CENTER FOR TRANSPORTATION RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

TECHNICAL REPORT 0-6663-1

TxDOT Project Number 0-6663

Field Evaluation of Automated Rutting Measuring Equipment

Pedro A. Serigos
Jorge A. Prozzi
Boo H. Nam
Mike R. Murphy

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

www.utexas.edu/research/ctr/pdf_reports/0_6663_1.pdf

Technical Report Documentation Page

1. Report No. FHWA/TX-12/0-6663-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Field Evaluation of Automated Rutting Measuring Equipment		5. Report Date February 2012, Published July 2012
		6. Performing Organization Code
7. Author(s) Pedro A. Serigos, Jorge A. Prozzi, Boo H. Nam, and Mike R. Murphy		8. Performing Organization Report No. 0-6663-1
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 1616 Guadalupe Street, Suite 4.202 Austin, TX 78701		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 0-6663
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, TX 78763-5080		13. Type of Report and Period Covered Technical Report, September 2010 to December 2011
		14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

16. Abstract

The Texas Department of Transportation (TxDOT) has developed a state-of-the-art 3D system for rut measurements. This system will allow more accurate assessment of road performance at both the network and project levels and potentially eliminate the need for manual visual assessments. Furthermore, the improved accuracy, which can be achieved while traveling at highway speeds, will eliminate any subjective elements and lead to more consistent and reliable data. The improved accuracy of the system will significantly impact the TxDOT Pavement Management Information System (PMIS). PMIS is used to monitor statewide pavement condition and to evaluate the effectiveness of pavement maintenance and rehabilitation treatments. PMIS is also used to report progress towards the annual statewide pavement condition goal.

To ensure the rational adoption of the new systems, TxDOT initiated this project to allow an independent assessment of the accuracy and repeatability of the newly developed system. The TxDOT system was compared to other, similar systems from a variety of different vendors to identify the most suitable system for implementation. The project consists of two phases. Phase I evaluated the rut measurements and Phase II will evaluate automated distress data measurements, including longitudinal, transverse, and alligator cracking; failures; spalled cracks; and punchouts. This report summarizes the Phase I tasks, data, analysis, main findings, and recommendations.

17. Key Words Automated rutting, rut depth, surface profile, 3D systems, laser, video	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161; www.ntis.gov.

19. Security Classif. (of report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	170	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Field Evaluation of Automated Rutting Measuring Equipment

Pedro A. Serigos
Jorge A. Prozzi
Boo H. Nam
Mike R. Murphy

CTR Technical Report:	0-6663-1
Report Date:	February 2012
Project:	0-6663
Project Title:	Evaluation of Pavement Rutting and Distress Measurements
Sponsoring Agency:	Texas Department of Transportation
Performing Agency:	Center for Transportation Research at The University of Texas at Austin

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe, Suite 4.202
Austin, TX 78701

www.utexas.edu/research/ctr

Disclaimers

Author's Disclaimer: The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

Patent Disclaimer: There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

Engineering Disclaimer

NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES.

Research Supervisor: Michael R. Murphy

Acknowledgments

The authors express appreciation to the TxDOT Project Director, Mike Arellano, and all the members of the Project Monitoring Committee for their support and contribution during Phase I of the study. In addition the following individuals are greatly acknowledged because of their support during the field testing: Jose Pablo-Aguiar Moya, Ambarish Banerjee, Doug Chalman, Jeawon Hwang, Prasad Sivaram, and Andre de Fortier Smit.

Products

This report contains Product 1 of the research project as Chapter 5: *Recommendations for the Selection of Rutting Measuring Equipment.*

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

This report documents the work performed and main findings for the first four tasks of the Texas Department of Transportation (TxDOT) Research Project 0-6663, "Evaluation of Pavement Rutting and Distress Measurements." The tasks covered in this report correspond to Phase I of the project, which evaluated the accuracy and precision of TxDOT and vendor automated rut measurement equipment operating at highway speeds. Phase II of the project, which will be the subject of a future report, will address evaluation of TxDOT and vendor automated visual distress measurement systems.

This report includes five chapters, and two Appendices which comprise both the Phase I Report (R1) and deliverable (P1), which is contained in Chapter 5, *Recommendations for Selection of Rutting Measuring Equipment*.

Chapter 1 contains the introduction and discusses the goals and objectives of the project, the Work Plan, and the outline for the remainder of the report.

Chapter 2 contains a literature review of methods for measuring pavement transverse profiles and rut depths using manual and automated equipment. Information is provided regarding the TxDOT 3D laser system and commercially available, state-of-the-practice automated rut measurement equipment that can operate at highway speeds. In addition, different methods are discussed for collecting manual rut data to establish ground truth (GT) or baseline measurements for evaluation of automated systems that operate at highway speeds.

Chapter 3 describes the experimental design for Phase I. The criteria and rationale used for selecting test sections are discussed, including variation in surface texture, lane widths, and a range of rut depths. Additional factors are discussed that could potentially pose challenges for automated rut measurement equipment. Chapter 3 also contains a description of each test section, including location, main characteristics, photographs, and other details.

Chapter 4 discusses the manual GT measurements established by the researchers and used to evaluate the TxDOT and vendor measurements. A discussion is included of the data analysis procedures developed to compare the TxDOT and vendor transverse profiles to the manual GT profiles. In addition, the analysis method used to compare participants' maximum rut depths to the manual GT measurements is discussed. For this report, the term Maximum Rut Depth (MRD) is the same as the ASTM E1703/1703M-10 term rut-depth, defined as: "the maximum measured perpendicular distance between the bottom surface of the straightedge and the contact area of the gauge with the pavement surface at a specific location" (ASTM E1703). The methods used for preparing a complete set of plots for the transverse profiles and maximum rut depths are also discussed. The resulting plots are contained in Appendix A and B (see accompanying CD).

Chapter 5 contains the researchers' recommendations for the selection of automated rutting equipment based on the experiment results. These recommendations comprise deliverable P1 as outlined in the project agreement. Chapter 5 is followed by a complete list of references used in this study.

Appendix A, *Measured Profiles*, and Appendix B, *Measured Rut Depths*, provide an entire set of plots that were prepared based on the methods discussed in Chapter 4. The researchers used this data to evaluate the accuracy and precision of the TxDOT and vendor systems, employing the statistics discussed in Chapter 4. These two appendices exceed 1,400 pages and are therefore stored on the accompanying CD rather than being included in the report.

1.1 Project Objectives

The project objectives are to provide TxDOT Administration and technical staff with the following:

1. an independent assessment of the accuracy and precision of the TxDOT 3D laser rut measurement system and state-of-the-practice commercially available automated rut measurement systems (Phase I);
2. recommendations regarding selection of automated rut measurement equipment selection (Phase I);
3. an independent assessment of the accuracy and precision of the TxDOT 3D laser visual distress measurement system and state-of-the-practice commercially available automated visual distress measurement systems (Phase II);
4. recommendations regarding selection of automated visual distress measurement equipment (Phase II); and
5. recommendations regarding incorporation of these measurements in PMIS considering that more accurate measurements could result in an increased amount of rutting and visual distress (Final Project Report).

Phase I addresses objectives 1 and 2 with regard to automated rut measurement equipment. The next section discusses the problem statement, including the need for improved rut measurement equipment.

1.2 Problem Statement

TxDOT has used a five-point ultrasonic sensor rut measurement system for the last 15 years. The five-point ultrasonic rut bar system was developed in-house and represented the state of the practice when first developed. However, the main disadvantages of the 5-point system are the tendency to underestimate the rut depth values due to the width of the rut bar (8 ft) in relation to travel lane widths (9 ft–12 ft) and the limited number of sensors and resulting data points collected at each transverse location (see Figures 1.1–1.2). Other disadvantages are the high sensitivity of the sensors to environmental factors (wind, temperature, humidity etc.). These issues motivated TxDOT to develop a new high-speed 3D laser camera system for rut measurements.

