AUTOMATED DATA COLLECTION EQUIPMENT FOR MONITORING HIGHWAY CONDITION

Final Report

SPR 332

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by

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16. Abstract

This study was conducted to evaluate automated vehicle mounted equipment to collect data on the needs of Oregon's highway inventory. Four vendors accepted invitations to evaluate their equipment. Although ODOT had conducted a similar evaluation in 1997, vendors claimed that improved technology had solved past problems. The evaluation included an assessment of the machines' performance in a survey of pavement condition, road roughness and the ODOT video log program.

Because the video log and the road roughness inventories had been already automated (although not combined), the main focus of the evaluation was on the pavement condition rating. Several test sections on the state highway system were selected, including both asphalt and concrete pavements in various stages of wear. A standard value for the condition of these sections was established by a conventional "walk and look" survey by experienced ODOT pavement unit staff members. Also a survey was made by three rating crews, typically used by ODOT in assessing pavement condition. A comparison was made between the crews' ratings, those of the automated equipment, and the "ground truth" established by ODOT staff. The analysis of ratings showed that those of the rating crews were closer to the ground truth than the automated equipment ratings were.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSION TO SI UNITS

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

* SI is the symbol for the International System of Measurement

(12/96 jrl)

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DISCLAIMER

AUTOMATED DATA COLLECTION EQUIPMENT FOR MONITORING HIGHWAY CONDITION

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1.0 INTRODUCTION

1.1 BACKGROUND

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

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

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

1.2 OBJECTIVES

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

Specific objectives included the following:

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

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

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

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

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

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

1.3 SCOPE

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

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

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

2.0 LITERATURE REVIEW AND STATE SURVEY

2.1 AUTOMATED DATA COLLECTION: RESEARCH AND DEVELOPMENT

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.2 CURRENT PRACTICES BY STATE DOT AGENCIES

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

2.2.1 Smoothness Data Collection

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

2.2.2 Distress Data Collection

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

2.2.3 Video Data Collection

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

3.0 STUDY DESIGN

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

3.1 INTERNAL SURVEY

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

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

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

3.2 FIELD TEST

Field tests were designed to meet Objectives 2 through 4:

