ Yes ☐No
	22. Will the system provide Internet security functionality on Public portals including encrypted network/secure socket layer. (TLS 1.0/SSL 3.0)?	☐ Yes ☐No
	23. Will the system provide Internet security functionality on a public portal to include firewalls?	☐ Yes ☐No

Group	COTS Vendor System Question	Response
	24. Will the system support automatic Windows-based report production and distribution to the State via the State Local Area Network (LAN)?	☐ Yes ☐ No
	25. It is State policy that no equipment can be connected to State Network without direct approval of BIT Network Technologies, would this affect the implementation of the system?	☐ Yes ☐ No
	26. Will all proposed software operate within the State standard equipment as given at: http://bit.sd.gov/bitservices/standards/?	☐ Yes ☐ No
	27. Will the server based software support: a. Windows server 2008R2 or higher b. IIS7.0 or higher c. MS SQL Server 2008R2 or higher d. Exchange 20010 or higher e. Citrix presentation server 4.5 or higher f. VMWare ESX 4.1 or higher g. MS Windows Updates h. Symantec End Point Protection Please specify the versions required by the system in your proposal.	☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No ☐ Yes ☐ No
	28. All network systems must operate within the current configurations of the State of South Dakota's firewalls, switches, firewalls, IDS/IPS and desktop security infrastructure. Would this affect the implementation of the system? A Generic Network Diagram will be provided after a Vender has been selected.	☐ Yes ☐ No
	29. It is State policy that all systems must be compatible with BITs dynamic IP addressing solution (DHCP). Would this affect the implementation of the system?	☐ Yes ☐ No
	30. It is State policy that all systems that require an email interface must leverage existing SMTP processes currently managed by BIT Datacenter. MailMarshall is the existing product used for SMTP relay. Would this affect the implementation of the system?	☐ Yes ☐ No
	31. It is State policy that all Vendor/Contractor Remote Access to systems for support and maintenance on the State Network will only be allowed through Citrix Secure Gateway. Would this affect the implementation of the system?	☐ Yes ☐ No
	32. It is State policy that all software must be able to use either standard Internet Protocol ports or Ports as defined by the State of South Dakota BIT Network Technologies. Would this affect the implementation of the system? For example, a web system should use TCP 80 and / or TCP 443 for client access. Deviation of Internet Protocol ports or Ports for your proposal should be mentioned with your response.	☐ Yes ☐ No

Group	COTS Vendor System Question	Response
	33. It is State policy that all HTTP/SSL communication must be able to be run behind State of South Dakota content switches and SSL accelerators for load balancing and off-loading of SSL encryption. If need is determined by the State, would this affect the implementation of the system? The State of South Dakota has hardware installed for an Enterprise solution for content switches and SSL accelerators for load balancing and off-loading of SSL encryption. A Generic Network Diagram will be provided once the Confidentiality agreement is signed.	☐ Yes ☐No
	34. It is State policy that BIT has a virtualize first policy that requires all new system to be configured as virtual machines. Would this affect the implementation of the system?	☐ Yes ☐No
	35. It is State policy that all access from outside of the State of South Dakota's private network will be limited to set ports as defined by the State, and all traffic leaving or entering the State network will be monitored. Would this affect the implementation of the system?	☐ Yes ☐No
	36. It is State policy that systems must support NAT and PAT running inside the State Network. Would this affect the implementation of the system?	☐ Yes ☐No
	37. It is State policy that systems must not use dynamic TCP or UDP ports unless the system is a well-known one that is state firewall supported (FTP, TELNET, HTTP, SSH, etc). Would this affect the implementation of the system?	☐ Yes ☐No
	38. Will the system require web presentation? If so, what are the server-side requirements? Will the system use any Java script?	☐ Yes ☐No ☐ Yes ☐No
Data access – export/import capability	39. How does data enter the system (transactional or batch or both)?	
	40. Is the system data exportable by the user for use in tools like Excel or Access?	☐ Yes ☐No
	41. Will user customizable data elements be exportable also?	☐ Yes ☐No
User configurable permissions	42. Will the system support authorization? If yes, specify in your proposal. For example, role based authorization for functionality and data.	☐ Yes ☐No
	43. Will the system distinguish between local versus global administrators where local administrators have rights to user management only for the program area that they are associated with and global administrators have rights for the entire system?	☐ Yes ☐No
Audit & Security Capabilities	44. Will this system provide the capability to track data entry/access by the person, date and time?	☐ Yes ☐No
	45. Will the system provide data encryption for sensitive information both in storage and transmission? If so, please explain in your proposal.	☐ Yes ☐No
	46. It is State policy that systems at the discretion of the State may have a Security Audit performed on it by BIT or a 3rd Party for security vulnerabilities. Would this affect the implementation of the system?	☐ Yes ☐No
	47. The Vendors/Contractors are also expected to reply to follow-up questions in response to the answers they provided to the security questions. At the state's discretion a vendor's answers to the follow-up questions may be required in writing and/or verbally. The answers provided may be used as part of the vendor selection criteria. Is this acceptable?	☐ Yes ☐No
Backup	48. The State of South Dakota currently schedules routine maintenance from 0400 to 0700 on Tuesday mornings for our non-mainframe environments and once a month from 0500 to 1200 for our mainframe environment. Systems will be offline during these scheduled maintenance time periods. Will this have a detrimental effect to the system?	☐ Yes ☐No