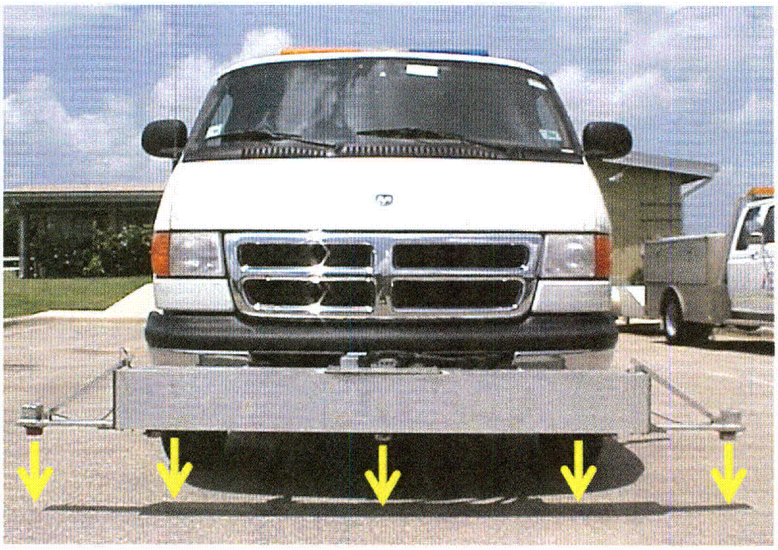


Figure 1.1: TxDOT five-point ultrasonic sensor rut bar showing sensor locations along the bar

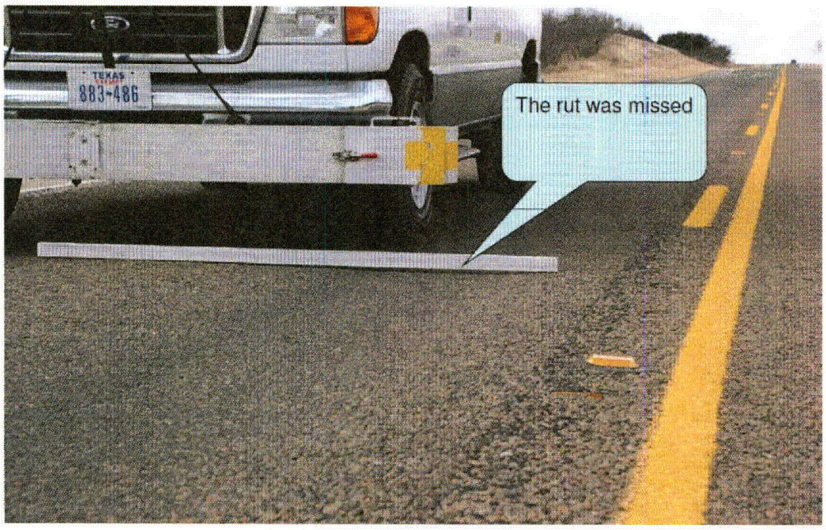


Figure 1.2: Limited rut bar width results in under-measurement of rut depth [TxDOT 2010]

Figure 1.3 shows a TxDOT van with the 3D laser-camera system developed in house. The red region depicts the laser plane projected from an aperture in the enclosure that houses the 3D camera and laser. The yellow plane indicates the angle between the laser plane and the camera orientation. As shown in the figure, the laser is projected vertically to the pavement surface and produces a reference line approximately 14 ft wide as shown by the dashed blue line. The 3D camera collects images of the laser line that are later processed to produce a transverse profile and to calculate rut depths.

The system is capable of measuring approximately 1,500 data points per transverse profile, depending on the pavement width, with a vertical (depth) range of ± 8 inches and a resolution of 0.0335 inches; the transverse resolution is 0.11 inches. The transverse profiles are collected on a one-inch interval as the van travels along the road at highway speeds. The one-inch interval spacing is for network-level data collection and can be adjusted for other applications. Twelve profiles are collected and averaged to provide a single transverse profile that is then filtered in preparation for rut depth calculations. The 14 ft wide transverse profile is wider than a normal traffic lane and projects into the opposing lane on the left side of the vehicle and into the shoulder or beyond the pavement edge on the right side of the vehicle. This profile provides TxDOT with sufficient width to accommodate the majority of pavement lane conditions, including normal and transition widening sections. However, because the pavement center line and edge stripes (when present) are used to define the pavement lane boundaries, the 14 ft wide transverse profile is truncated using the lane striping. In this regard, the actual transverse profile width used for the rut depth analysis can and does vary along the route depending on lane striping, pavement lane width, shoulder and edge conditions, and other factors.

Once the transverse profiles for a given location have been processed, the rut depth calculations are accomplished using algorithm(s) programmed based on different criteria. For this study, TxDOT provided two sets of maximum rut depth (MRD) values, named *TxDOT PMIS* and *TxDOT ASTM* respectively by the researchers, calculated using different algorithms and filters.

Figure 1.3: TxDOT 3D system for automated measurement of rutting

The next section discusses the Phase I work plan, which addresses the first four tasks of the project agreement detailed in subsequent chapters.

1.3 Phase I Work Plan

The Phase I work plan included four tasks: Literature Review, Experiment Design, Field Survey and Analysis of Rutting Results, and Recommendations. In Task 1, covered in Chapter 2, an extensive literature review was conducted to gather information about automated rut measurement equipment technologies and standards used nationally and worldwide. In addition, a detailed description of manual rut measurement methods is provided including different indices and definitions used to characterize rutting.

The objective of Task 2, covered in Chapter 3, was to develop an experimental design that included both coarse and fine surface textures, narrow and wide lanes, and a range of rut depths. The 26 550-ft sections selected by the research team covered the basic experimental design plus particular cases or anomalies considered potentially challenging for automated equipment. Two of the test sections were repaired by District maintenance staff before automated data collection could occur and thus were discarded from the study. A 10-mile section was also selected by the researchers to be used for the network-level data comparison.

During the field survey conducted as part of Phase I, manual and automated measurements of surface transverse profiles and MRDs were collected. This task was divided into two main parts: 1) manual measurements performed by the research team to establish the benchmark or GT MRD and transverse profile; and 2) automated transverse profile and rut depth measurements collected at highway speeds with the TxDOT 3D system and commercially available systems.

During the first part of the task, the researchers established the benchmark reference by manually measuring the MRD values of each wheel path at 5-ft stations spaced longitudinally along each 550-ft test section. This resulted in 111 MRD values per wheel path per test section, and a total of 5,328 reference MRD values for the entire experiment. Transverse profiles were collected starting at the 0-ft station and at 25-ft intervals thereafter using the same stationing reference as the MRD values. This resulted in 23 transverse profiles per test section and 552 reference transverse profiles for the experiment.

The manual reference transverse profiles were used to compare and evaluate the accuracy and precision of the transverse profiles reported by each participant. Unless a system is capable of collecting quality transverse profiles, the MRDs calculated using these profiles were expected to be inaccurate. Each participant was also asked to provide their best estimate of the inside wheel path (IWP) and outside wheel path (OWP) MRD at each test location in a specific format for the station spacing matching the GT measurements. In this way the researchers were able to evaluate the accuracy and precision of profiles and MRD measurements independently.

Technically, the more difficult task is to collect accurate, precise transverse profiles at highway speeds; MRD algorithms may give systematically biased results depending on the criteria used by the developer. However, adjusting or calibrating rut depth algorithms may be possible as necessary.

In order to participate in the study each equipment system had to meet the following minimum criteria:

1) collect at least 30 data points at each transverse profile location;

2) collect at least one transverse profile every 1 foot;

3) operate at highway speeds;

These requirements were defined by the researchers in order to avoid the participation of discrete, point-based systems (rut bars), which is the type of technology being replaced by TxDOT's new 3D system. Criterion 2 was relaxed at an early point in the study, based on discussions with the TxDOT PMC, to allow a broader range of commercially available systems to participate. Thus, commercially available systems that could collect at least one transverse profile every 3 feet were considered acceptable and included in the study.

Initially, a comprehensive list of equipment vendors and service providers was created and the vendors contacted. Eight different vendors were invited to participate in the field experiment and a webinar was conducted by the researchers to 1) explain the project objectives; 2) describe the manual data collection procedures; 3) discuss the statistical analysis that would be performed for the comparison; and 4) answer questions posed by the webinar participants. Of the eight vendors that attended the webinar, three decided to participate in the project: Pathway Services Inc., Dynatest, and Fugro-Roadware Inc. After the webinar, Applus RTD of Quebec contacted the researchers to express their intention to participate. Therefore, in addition to TxDOT's system, four vendors participated in the experiment.

Each participant operated an optical system capable of measuring a continuous transverse profile at highway speeds. Figures 1.4 to 1.7 show the equipment used by each vendor in the project. As in Figure 1.3, the red and yellow regions in Figures 1.4 to 1.7 are drawn to indicate the laser and camera plane respectively, and the dashed blue line indicates the location of the pavement surface transverse profile points being measured. Each system basically consists of a laser and a camera; however, the configuration of the system as well as the number of sensors varied. The orientation of specific systems varies as well. Thus, both TxDOT's SICK® 3D camera and laser system and the Applus RTD INO® (Institut National d'Optique, or the National Optics Institute) laser crack monitoring system (LCMS) system project the laser plane perpendicular to the pavement surface whereas the remaining three vendor systems project the laser plane at an angle.

The angle between the Pathway Services camera and laser system is proprietary and was developed in house and therefore is unknown to the researchers. The Dynatest and Roadware systems use an INO Laser Rut Measurement System(LRMS) system that projects the laser lines at approximately 21° with respect to the horizontal plane. The TxDOT 3D system uses a single enclosure containing both the camera and the laser (Figure 1.3). The Pathway Services system uses one 3D camera and two lasers in separate enclosures (one per wheel path, as shown in Figure 1.4). The INO LRMS and LCMS employ two separate enclosures, one for each wheel path, which each contain a camera and laser (Figures 1.5 to 1.7).