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

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

3.2.1 Test section selection

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

Table 4.1: Test sections

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

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

3.2.2 Ground truth

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

Table 4.2: Ground truth sections

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

3.2.3 Data collection

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

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

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

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

4.0 CURRENT PROCEDURES

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

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

4.1 ROAD ROUGHNESS

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

4.2 ODOT VIDEO LOG PROGRAM

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

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

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

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

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

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

4.3 PAVEMENT DISTRESS

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

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

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

5.0 DATA ANALYSIS AND RESULTS

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

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

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

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

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

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

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

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

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

5.1 PAVEMENT CONDITION DATA EVALUATION

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

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

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

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

5.1.1 Graphical comparisons

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

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

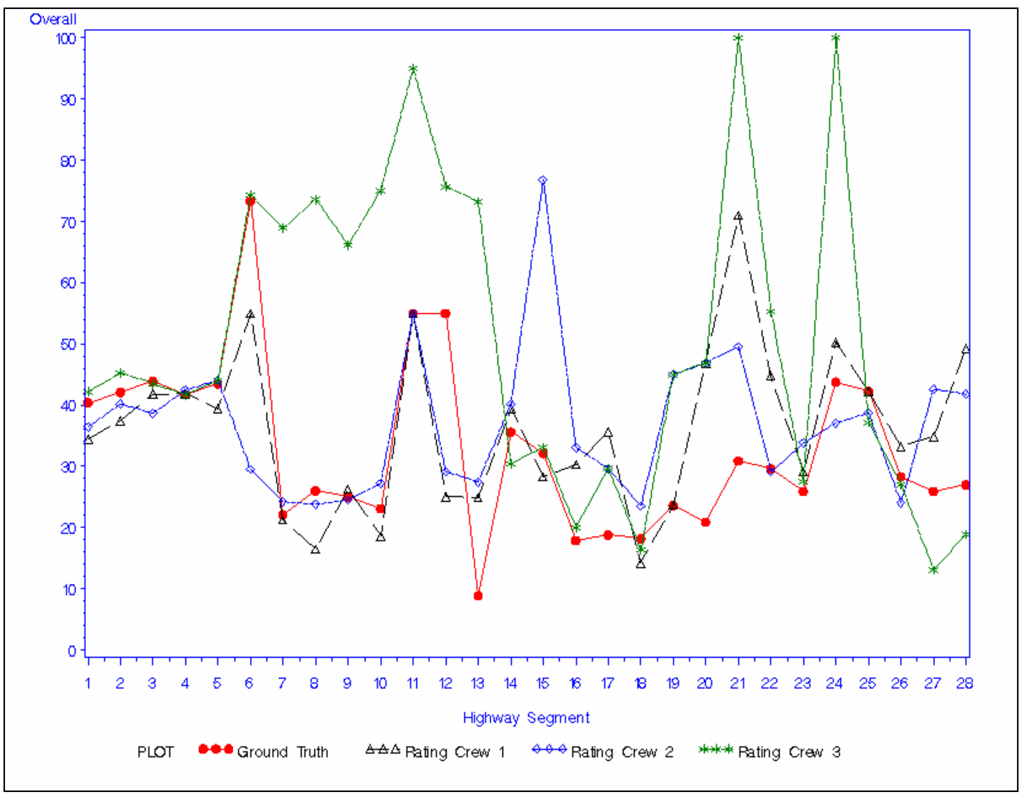

Figure 5.1: Overall Index comparing ground truth and ODOT rating crews

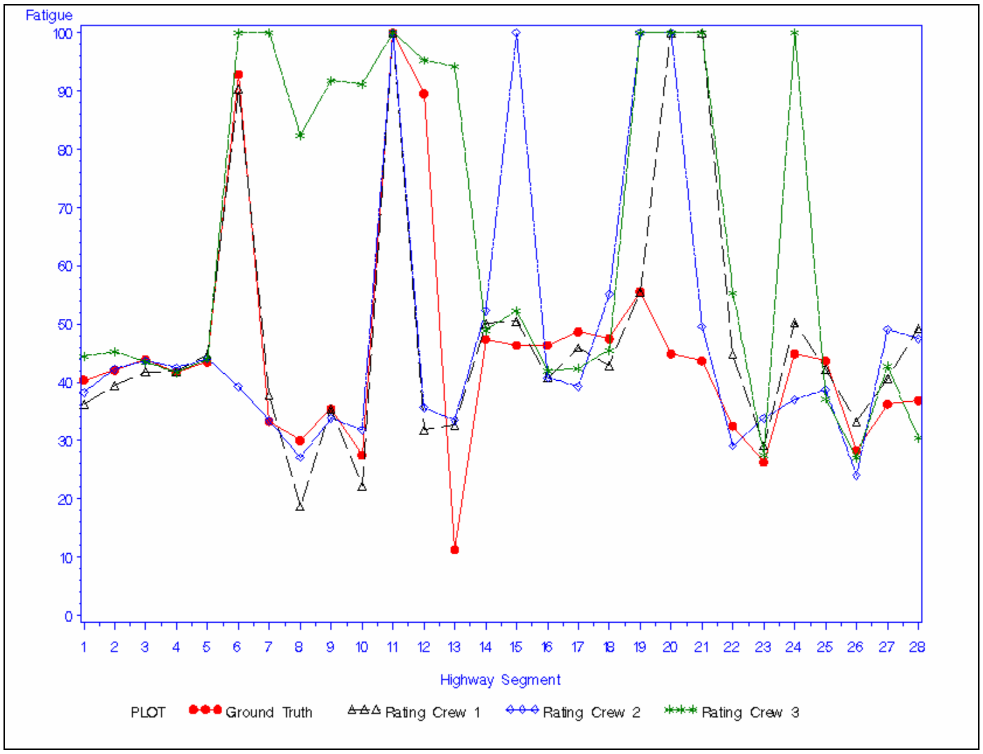

Figure 5.2: Fatigue Index comparing ground truth and ODOT rating crews

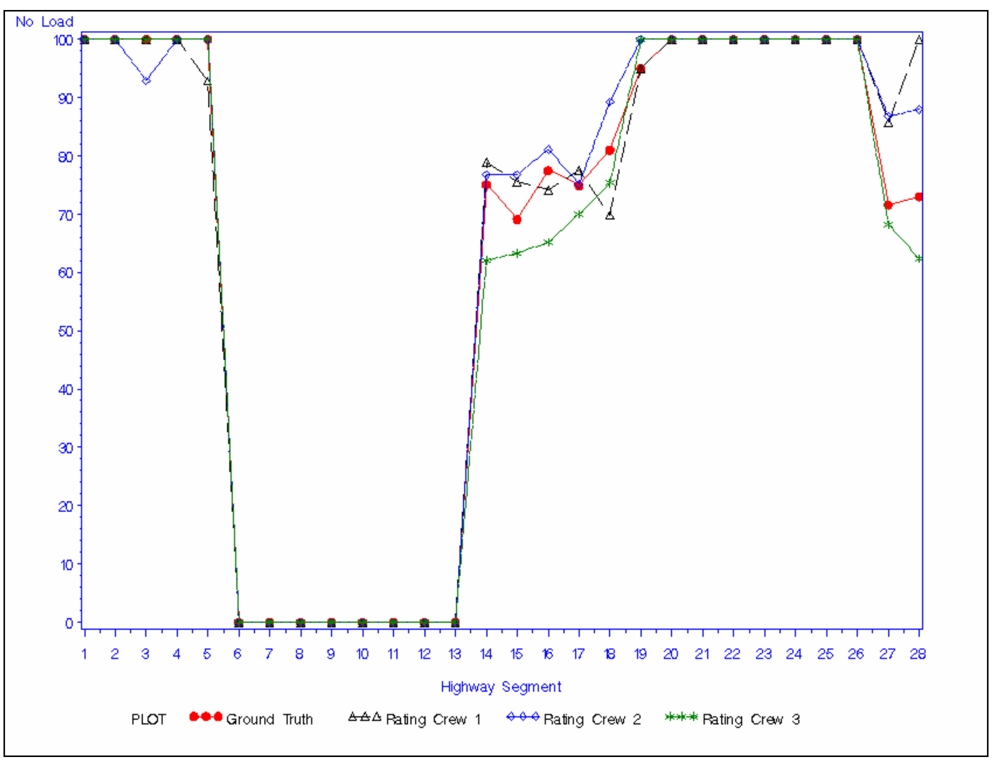

Figure 5.3: No Load Index comparing ground truth and ODOT rating crews

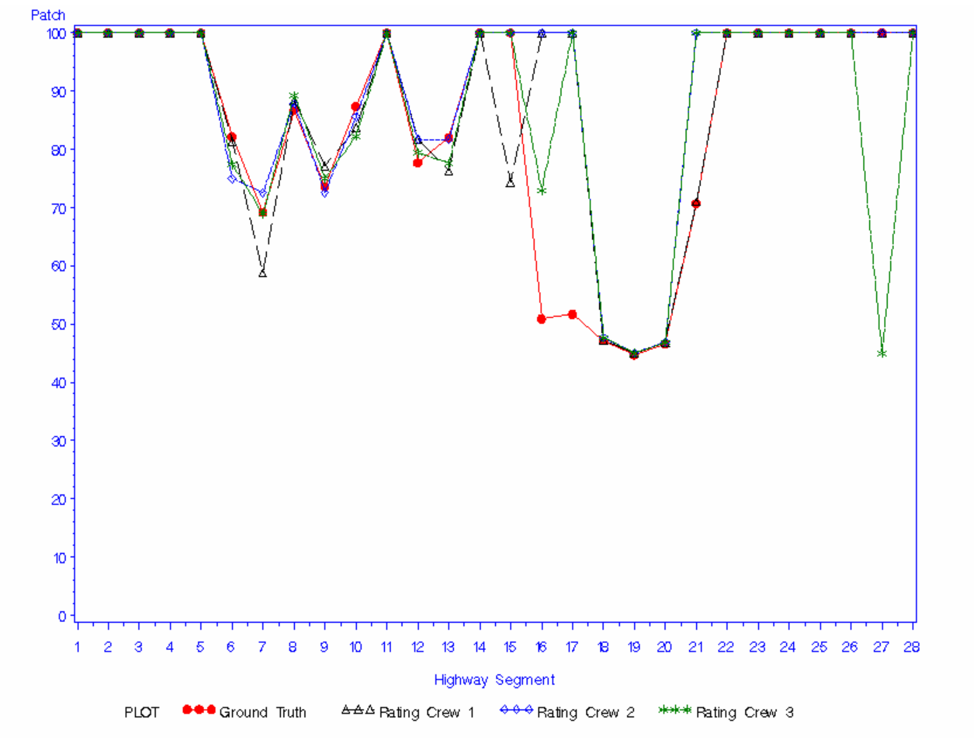