Group	COTS Vendor System Question	Response
nstallation	49. Will the vendor provide assistance with installation?	☐ Yes ☐No
	50. Is there an installation guide available and will you provide a copy to the State (The State is willing to sign a non-disclosure agreement?	☐ Yes ☐No
	51. Is telephone assistance available?	☐ Yes ☐No
	52. Is on-site assistance available? If so, is there a charge?	☐ Yes ☐No
Testing	53. Will the implementation plan include user acceptance testing?	☐ Yes ☐No
	54. Will there be documented test plans for future releases including any customizations done for the State of South Dakota?	☐ Yes ☐No
Training	55. Is training part of the package? If yes, please specify in your proposal. For example, initial training for all users and supplemental training for new employees.	☐ Yes ☐No
User Manual	56. Is there a user manual and will you provide a copy to the State (The State is willing to sign a non-disclosure agreement)?	☐ Yes ☐No
	57. If yes, is the manual electronically available?	☐ Yes ☐No
	58. Is there on-line help assistance available?	☐ Yes ☐No
Post-installation support	59. Do you have Support options available? If yes, specify options in the proposal.	☐ Yes ☐No
	60. It is State policy that all Vendor/Contractor Remote Access to systems for support and maintenance on the State Network will only be allowed through Citrix Secure Gateway. Would this affect the implementation of the system?	☐ Yes ☐No
	61. Is there a method established to communicate availability of system updates? If yes, please indicate the method and the number of updates per year in the proposal.	☐ Yes ☐No
	62. Is there an established method to acquire system updates? If yes, specify in the proposal.	☐ Yes ☐No
	63. The State implements enterprise-wide anti-virus solutions on all servers and workstations as well as controls the roll-outs of any and all Microsoft patches based on level of criticality. Do you have any concerns in regards to this process? If yes, specify in your proposal.	☐ Yes ☐No
Customization	64. Will you provide customization of the system if required by the State of South Dakota? If yes, then specify the process and fee structure for custom work in your proposal.	☐ Yes ☐No
	65. Do you have a formal change management process? If yes, please specify in your proposal.	☐ Yes ☐No
Intellectual Property	66. Will the State of South Dakota have access to the underlying data and data model for ad hoc reporting purposes?	☐ Yes ☐No
	67. Will the source code for the system be put in escrow for the State of South Dakota?	☐ Yes ☐No
	68. If the source code is placed in escrow, will the vendor pay the associated escrow fees?	☐ Yes ☐No
	69. If the State of South Dakota will gain ownership of the software, does the proposal include a knowledge transfer plan? If yes, please specify in the proposal.	☐ Yes ☐No

Group	COTS Vendor System Question	Response
Licensing	70. Explain the software licensing model, including the number of concurrent users, ownership of the product, and license duration and renewal. When providing licensing options and costs please include the options and costs for both a leased model as well as a perpetual license agreement. Please specify in your proposal.	
	71. Explain the basis on which pricing could change for the state based on your licensing model. Can it change for example based on: install base, number of concurrent users, number of authorized users, size of the enterprise, attributes of the hardware hosting the application, attributes of the VM in which the application runs, number of servers (host or guest) in which the application is executing, usage based, etc. Please specify in your proposal.	
	72. Contractually, how many years price lock are you offering as part of your response? Also as part of your response, how many additional years are you offering to limit price increases and by what percent? Please specify in your proposal.	

Vendor Security Questions—Commercial Off-the-Shelf (COTS) Software

The Offerer must include this table, with answers to each of the COTS Vendor Security Questions, in the proposal. If a question is not applicable to the Offerer's systems, enter "N/A" in the response column.