Figure 1.4: The Pathway Services automated rut measurement system

Note that although these specific rut measurement systems were used for the Phase I study, the vendors indicated that options are offered to customers to meet their specific needs. Thus, each vendor operating an INO system can potentially provide the same data collection system as any other INO vendor that participated in the study. This implies that the vendor can also provide the necessary rut measurement algorithm. Hypothetically, the same could be said for the SICK 3D camera, which is commercially available, and is used in the TxDOT system. However, as with the INO systems, the control and analysis software for transverse profile and rut measurements would need to be developed or supplied as a packaged system. Hypothetically, the same would be true for the Pathway Services 3D camera system, although the researchers were not told the brand, model, or operational features of the Pathway Services 3D camera laser system.

Figure 1.5: The Dynatest INO LRMS automated rut measurement system

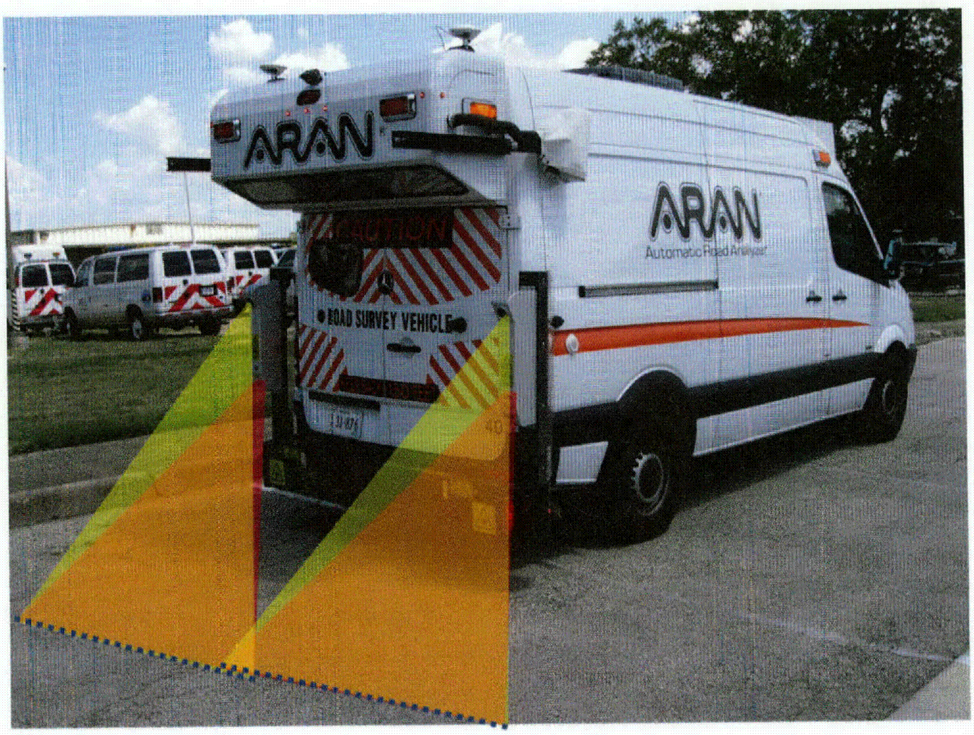


Figure 1.6: The Roadware INO LRMS automated rut measurement system

Figure 1.7: The Applus RTD INO LCMS automated rut measurement system

Also interesting to consider is that the Applus RTD rut measurement sensors and analysis hardware system were mounted on a trailer, whereas the other systems' sensors were directly mounted on the rear of a van.

Because all the participants used proprietary algorithms to process their measured transverse profiles, the researchers hypothesized that the MRD results could differ even if participants operated the same brand and model of sensor. When possible, the researchers noted the brand, model, and serial numbers of the different pieces of equipment. This information was collected to take into account that two vendors operating the same brand and model of sensor could potentially be operating different sensor versions depending on date of manufacture.

All of the systems were equipped with a control unit installed in the cargo compartment of the survey vehicle, except for the system used by Applus. Each system required two people to perform the rut data collection: one to drive and one to operate the host computer. Figure 1.8 shows the control unit of TxDOT's system and the space designated for the operator of the control computer.

Figure 1.8: TxDOT System's Control Unit

Each participant was asked to collect the data at highway speeds on the 24 550-ft test sections and to provide 1) their best estimate of the MRD in each wheel path measured every 5 ft, and 2) their best estimate of transverse profile measured every 25 ft. In addition, the participants were asked to report the MRD values every 0.01 miles for a 10-mile section established to evaluate a longer sampling interval.

Each participant measured each of the 24 sections 3 times and the 10-mile section once. Each participant was accompanied by a member of the research team who guided them along the route, documented the system used, and monitored the speed and number of times data was collected. The participants were asked to collect data at a minimum speed between 45 and 50 mph but could, at their discretion, collect data up to the posted speed. The minimum data collection speed was not imposed for the sections 14, 25, and 26 which had posted speed limits of were 30, 35, and 40 mph, respectively.

All participants were able to complete the 24 sections in approximately 6 to 8 hours without major difficulties except for Dynatest, who had to cancel testing during data collection on 2 separate days due to technical problems with their system. Thus, Dynatest data was collected over 3 separate days whereas all other participants collected the data in 1 day. The technical malfunction was eventually traced to a connection problem in a recently purchased custom-built computer used to control the INO laser systems; the malfunctions were not due to the INO rut measurement equipment itself.

Each participant required different amounts of time to process and report the transverse profiles and MRD values for all test sections in the format requested. Table 1.1 presents the relevant dates at which each participant collected and reported the data. As shown in the table, TxDOT delivered the majority of the requested results in approximately 8 days—the fastest post-processing time—followed by Dynatest and Roadware, who each took 21 days.

Table 1.1: Dates at which each participant collected and reported the data

Participant	Date	Time to deliver the data	Event
TxDOT	05/24/11	-	*Completed data collection*
	06/01/11	8 days	*Report of transverse profiles and set of MRD values for all 550-ft sections except for section 7*
	06/30/11	37 days	*Report of transverse profiles and set of MRD values for section 7 and 10-mile section*
Pathway	06/17/11	-	*Completed data collection*
	07/29/11	42 days	*Report of all requested values*
Dynatest	06/22/11	-	*Incomplete data collection*
	06/23/11	-	*Incomplete data collection*
	07/01/11	-	*Completed data collection*
	07/22/11	21 days	*Report of all requested values*
Roadware	06/29/11	-	*Completed data collection*
	06/30/11	1 days	*Report of 10-mile section measurements*
	07/16/11	17 days	*Report of all MRD values*
	07/20/11	21 days	*Report of all measured transverse profiles*
Applus	06/30/11	-	*Completed data collection*
	07/18/11	18 days	*Report of all measured transverse profiles*
	07/27/11	27 days	*Report of 10-mile section measurements*
	08/02/11	33 days	*Report of all MRD values*

The fourth task of Phase I was the analysis of rut measurement results, with the objectives of analyzing the data collected in Task 3 and recommending the best technology for measuring rutting at highway speed.

The first step in the comparison consisted of quantifying the random error (precision) and systematic error (bias) of each set of equipment for each test section. The Mean Squared Error (MSE) = (Random Error)^2 + (Bias)^2 was also calculated as an overall measure of data quality. MSE combines both the random and systematic biases of a measurement. Other statistical properties, such as the correlation coefficient of the GT and each participant's results, were also calculated. The calculated statistics were used to rank the different systems.

The recommendations for the selection of rut measurement equipment were based on the findings from the data analysis and the rankings obtained from the calculated statistics, which are contained in Chapter 5.

The following chapter provides an extensive literature review discussing the state of the practice in automated rut measurement equipment and manual rut measurement methods used to establish GT or baseline measurements.

Chapter 2. Literature Review

In Texas, pavement rutting is a flexible pavement distress that can 1) indicate a structural defect or excessive traffic loadings compared to original design criteria; 2) lead to safety issues due to hydroplaning or small vehicle handling at highway speeds; and 3) potentially reduce ride quality. Rut data collection is necessary to monitor pavement conditions and to detect unacceptable increases in the amount or severity of rutting. Rut data is essential for characterizing network- and project-level pavement conditions and is used to support pavement management needs assessments and treatment selection decisions. Rutting of portland cement concrete pavements occurs in some U.S. states due to abrasive carbide-tipped studded snow tires; however, these tires are rarely used in Texas. Thus, the Phase I study and literature review will focus on measurement of rutting in the asphalt concrete or surface-treated pavements that constitute approximately 94% of the TxDOT roadway network.

Rut measurement methods can be categorized as either manual, static measurements or automated, dynamic measurements made at highway speeds. Manual measurements for pavement management applications are considered a low-budget option that is inefficient and potentially unsafe for network-level data collection in many cases. For a manual measurement, the rater must occupy the travel lane during data collection or visually rate the pavement from the shoulder or pavement edge. In addition, manual methods that require the rater to occupy the travel lane necessitate traffic control, which can disrupt traffic flow and expose personnel to traffic in the opposing lane. However, when manual rut measurements are conducted based on accepted practice, using the appropriate equipment, the resulting data is still considered to provide rut measurements sufficiently accurate for use as baseline or "ground truth" data when evaluating automated equipment systems. A manual, static maximum rut measurement is expected to be more accurate than an automated measurement made at highway speeds using currently available equipment technology and software algorithms. This assumption arises partly from the many variations that develop on a pavement surface or along a route. These variations can pose difficulties for automated equipment, but can be more readily interpreted by a knowledgeable manual rater who can consider and reconcile these factors.