Figure 5.4: Patching Index comparing ground truth and ODOT rating crews

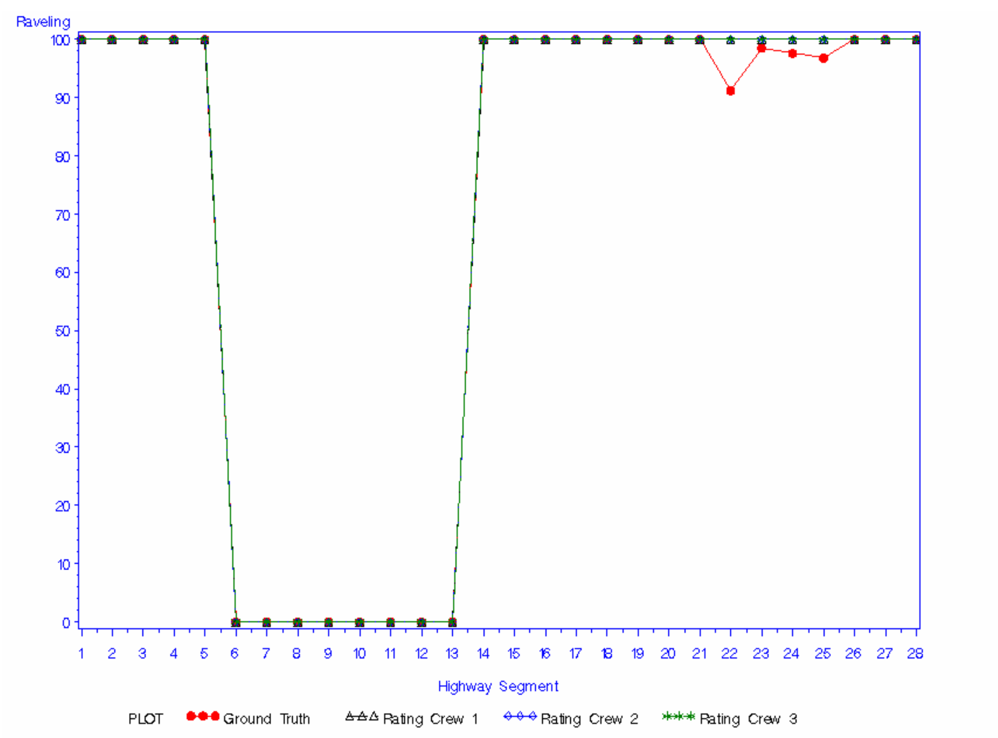

Figure 5.5: Raveling Index comparing ground truth and ODOT rating crews

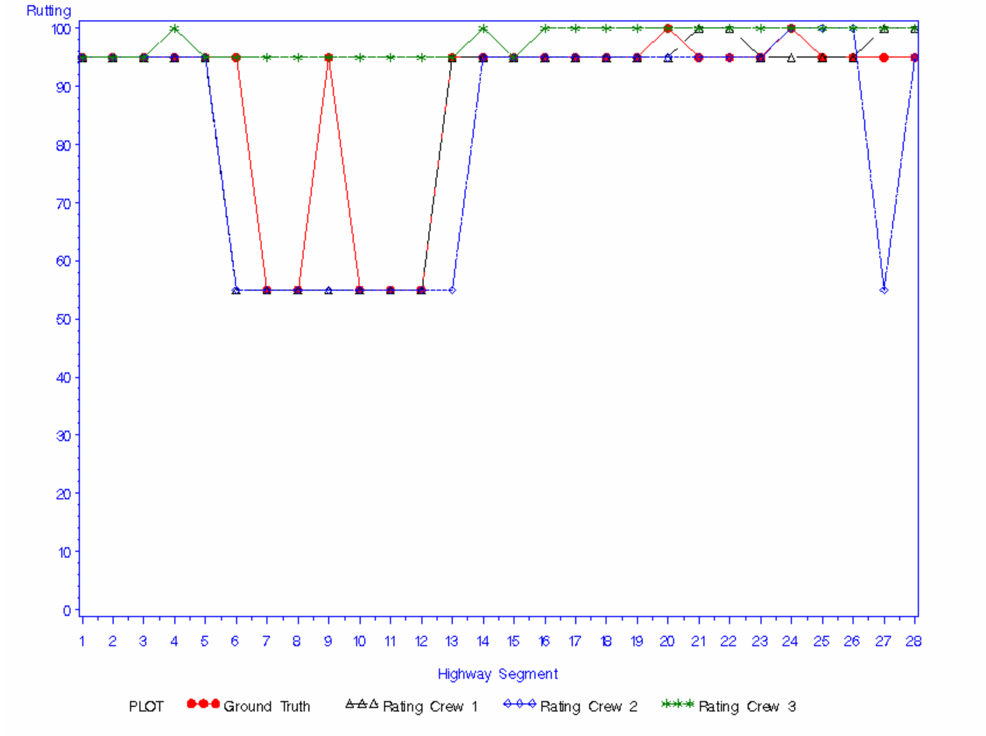

Figure 5.6: Rutting Index comparing ground truth and ODOT rating crews

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

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

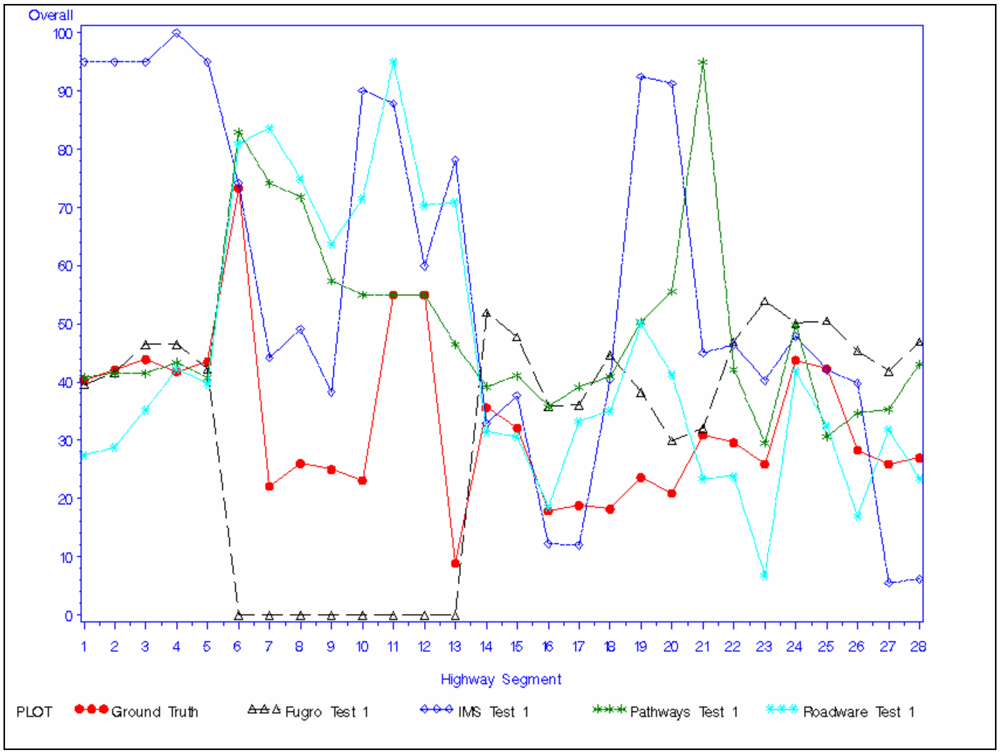

Figure 5.7: Overall Index comparing ground truth and ADC equipment

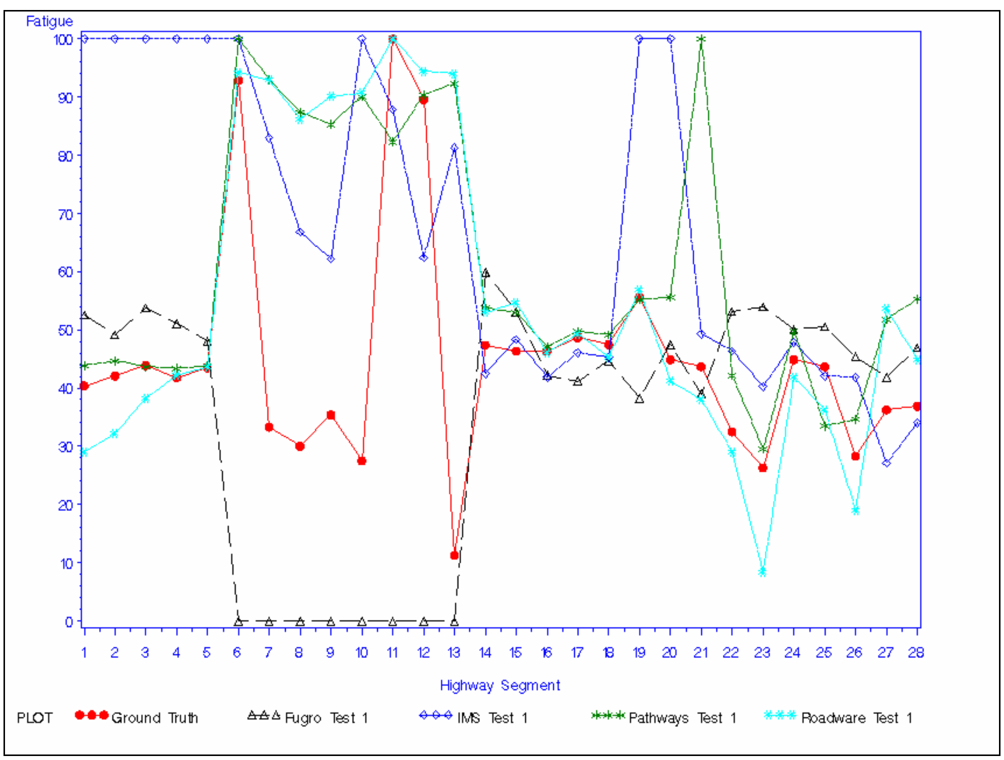

Figure 5.8: Fatigue Index comparing ground truth and ADC equipment

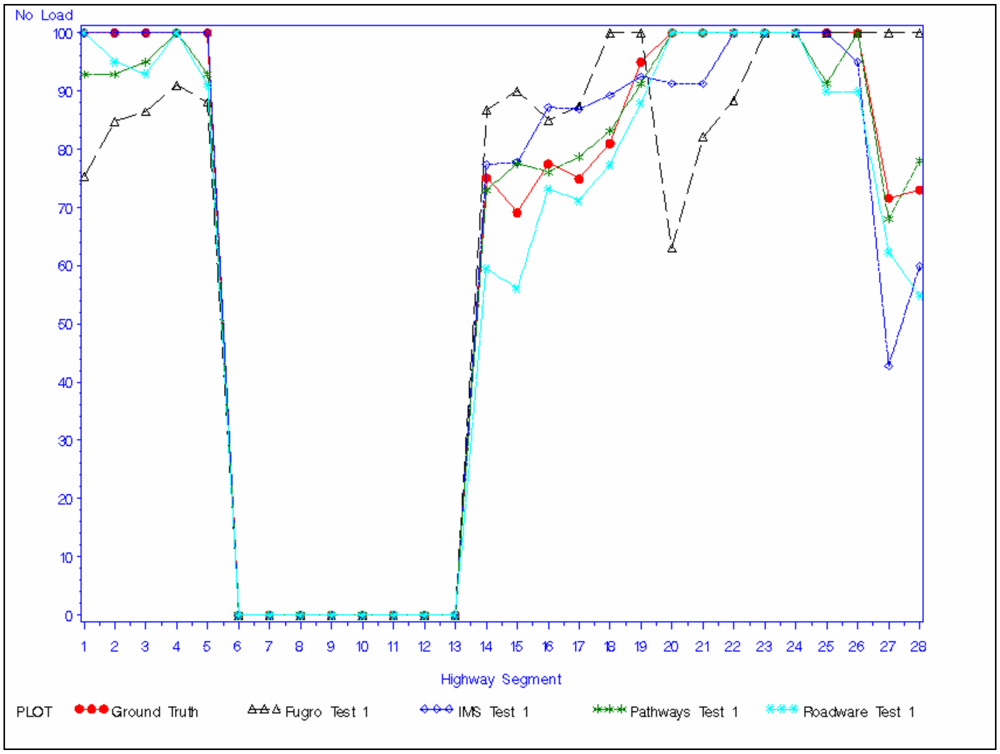

Figure 5.9: No Load Index comparing ground truth and ADC equipment

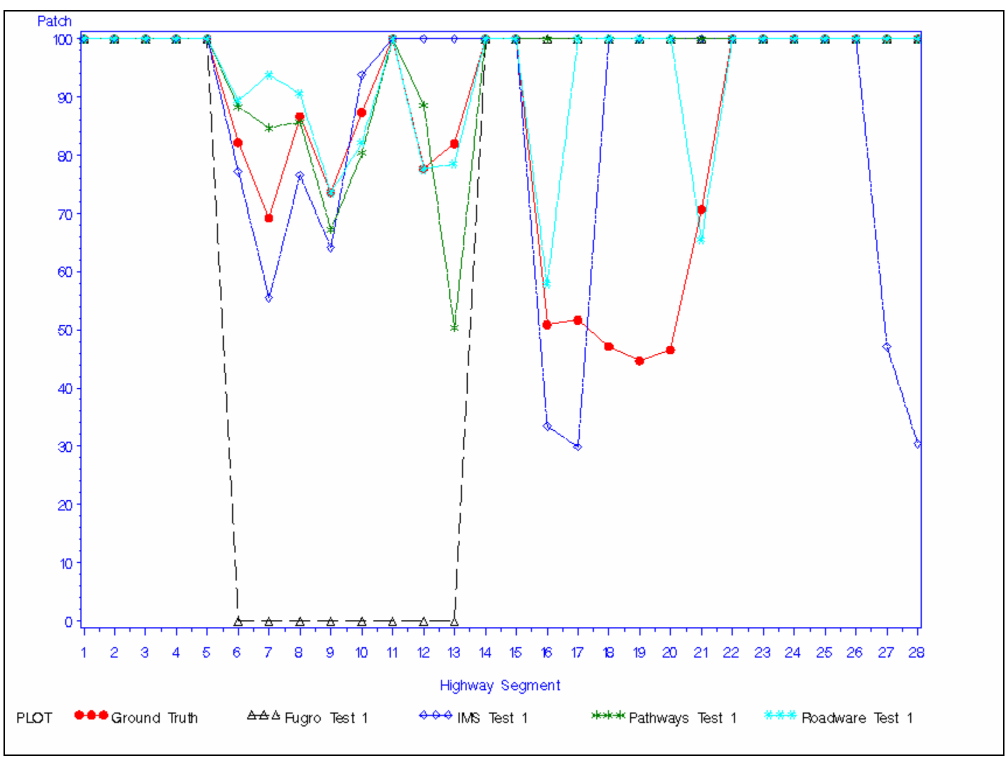

Figure 5.10: Patching Index comparing ground truth and ADC equipment

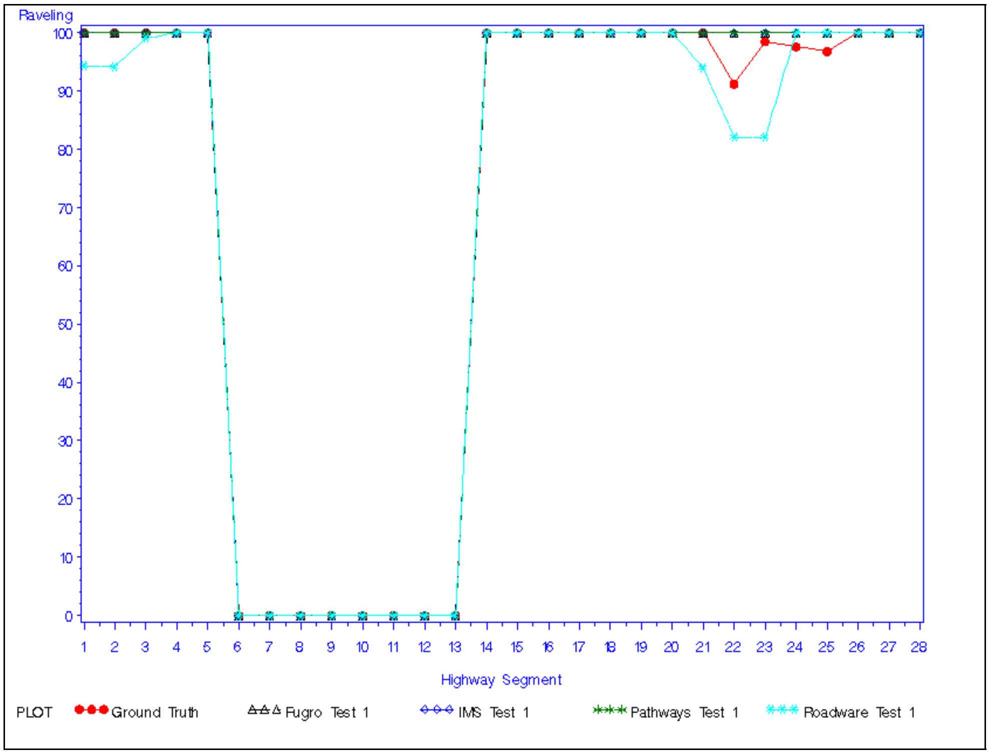

Figure 5.11: Raveling Index comparing ground truth and ADC equipment

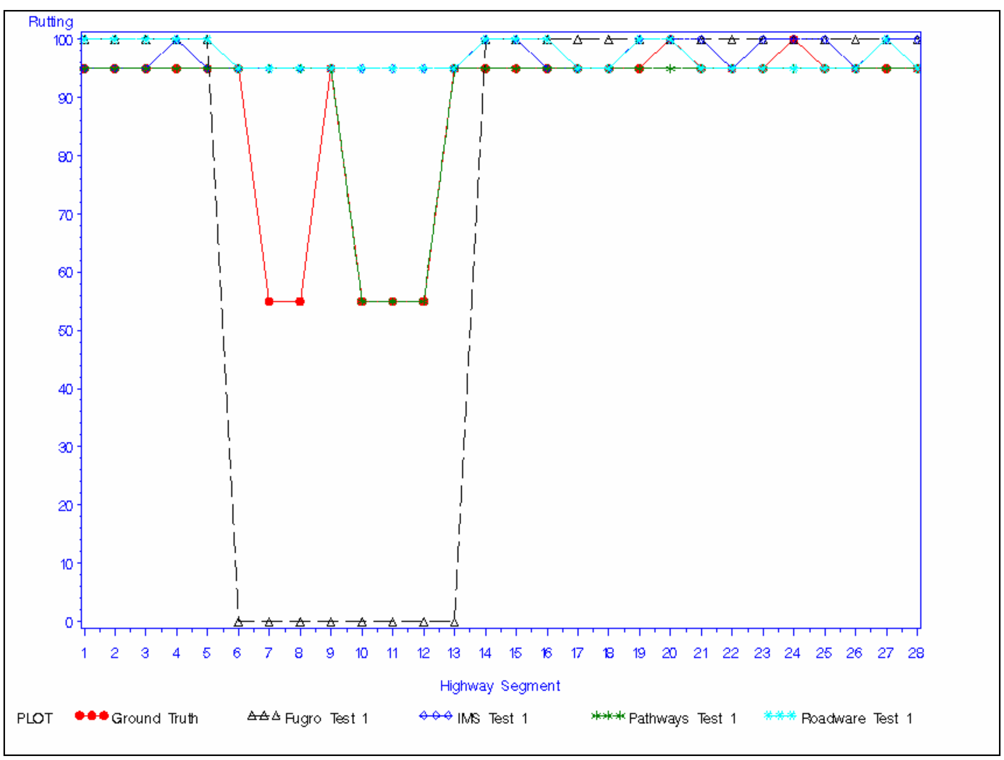

Figure 5.12: Rutting Index comparing ground truth and ADC equipment

5.1.2 Correlation analysis

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

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

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

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

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

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