#	COTS Vendor Security Question	Offerer's Response
Software History and Licensing		
1	Can the pedigree of the software be established? Briefly explain what is known of the people and processes that created the software.	
2	Explain the change management procedure that identifies the type and extent of changes conducted on the software throughout its lifecycle.	
3	Is there a clear chain of licensing from original author to latest modifier? Describe the chain of licensing.	
4	What assurances are provided that the licensed software does not infringe upon any copyright or patent? Explain	
5	Does your company have corporate policies and management controls in place to ensure that only corporate-approved (licensed and vetted) software components are used during the development process? Provide a brief explanation. Will the supplier indemnify the Acquirer from these issues in the license agreement? Provide a brief explanation.	
Development Process Management		
6	What are the processes (e.g., ISO 9000, CMMi), methods, tools (e.g., IDEs, compilers) techniques, etc. used to produce and transform the software (brief summary response)?	
7	What security measurement practices and data does your company use to assist product planning?	
8	Is software assurance considered in all phases of development? Explain	
Software Security Training and Awareness		
9	Describe the training your company offers related to defining security requirements, secure architecture and design, secure coding practices, and security testing.	
10	Do you have developers that possess software security related certifications (e.g., the SANS secure coding certifications)?	
11	Describe the company's policy and process for professional certifications and ensuring certifications are valid and up-to date.	

#	COTS Vendor Security Question	Offerer's Response
Concept and Planning		
12	Are there some requirements for security that are "structured" as part of general releasability of a product and others that are "as needed" or "custom" for a particular release?	
13	What process is utilized by your company to prioritize security related enhancement requests?	
Architecture and Design		
14	What threat assumptions were made, if any, when designing protections for the software and information assets processed?	
15	What security design and security architecture documents are prepared as part of the SDLC process?	
16	How are design documents for completed software applications archived?	
Software Development		
17	What are/were the languages and non-developmental components used to produce the software (brief summary response)?	
18	What secure development standards and/or guidelines are provided to developers?	
19	Are tools provided to help developers verify that the software they have produced software that is minimized of weaknesses that could lead to exploitable vulnerabilities? What is the breadth of common software weaknesses covered (e.g., specific CWEs)?	
20	In preparation for release, are undocumented functions in the software disabled, test/debug code removed, and source code comments sanitized?	
Built-in Software Defenses		
21	Does the software validate (e.g., filter with white listing) inputs from untrusted sources before being used?	
22	Has the software been designed to execute within a constrained execution environment (e.g., virtual machine, sandbox, chroot jail, single-purpose pseudo-user) and is it designed to isolate and minimize the extent of damage possible by a successful attack?	
23	Does the documentation explain how to install, configure, and/or use it securely? Does it identify options that should not normally be used because they create security weaknesses?	
24	Where applicable, does the program use run-time infrastructure defenses (such as address space randomization, stack overflow protection, preventing execution from data memory, and taint checking)?	

#	COTS Vendor Security Question	Offerer's Response
25	How do you minimize the threat of reverse engineering of binaries? Are source code obfuscation techniques used? Are legal agreements in place to protect against potential liabilities of non-secure software?	
Component Assembly		
26	What security criteria, if any, are considered when selecting third-party suppliers?	
27	Is the software required to conform to coding or API standards in any way? Explain.	
Testing		
28	What types of functional tests are/were performed on the software during its development (e.g., spot checking, component-level testing, integrated testing)?	
29	Who and when are security tests performed on the product? Are tests performed by an internal test team, by an independent third party, or by both?	
30	What degree of code coverage does your testing provide?	
31	Are misuse test cases included to exercise potential abuse scenarios of the software?	
32	Are security-specific regression tests performed during the development process? If yes, how frequently are the tests performed?	
33	What release criteria does your company have for its products with regard to security?	
Software Manufacture and Packaging		
34	What security measures are in place for the software packaging facility?	
35	What controls are in place to ensure that only the accepted/released software is placed on media for distribution?	
36	How is the software packaged (e.g. Zipped , Linux RPM etc.) and distributed?	
37	How is the integrity of downloaded software (if an option) protected?	
38	For the released software "object", how many "files" does it consist of? How are they related?	
Installation		
39	Is a validation test suite or diagnostic available to validate that the application software is operating correctly and in a secure configuration following installation? If so, how is it obtained?	