The advantages offered by automated methods include data collection at highway speeds, increased sampling rates that can result in better pavement network characterization, reduced personnel requirements, and no need for traffic control. Depending on the equipment, current automated systems are capable of collecting transverse profiles at highway speeds, with each profile consisting of hundreds of data points. This chapter presents a selection of indices to characterize rutting as found in the literature, and discusses manual and automated methods for rut measurement.

2.1 Definition and Characterization of Rutting

Rutting is defined as the progressive consolidation or displacement of materials under repeated loads in either the asphalt pavement layers or the underlying base (Roberts et al., 1996). The distorted surface shape of a rutted pavement is a consequence of the permanent deformations present in each pavement layer and the subgrade. While some consensus exists on the definition and mechanisms that cause rutting, no universally accepted method to characterize and quantify rutting has been developed.

Other definitions do not include the association to wheel loads or wheel paths. For instance, the American Society for Testing and Materials (ASTM) defines a rut as "a contiguous longitudinal depression deviating from a surface plane defined by transverse cross slope and longitudinal profile" (ASTM E867-06). The most frequently used index to characterize rutting is rut depth, which is defined by ASTM as "the maximum measured perpendicular distance between the bottom surface of the straightedge and the contact area of the gage with the pavement surface at a specific location." This definition is used in the ASTM standard E1703 for measuring rut depth using a straightedge. The rut-depth index may also be obtained using a wire instead of a straightedge. These methods are described with more detail in the next section.

Simpson (2001) listed several rutting indices considered for use in the Long-Term Pavement Performance (LTPP) experiment, which may be grouped into area, depth, and width indices, and radius of curvature. The area indices were "Negative Area," "Positive Area," and "Fill Area." For the case of the rut depth and width indices, different indices were considered depending on whether they were measured using a 1.2 or a 1.8m straight-edge, or a wire line. Thus, examples of the postulated indices are "1.2-m rut depth" and "1.2-m rut width." That is, the indices are associated with the particular instrument.

Another depth index considered was the water depth. The radius of curvature of the rut was also considered by Simpson, although the author did not recommend the use of it due to "the difficulties in defining and calculating the index."

Figure 2.1 shows the illustration of some of the indices considered for use in the LTPP study. The thick line in each figure is the transverse profile of a rutted pavement and the thin line represents the wire line that connects the first and the last coordinate of the lane. Figure 2.1a illustrates the negative and positive area indices. Once the coordinates of the profile are obtained, it is possible to calculate the areas formed between the profile coordinates and the straight line connecting the end points. The areas below the straight line are defined as negative areas and the ones above the straight line are defined as positive areas. The "Negative Area" index is calculated as the sum of the negative areas and the "Positive Area" index is calculated as the sum of the positive ones. The "Fill Area" index is obtained by calculating the total area between the profile coordinates and the straight lines connecting the peaks of the profile. Figure 2.1b shows the "Fill Area" of the rutted surface in gray. Each area index provides a two-dimensional characterization of rutting. The negative and positive areas provide information about the severity of rutting and, according to Simpson (2001), may also potentially indicate the cause of the rutting. The "Fill Area" index may be used as an estimate of the amount of material necessary to repair the pavement. However, the researchers note that if the "Fill Area" was actually used to determine level up quantities and the ruts were filled as shown, the resulting pavement cross-slope would not conform to the standard practice of providing a uniform slope within the travel lane that drains to the outside shoulder or pavement edge. In the case shown, water would divide at the center of the lane and potentially drain to the left into the opposing lane and to the right and into the adjoining ditch. This condition was in fact encountered during manual data collection for this project.

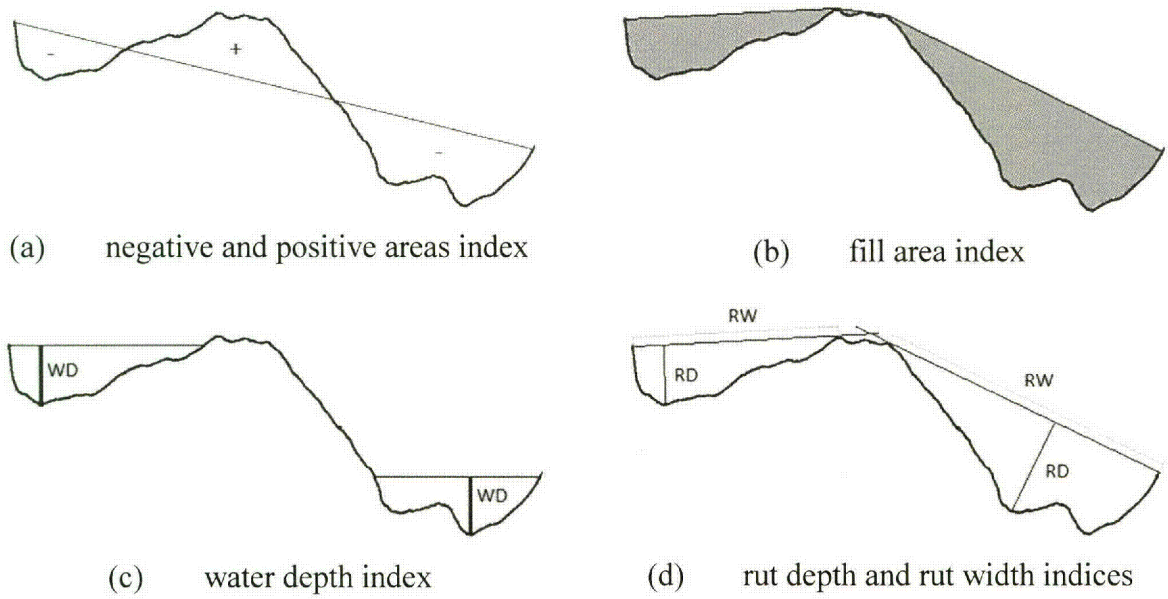


Figure 2.1: Illustration of some of the indices postulated in Simpson (2001)

The water depth index is illustrated in Figure 2.1c. Water may pool in the formed rut, reducing the pavement drainage capacity and increasing the potential for wet-weather accidents due to hydroplaning. As shown in the figure, this index is obtained for each wheel path as the maximum vertical distance (indicated in the figure as WD) between the profile coordinates and a horizontal line positioned at the maximum point at which water would pond. This index is not commonly calculated during rut data collection, possibly because not all automated systems currently measure the cross-slope of the pavement, which is required to calculate the index. In addition, ponding is dependent on longitudinal grade and whether a location is at the crest or sag of a vertical curve. Even if the rut depth was sufficient to pond water based on a two-dimensional analysis (depth and width), adding a third dimension—the longitudinal grade (elevation change)—might indicate that water would drain along the wheel path, which could minimize ponding. In any case, each location requires evaluation of these and other factors such as driveway locations, which can form a trough-like depression at the intersection point with the pavement lane, cross roadway intersection grades, etc., and other features necessary to determine ponding and hydroplaning potential.

The rut depth is the most frequently used index to characterize rutting. Figure 2.1d shows the rut depth and the rut width obtained for each wheel path of the rutted pavement. The rut depth is the maximum distance perpendicular to the straightedge or wire line, and the profile coordinates, whereas the rut width is defined as the distance between the points at which the straightedge of wire is supported. The straightedge and wire will provide the same information as long as the straightedge length is long enough to cover the same support points at the ends of the wheel path. Simpson (2001) disregarded the 1.2 m straightedge rut depth and width indices, indicating that a 1.8 m (6 ft) straightedge and wire line provide essentially the same information. In other studies, the rut depth was estimated perpendicular to the elevation datum instead of to the straightedge or wire line as shown in Figure 2.1d. Bennett et al. (2002) estimated the difference in magnitude for both cases, concluding that the difference is not significant for the range of rut depth commonly found. All the indices presented in the previous section require transverse profile point coordinates for the entire pavement lane width. In some cases, certain indices can be directly measured in the field.

2.2 Measurement of Rutting

Rutting data collection methods can be grouped into two main categories: manual and automated methods. This section is divided in two parts: the first part presents the most frequently used manual methods and the second part covers the different technologies developed for the automated measurements.

2.2.1 Manual methods

Manual methods were traditionally used for rut data collection until reliable automated methods were developed. Manual methods are also still used to establish the benchmark reference or "true" MRDs and transverse profiles for automated instrument evaluations or as the preferred option for agencies where rutting is not a major distress or agencies that have a low budget.

The most common method to directly measure the MRD of each wheel path uses either a straightedge or wire and a depth gage. The "wire string" method consists of stretching a wire from the extreme edges of the pavement lane perpendicular to the direction of traffic. The maximum distance is then measured between the wire and the pavement surface using a gage. For this reason, two people are required to stretch the wire at the extremes while a third operator measures the rut depth for each wheel path (Wang, 2005). The straightedge method uses a straightedge (such as a box beam carpenter's level) instead of a wire, and requires one operator to place the straightedge in the correct position in each wheel path and take depth readings using the gage. Although one operator is the minimum required, increased data collection rates can be achieved with two operators (one per wheel path). The measurements obtained by manual methods inevitably contain human error, which is expected to increase due to factors such as fatigue caused by extreme weather or extended physical activity. These methods are slow, tedious, and require traffic control, making them impractical when collecting data at the network level.