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

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

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

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

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

5.1.3 Comparison of mean values to ground truth

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

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

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

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

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

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

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

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

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

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

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

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

5.1.4 Comparisons among raters for agreement

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

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

Table 5.3: Duncan Multiple Range Test results

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

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

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

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

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

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

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

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

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

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

5.1.5 Test of repeatability

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

5.1.6 Summary of Results

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

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

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

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

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

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

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

5.2 RAW DATA ANALYSIS

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

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

Table 5.5: Fatigue cracking measurements

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

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

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

Table 5.6: Patching quantity for asphalt pavements

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

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

Table 5.7: Patch quantity for CRC pavements

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

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

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

Table 5.8: Transverse crack quantity

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

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

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

Table 5.9: Longitudinal Crack Quantity for AC Pavement

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

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

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

Table 5.10: Longitudinal crack quantity for CRC pavement

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

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

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

5.2.1 Summary of raw data analysis

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

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

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

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

5.3 VIDEO LOG EVALUATION

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

Image Quality

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

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

Location/referencing method

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

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

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

<u>Availability of video to the rest of the world</u>

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

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

<u>Other Uses</u>

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

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

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

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

6.0 DISCUSSION OF RESULTS

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

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

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

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

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

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

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

1. Quality of the video log images.

2. Quality of pavement distress data.

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

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

7.0 RECOMMENDATIONS

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

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

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

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

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

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

8.0 REFERENCES

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