#	COTS Vendor Security Question	Offerer's Response
40	What training programs, if any, are available or provided through the supplier for the software? Do you offer certification programs for software integrators? Do you offer training materials, books, computer-based training, online educational forums, or sponsor conferences related to the software?	
Assurance Claims and Evidence		
41	How has the software been measured or assessed for its resistance to identified, relevant attack patterns? Are Common Vulnerabilities & Exposures (CVE®) or Common Weakness Enumerations (CWEs) used? How have the findings been mitigated?	
42	Has the software been evaluated against the Common Criteria, FIPS 140-2, or other formal evaluation process? If the CC, what evaluation assurance level (EAL) was achieved? If the product claims conformance to a protection profile, which one(s)? Are the security target and evaluation report available?	
43	Are static or dynamic software security analysis tools used to identify weaknesses in the software that can lead to exploitable vulnerabilities? If yes, which tools are used? What classes of weaknesses are covered? When in the SDLC are these scans performed? Are SwA experts involved in the analysis of the scan results?	
44	Does the software contain third-party developed components? If yes, are those components scanned by a static code analysis tool?	
45	Has the product undergone any penetration testing? When? By whom? Are the test reports available under a nondisclosure agreement? How have the findings been mitigated?	
46	Are there current publicly-known vulnerabilities in the software (e.g., an unrepaired CWE entry)?	
Support		
47	Is there a Support Lifecycle Policy within the organization for the software in question? Does it outline and establish a consistent and predictable support timeline?	
48	How will patches and/or Service Packs be distributed to the Acquirer?	

#	COTS Vendor Security Question	Offerer's Response
49	What services does the help desk, support center, or (if applicable) online support system offer?	
Software Change Management		
50	How extensively are patches and Service Packs tested before they are released?	
51	Can patches and Service Packs be uninstalled? Are the procedures for uninstalling a patch or Service Pack automated or manual?	
52	Will configuration changes (if needed for the installation to be completed) be reset to what was there before the patch was applied in cases where the change was not made explicitly to close a vulnerability?	
53	How are reports of defects, vulnerabilities, and security incidents involving the software collected, tracked, and prioritized?	
54	Do you determine relative severity of defects and does that drive other things like how fast you fix issues?	
55	What are your policies and practices for reviewing design and architecture security impacts in relation to deploying patches?	
56	Are your version control and configuration management policies and procedures the same throughout your entire organization and for all your products? How are they enforced? Are third-party developers contractually required to follow these policies and procedures?	
57	What policies and processes does your company use to verify that software components do not contain unintended, "dead," or malicious code? What tools are used?	
58	How is the software provenance verified (e.g. any checksums or signatures)?	
Timeliness of Vulnerability Mitigation		
59	Does your company have a vulnerability management and reporting policy? Is it available for review?	
60	Does your company publish a security section on its Web site? If so, do security researchers have the ability to report security issues?	
Security "Track Record"		

#	COTS Vendor Security Question	Offerer's Response
61	Does your company have an executive-level officer responsible for the security of your company's software products and/or processes?	
Financial History and Status		
62	Has your company ever filed for Recompany under U.S. Code Chapter 11? If so, please provide dates for each incident and describe the outcome.	
63	Does your company have policies and procedures for periodically reviewing the financial health of the third-party entities with which it contracts for software development, maintenance, or support services?	
64	Does your company have established policies and procedures for dealing with the contractual obligations of third-party developers that go out of business?	

Storage Requirements

Database files shall be non-proprietary and all software shall be Microsoft Windows Server compatible. The State of South Dakota Bureau of Information and Telecommunications (BIT) will provide a network server for storing video images and pavement condition data. BIT hardware and software standards can be found at: http://bit.sd.gov/standards/.

The Offerer must include this table listing the significant storage requirements for each of the image and measurement categories. The Offerer may insert additional table rows as needed.

Storage Requirements	File Type(s)	Compression	Files per Mile	MB per Mile
Distance Measuring Instrument measurements				
Global Positioning System measurements				
Three forward facing 2500x2000 minimum camera images, assuming a capture interval of 0.005 mile (26.4').		:1		
One right-side 2500x2000 minimum camera images, assuming a capture interval of 0.005 mile (26.4').		:1		
Longitudinal profile and roughness measurements				
Slab faulting measurements				
Transverse profile and rut depth measurements				
Pavement surface intensity images, surface elevation profiles, and automated crack detection measurements				
Pavement texture measurements				
Edge drop-off measurements				
Roadway geometry measurements				
LiDAR roadway feature measurements				
Other (please specify):				

COST PROPOSAL

The vehicle and systems are separated into a base system and optional systems. The Offerer shall enter a bid amount for each line item. All responses will be evaluated to select the package most beneficial to the DOT considering cost, available budget, departmental needs, production requirements, and delivery. Options are intended to allow DOT to maximize equipment capabilities depending on available funds.