A more efficient approach for collecting rut data over long distances consists of an experienced surveyor visually determining the rutting level of every section. The surveyor travels the rating sections in a vehicle, either in the travel lane or along the paved shoulder. This eliminates the need for traffic control and speeds up the data collection process. The results from the visual inspection involve subjective human judgment, which affects the accuracy, repeatability, and reproducibility of the measurements. In addition, the time of day, position of the sun, weather conditions, and other factors can vary even along a single section of roadway and can affect the rater's judgments. Note also that although the survey process is considered a manual rut measurement method, it is not a "static" measurement because the rater is traveling along the roadway in a vehicle.

The static, manual methods described above allow for the direct measurement of the rut depth and, in some cases, a rut-width index as well. Other rutting indices require the collection of pavement transverse profile surface coordinates. Presently, automated rut measurement equipment operates at highway speeds and collects transverse profiles for further processing to obtain MRD measurements. Manual methods and equipment may also be used for calibrating the automated systems.

Traditionally pavement surface coordinates were collected using a rod and level. Other manual instruments such as the Face® Dipstick Road Profiler have been used for transverse profile measurements of the LTPP test sections, at test tracks and for various research projects (Simpson, 2001). The Dipstick consists of a rectangular enclosure housing the instrumentation that is attached to two measurement pads or "feet" on which the Dipstick rests. A vertical stick projects from the top of the box and is used by the operator to pivot the device from one measurement foot to the other following the line of the profile being measured. The instrument uses an inclinometer to calculate the elevation difference between the two measurement feet, obtaining the coordinates of the transverse profile along the entire width of the lane.

Some agencies use more advanced manual equipment for the measurement of transverse profiles. TxDOT owns a transverse profile beam developed for the Texas Mobile Load Simulator (MLS) accelerated pavement testing program. The MLS profiler was constructed over 20 years ago for TxDOT at an Austin machine shop by the proprietor, Mr. Robert Sieberg (Figure 2.2). This equipment requires an operator to roll a wheel over the pavement surface along a transverse line. The wheel is guided by a leveled beam and contains a linear variable differential transformer (LVDT) that measures the changes in elevation with respect to the reference plane for each horizontal coordinate. The system is connected to a computer that stores the measured coordinates of the transverse profile. Although the research team intended to use the MLS profiler for this study, a mechanical problem required development of a different system to measure transverse profiles.

Figure 2.2: MLS transverse profile beam used on IH 35 during an accident investigation

Several other manual profilers can also be found in the literature such as the Transverse Profile Beam (TPB) reference profiler" (Figure 2.3) commercialized by ROMDAS. These systems are generally similar in concept and usually are capable of collecting multiple points of the profile using sensors with high accuracy and resolution. These devices are typically designed for research or forensic level applications and, due to slow operation, are typically not used for network-level data collection.

Figure 2.3: ROMDAS "TPB reference profiler" [Henning 2006]

Straightedge Method

Manual straightedge rut measurement is a widely accepted standard rut measurement method. ASTM Standard E1703M-10, "Standard Test Method for Measuring Rut Depth of Pavement Surfaces Using a Straight Edge," is one among several standards used worldwide for conducting manual straightedge testing. The ASTM standard addresses direct measurement of the MRD at a given location using a straightedge and a gage (Figure 2.4).

Based on the standard, straightedge lengths may range from a minimum of 1.73 meters (5.67 ft) to 4.88 meters (16 ft) to ensure that the straightedge spans the two highest points on either side of the rut. The straightedge is placed on the pavement surface in a plane perpendicular to direction of traffic movement and the measurement is taken as the perpendicular distance between the bottom surface of the straightedge and the contact area of the gage with the pavement surface (Figure 2.5).

Figure 2.4: Straightedge and rut gage method field measurement

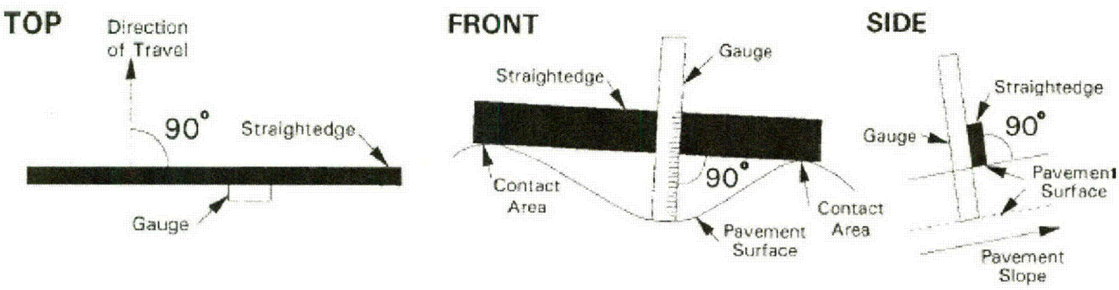


Figure 2.5: Straightedge Method (ASTM E1703)

It should be noted that although the standard shows a ruler-type rut gage, it does not specify the gage type, location of reference markings, or other features other than the gage width (0.75 to 3 in.) and the gage-pavement contact shape (which is rectangular). No specifics are provided in the standard or the accompanying figure to clarify which side of the gage is considered the "width" or whether the specified dimensions apply to both sides of the rectangular shape. This issue will be discussed in greater detail in the final project report.

2.2.2 Automated methods

Automated methods were developed with the objective of performing more accurate, repetitive, and fast collection of transverse profiles. Automated equipment measures the distance from the reference sensors to points on the pavement surface. Thus, by operating the survey vehicle at highway speeds that eliminate traffic interruptions, it is possible to obtain a transverse profile of the pavement that contains from 3 to over 1,500 profile coordinates depending on the type of equipment used.

Automated rut measurement systems are usually grouped into four categories according to the technology applied: ultrasonic, point laser, scanning lasers, and optical camera and laser systems. The first two system types generally collect from 3 to approximately 30 data points and are considered point-based "discrete" systems whereas the last two systems can collect up to approximately 1,500 data points per profile and are therefore considered continuous profile systems.

Ultrasonic and laser point-based "discrete" systems

Discrete systems use either ultrasonic or laser sensors, or a combination of both, to measure the distance to the pavement surface. The sensors are mounted within a hollow box beam (referred to as a "rut bar") usually mounted on the front of the survey vehicle. The number of sensors varies from the most basic configurations of 3 points—such as the Kansas Department of Transportation's South Dakota profilometer (Vedula et al., 2002) or the TxDOT 5-point ultrasonic sensor rut bar—to denser configurations of 28 points or more, such as the ROMDAS Transverse Profile Logger Ultrasonic Rut Bar (TPL-URB Spec Sheet) or the ARAN Smart Rutbar (ARAN Smart Rutbar Spec Sheet), shown in Figure 2.6. These systems typically require correction of the distance measurements from the sensor to the pavement surface considering temperature, humidity, and wind speed. These corrections are usually applied automatically while reporting the transverse profile of the road. In order to extend the width of the rut bar and provide additional sensor data points, some systems are fitted fold-out wings that can later be stowed to prevent accidents and potential damage to the system.

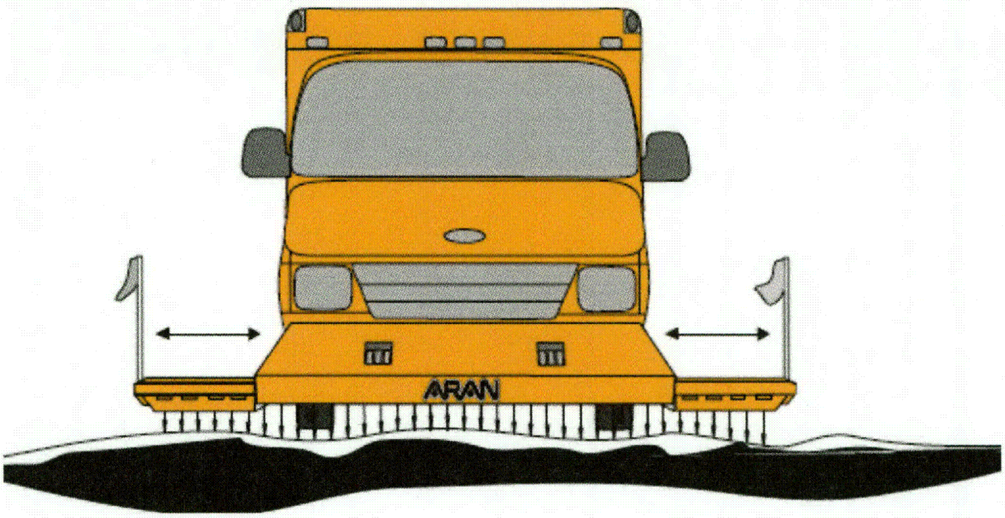


Figure 2.6: ARAN Smart Rutbar point-based discrete system

When measuring transverse profiles using equipment with three or five sensors, the only index estimated is the rut depth in each wheel path. For the case of three coordinates, the rut depth is estimated by an index defined as pseudo-ruts (Figure 2.7), which is calculated as the difference between the highest and lowest points on the transverse profile of the road. The high-point coordinate is estimated as the reading from the center sensor whereas the low-point coordinates are estimated as the reading taken from the sensors at the sides.

For the case of five coordinates, the rut depth may be calculated using the formula from AASHTO Standard R48-10, "Determining Rut Depth in Pavements" (AASHTO 2010). These formula include outer wheel path = $D_2 - \frac{D_1+M}{2}$ and inner wheel path = $D_4 - \frac{M+D_5}{2}$, where $M = \min(D_3, \frac{D_1+D_5}{2})$. The values of D_1 to D_5 are the measurements taken from the sensors, as indicated in Figure 2.8, obtained from AASHTO R48-10. The main problem with using three- or five-sensor systems is that these systems may underestimate the actual rut depth. For this type of equipment to produce accurate results, the position of the sensors should be close to the position of the maximum and minimum points of the each rut, as in the hypothetical case illustrated in Figure 2.9. Huang et al. (2009) estimated that the five-point system underestimates the rut depth value obtained manually by up to 40%.

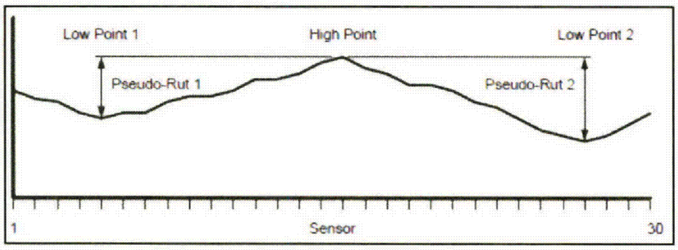


Figure 2.7: Definition of Pseudo-Ruts (Bennett et al., 2002)

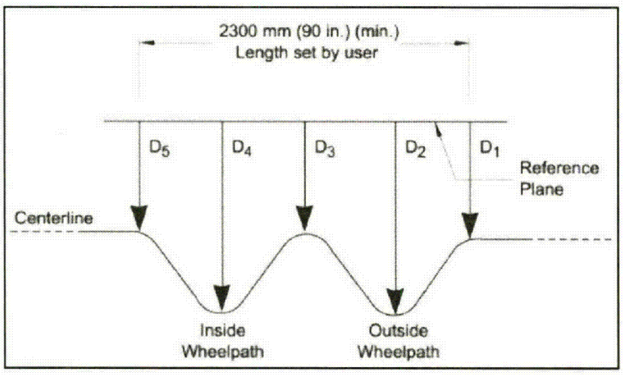


Figure 2.8: Determination of rut depths using five coordinates (AASHTO 2010)

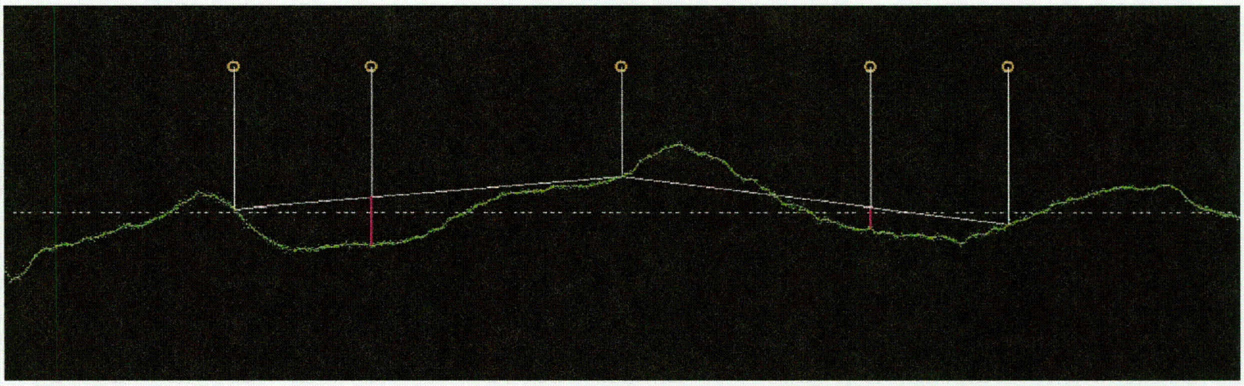


Figure 2.9: Underestimation of rut depth based on a five-point rut bar system (TxDOT 2009)

An increased number of sensors can produce a more accurate estimation of the actual rut depth and several systems with multiple sensor rut bars are commercially available. Increasing the number of sensors reduces sensor spacing; in the case of ultrasonic sensors, this reduction can result in signal interference. To avoid this problem, multiple sensor rut bar systems may collect measurements progressively along the road, as illustrated in Figure 2.10 (Bennett et al., 2002). Thus, the coordinates of the resulting measured profile are not from the same transverse location on the pavement but combine multiple segments from consecutive sensor firings collected as the vehicle travels along the route. The error introduced by this approach increases with vehicle speed and as the longitudinal profile segment locations spacing increases.

Laser sensors, on the other hand, are much faster than ultrasonic sensors and are not affected by signal interference from adjacent sensors, which allows for simultaneous firing. However, because ultrasonic sensors are less expensive than lasers, in practice ultrasonic systems usually contain a greater number of sensors.

Regarding the sampling effect on the accuracy of the measurements, Simpson (2001) concluded that when cubic splines are used to interpolate between the points, nine sensors can be used to represent the profile with sufficient accuracy for network-level applications. These points should be located such that they take measurements at 0, 305, 914, 1524, 1829, 2134, 2734, 3353, and 3658 mm (0, 1 ft, 3 ft, 5ft, 6 ft, 7 ft, 9 ft, 11 ft, and 13 ft) from the lane edge.

Another significant source of error in discrete system measurements is related to variations in lateral placement (wheel path wander) of the survey vehicle during data collection. If the survey vehicle runs the same section twice, the lateral placement of the vehicle during both runs will likely differ, resulting in variability in the measurements. Conversely, continuous systems are not affected by lateral placement of the survey vehicle.

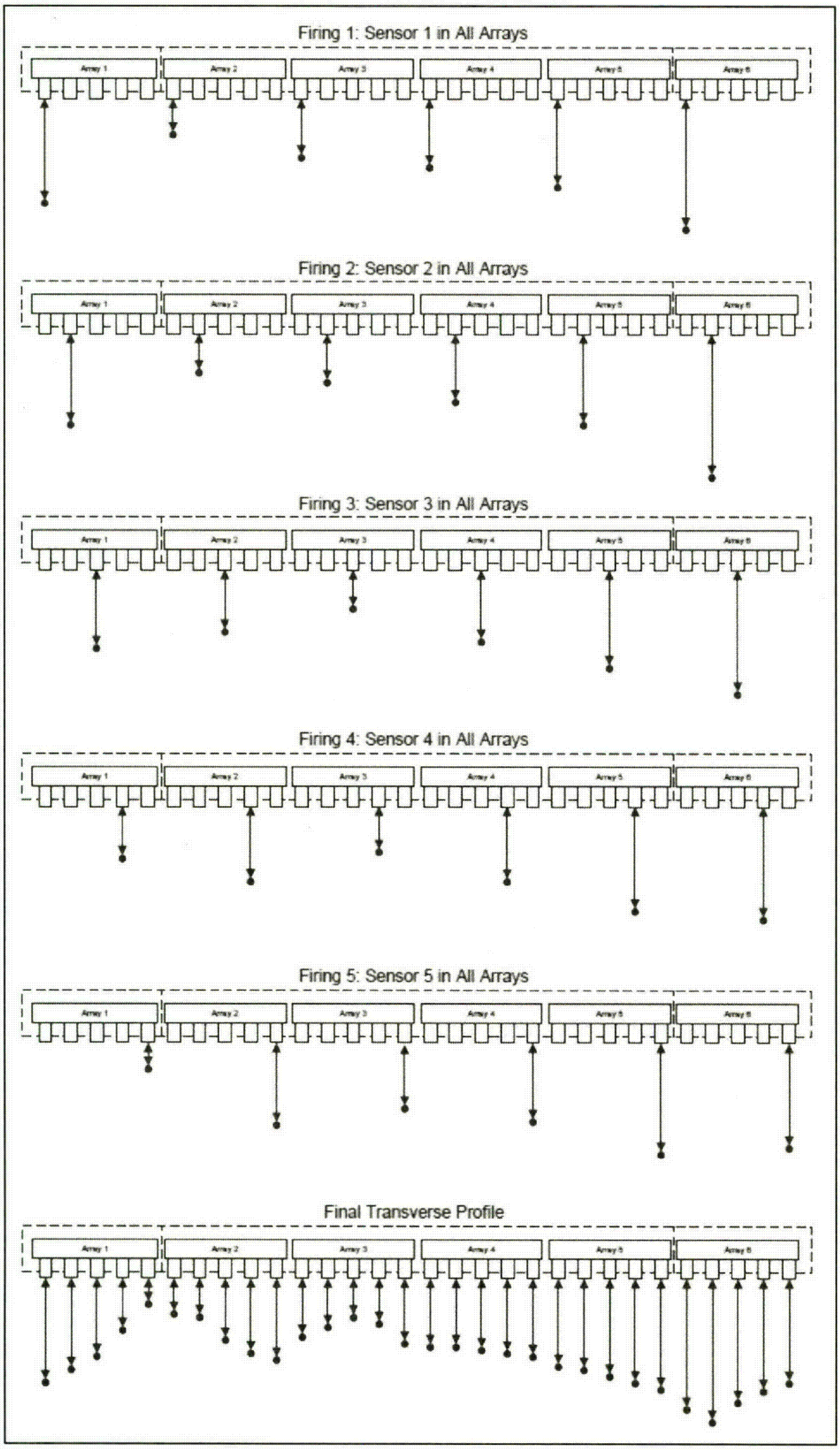


Figure 2.10: Sequential firing of ultrasonic sensors (Bennett et al., 2002)