Item	Cost	Annual Service Agreement
Base System ▪ Vehicle ▪ Distance measuring instrument ▪ Linear referencing ▪ Global positioning system ▪ Roadway digital imaging subsystem ▪ Longitudinal profile and roughness subsystem ▪ Transverse profile and rutting subsystem ▪ Onboard computer system ▪ Dedicated workstation software (up to 5 workstations) ▪ Web-based viewing software (agency-wide license)	$	$
Automated Crack Detection Subsystem	$	$
Pavement Texture Measurement Subsystem	$	$
Edge Drop-Off Subsystem	$	$
Roadway Geometry Subsystem	$	$
LiDAR Subsystem	$	$
Hourly rate for service beyond warranty or annual service agreement	$ /hour	$ /hour

PAVEMENT DISTRESS TABLES

Tables I-1 and I-2 show the deficiencies, severity levels, and extent levels DOT currently uses to classify pavement distress. Additional information is available at http://www.sddot.com/resources/Manuals/DistressManual.pdf.

Table I-1: SDDOT Pavement Distress Severity Levels.

DEFICIENCY	LOW	MEDIUM	HIGH
Transverse Cracking	Crack <1/4 inch width or Routed & sealed crack < 1/2 inch	Crack > 1/4 and< 1 inch width and/or <1/4 inch depressions	Crack > 1 inch or (Crack > 1/4 inch width & >1/4 inch depressions)
Fatigue Cracking	Fine parallel cracks in the wheel path(s)	Alligator pattern clearly developed	Alligator pattern clearly developed with spalling and distortion
Patching and Patch Deterioration	Patch shows no visual distress of any type and with a smooth ride	Patch shows low or medium severity distress of any type and/ or notable roughness	Patch shows a high severity distress of any type and/ or distinct roughness
Block Cracking	Random longitudinal cracks between the wheel paths, Or interconnected transverse and longitudinal cracks that form blocks greater than 6 ft per side	Interconnected transverse and longitudinal cracks that form blocks 3 feet to 6 feet per side	Interconnected transverse and longitudinal cracks that form blocks less than 3 feet per side
D Cracking & ASR	Cracks are light, with no loose or missing pieces.	Cracks are well defined and some small pieces are loose or missing.	Cracks are well developed pattern with a significant amount of loose or missing material.
Joint Spalling	Spalls < 3 inches wide with no significant loss of material or Joint & Spall repair patch with cracking.	Spalls 3 to 6 inches with loss of material.	Spalls > 6 inches with significant loss of material.
Corner Cracking	Crack not spalled with no faulting & piece not broken.	Crack spalled slightly, or faulting < 1/2 inch, or piece broken.	Crack spalled, or faulting > 1/2 inch, or piece broken.
Punchout	NO SEVERITY LEVELS		
Joint Seal Damage	Damage to < 10% of joint.	Damage to 10% - 50% of joint.	Damage to > 50% of joint.

Table I-2: SDDOT Pavement Distress Extent Levels.

DEFICIENCY	LOW	MODERATE	HIGH	EXTREME
Transverse Cracking	> 50 ft. spacing.	>25 ft. & < 50 ft. spacing	< 25 ft. spacing.	<12 ft. spacing
Fatigue Cracking	1-9% of wheel path	10-24% of wheel path	25-49% of wheel path	> 49 % of wheel path
Patching and Patch Deterioration	1-9% of section	10-24% of section	25-49% of section	> 49 % of section
Block Cracking	1-9% of section	10-49% of section	>49% of section	N/A
D Cracking & ASR	1-9% of slabs	10-24% of slabs	25-49% of slabs	> 49 % of slabs
Joint Spalling	1-9% of joints	10-24% of joints	25-49% of joints	> 49 % of joints
Corner Cracking	1-9% of slabs	10-24% of slabs	25-49% of slabs	> 49 % of slabs
Punchout	<10 per mile	10 to 25 per mile	>25 per mile	N/A
Joint Seal Damage	1-9% of joints	10-24% of joints	25-49% of joints	> 49 % of joints
Longitudinal Cracking	1-9% of joints	10-24% of joints	25-49% of joints	> 49 % of joints