The ROMDAS TPL-URB Spec Sheet provides an example ultrasonic rut bar system arrangement:

1) Sensor type: Ultrasonic
2) Scan rate: 100 Hz
3) Number of sensors: 28
4) Sensor spacing: 125 mm (5 inches)
5) Sensor resolution: +/- 0.2 mm (0.007 inches)
6) Standoff: 300 mm (approximately 1 ft)
7) Range: 250 mm (approximately 10 inches)
8) Dimensions: 2.2 m main housing with 2 x 0.6 m foldout extensions

The RoadSTAR transverse evenness measuring device (Wang, 2005) provides an example of a discrete laser rut bar system. The RoadSTAR system contains a fan-shaped measuring beam with 23 laser sensors (Figure 2.11). The laser sensors have an accuracy of 0.1 mm and the separation between sensors is 150 mm (approximately 6 inches). The fan shape of the sensor layout allows measurement of a 3.3 m (10.86 ft) wide profile, even though the beam is 2.5 m (8.23 ft) wide. According to Bennett (2002), laser systems are capable of measuring transverse profiles every 10 mm in the travelled direction, presenting an advantage when compared to the 1.0 (3.29 ft) or 2.0 (6.58 ft) meter sampling intervals of ultrasonic systems.

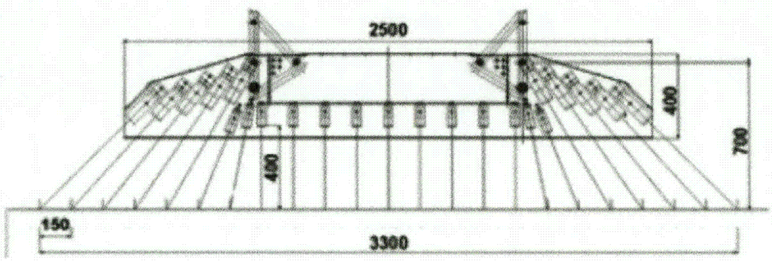


Figure 2.11: RoadSTAR fan-shaped measuring beam (Wang, 2005)

Optical systems

Optical systems for rutting measurement digitalize the transverse profile of the pavement using a laser and a 3D camera (not to be confused with a digital photographic camera). The methodology uses the same techniques often used to develop 3D images in industrial applications. A thin laser line is projected on top of the pavement surface while a camera captures the laser line at an angle (Figure 2.12). The captured image is digitized and then processed to obtain a continuous transverse profile of the road.

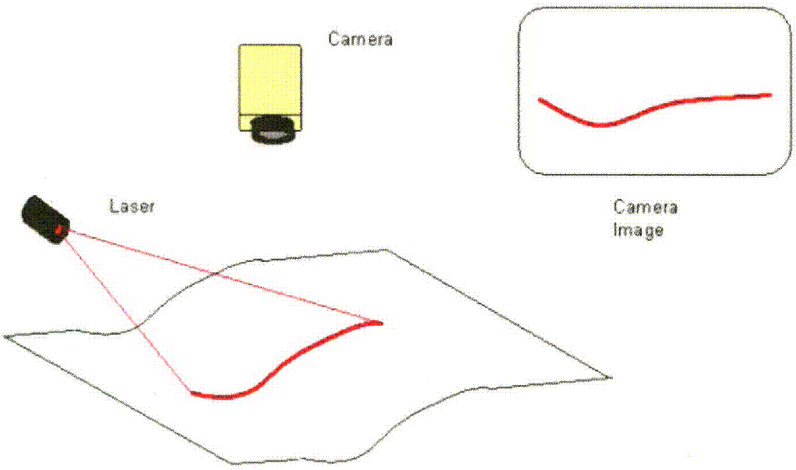


Figure 2.12: Optical system diagram (Wang, 2005)

Triangulation principles are used to calculate the shape of the pavement surface. Figure 2.13 illustrates the case in which the laser plane is projected vertically, where h is the elevation or depression of the pavement surface at a specific point; f is the focal length of the camera; C is the center of the camera; H and L are the respective vertical and horizontal distances of C from the intersection between the laser plane and the camera plane; and y is the distance h projected on the focal plane of the camera by the image. The values of H, L, and f are obtained during calibration. The angles θ and α are calculated as $\theta = \tan^{-1}(H/L)$ and $\alpha = \tan^{-1}(y/f)$. Lastly, $h = L\tan(\theta + \alpha) - H$. Thus, the transverse profile of the pavement section is obtained by calculating the value of h for each point of the digitalized laser line.

Note that the accuracy of the measurements can be affected by environmental factors like water spray on wet pavements. The accuracy of the systems depends on the precision, power, and quality of the laser line, because sunlight can influence the line image quality (sunlight energy may not be completely blocked in the filter system). The general design of the optic system and camera's resolution and performance can also impact the rutting data quality.

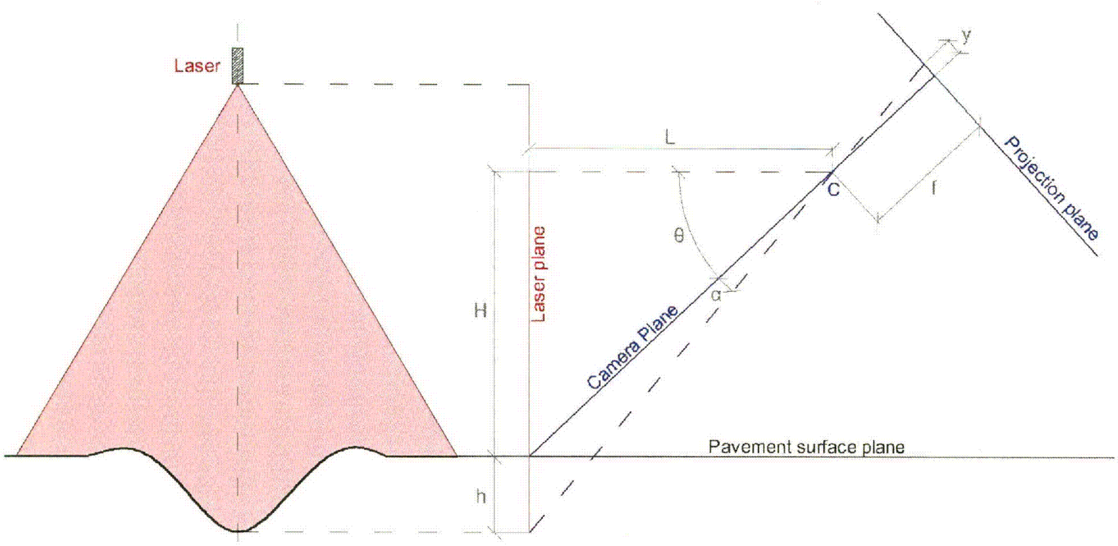


Figure 2.13: Triangulation principle diagram

Once the pavement profile is obtained, algorithms are applied to calculate the desired rutting indices. As the survey vehicle moves forward, the camera captures consecutive images of laser lines, which can also be used to compute a 3D representation of the pavement surface, as shown in Figure 2.14 (Li et al., 2009).

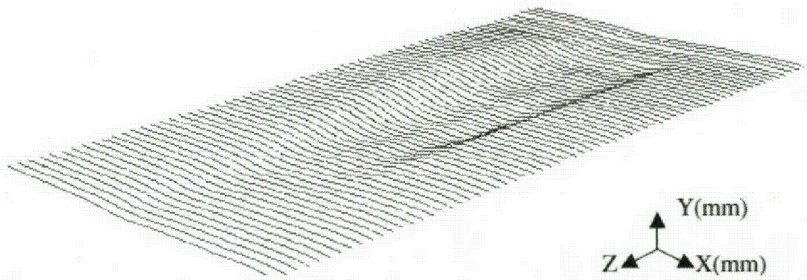


Figure 2.14: 3D Representation of the Pavement Surface (Li et al., 2009)

The INO LRMS is a commercially available rut measurement widely used by vendors and state agencies. The following section provides a brief description of INO LRMS and TxDOT VRUT systems.

INO LRMS and LCMS

In 2001, INO and the Ministry of Transportation of Quebec (Ministère des Transports du Québec) developed the LRMS system. In 2009 INO created Pavemetrics Systems Inc., which markets the INO LRMS as well as other INO products. The INO LRMS or LCMS hardware is used by several automated rut and visual distress data collection vendors such as Mandli Communications Inc., Dynatest, Fugro-Roadware, and Applus RTD in their data collection vehicles. The newer INO LCMS system can be used to obtain both crack and rut measurements. Regardless of the hardware system, however, each vendor uses their own algorithms to process the raw data and compute rut indices. Thus, different systems with the same hardware can produce different results for the same pavement section.

The INO LRMS consists of two profilometers that digitize the transverse pavement profile with 1,280 data points (Figure 2.15a). The two profilometer enclosures are mounted on either side of the rear of the vehicle (Figure 2.15b), and each one measures approximately half the width of the transverse section and overlap at the profile mid-point may occur depending on the installation. Each profilometer contains a laser and a camera that form the optical system. Custom optics and high-power pulsed laser line projectors allow the system to operate in full daylight or in nighttime conditions. The LRMS can acquire full 4-meter (13.16 ft) width profiles at normal traffic speeds, with two options of maximum sampling rate: 30 or 150 Hz.

The manufacturer provides these specifications (Pavemetrics INO LRMS):

1. Number of laser profiles: 2
2. Number of 3D points per profile (max): 1,280 points
3. Sampling rate: Standard (30 profiles/s) and High-Speed (150 profiles/s)
4. Vehicle speed: 0 to 100 km/h

5. Profile spacing: adjustable
6. Transversal field-of-view (nominal): 4 m (13 ft)
7. Transversal resolution: ±2 mm (0.08 inches)
8. Depth range of operation: 500 mm (@30 profiles/s) or 450 mm (@150 profiles/s)
9. Depth accuracy (nominal): ±1 mm (0.04 inches)
10. Laser profiler dimensions (approx.): 108 mm(W) x 692 mm(H) x 220 mm(D)
11. Laser profiler weight (approx.): 12 kg

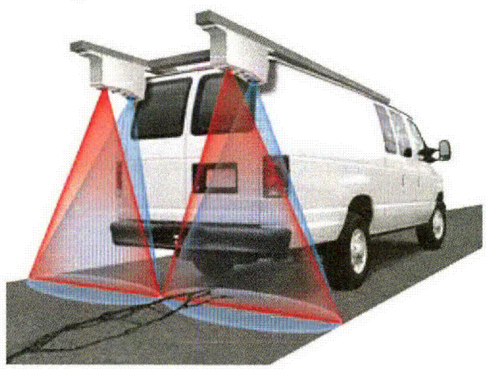
a) INO LRMS profilometer

b) INO LRMS mounted on vehicle

Figure 2.15: Pavemetrics INO LRMS

INO has also developed the LCMS, which, based on the specifications, is capable of collecting up to 4,160 points per transverse profile at highways speeds. As shown in Figure 2.16b, the INO LCMS projects the laser plane vertically onto the pavement surface compared to the LRMS, which projects the laser at a 20° angle with respect to the horizontal (Figure 2.13b).

a) INO LCMS profilometer



b) INO LCMS mounted on vehicle

Figure 2.16: Pavemetrics INO LCMS

The manufacturer provided the following specifications (Pavemetrics INO LCMS):

1. Number of laser profiles: 2
2. Number of 3D points per profile (max): 4,160
3. Sampling rate: 5,600 profiles/s
4. Vehicle speed: up to 100 km/h (62 mph)
5. Profile spacing: 5mm (0.2 inches) (adjustable)
6. Transversal field-of-view: 4 m (13 ft)
7. Transversal resolution: 1 mm (0.039 inches)
8. Depth range of operation: 250mm (adjustable)
9. Depth resolution: .5 mm; Laser profiler dimensions (approx.): 428mm (h) x 265mm (l) x 139mm (w)
10. Laser profiler weight (approx.): 10 kg

TxDOT VRUT 3D System

In 2009, TxDOT completed development of the 3D pavement surface image-based rut measurement system called VRUT. The VRUT 3D system is mounted on the rear of the survey vehicle (Figure 2.17). It consists of a metal enclosure containing a high-power infrared laser line projector and the high-speed 3D camera that form the optical system. The laser is projected vertically onto the pavement surface. Because the laser projector has a 90° fan angle, the measured width on the pavement will be equal to twice the height at which the laser projector is mounted.

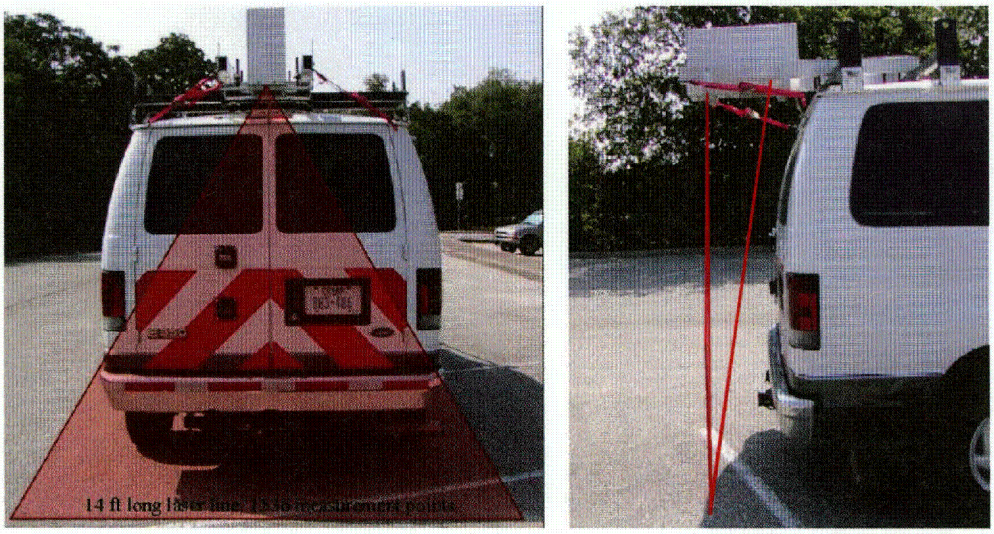
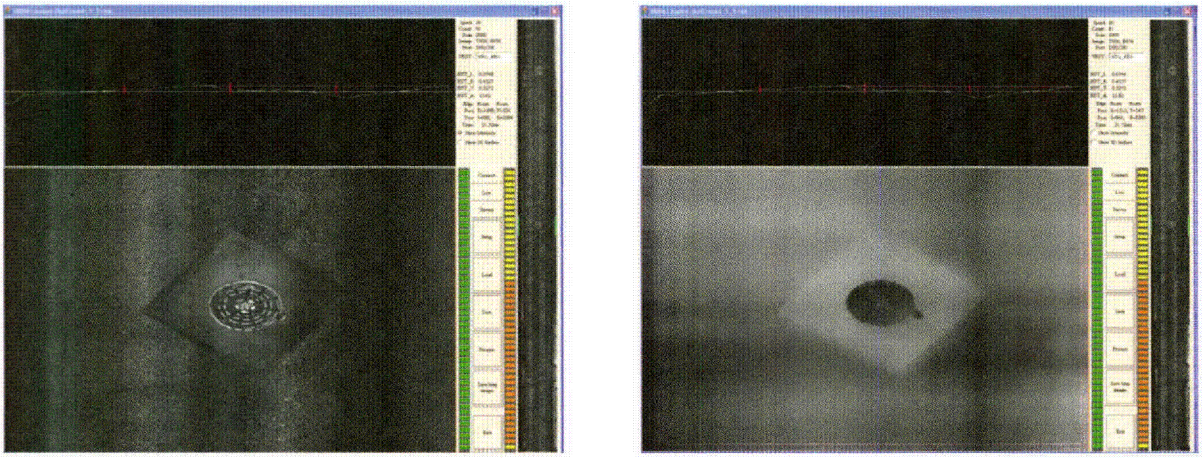


Figure 2.17: TxDOT VRUT 3D system mounted on survey vehicle (Huang et al., 2009)

Based on a TxDOT report (Huang et al., 2009), the Center of Gravity Algorithm (CGA) used in the camera "gives a final system height resolution sixteen times greater than traditional pixel level laser line detection methods." The camera can locate the laser line, capture the image, and perform the majority of the image processing steps before sending the data to the host computer, achieving a higher sampling rate compared to traditional optical systems.

The system software was developed in house by TxDOT personnel. Figure 2.18 shows the intensity image (on the left) and the range image (on the right), which are produced simultaneously by the 3D camera. The intensity image (Figure 2.18a) is useful for surface feature detection and currently it is processed only during rut data collection for lane stripe and sealed crack detection. The range image (depth image), shown in Figure 2.18b, represents the elevation changes on the pavement surface and is also used to detect the pavement edge, roadside vegetation, curbs, and other lane width limitation information (Huang et al., 2009).



a) Intensity Image Display b) Range Image Display

Figure 2.18: TxDOT VRUT 3D system principles (Huang et al., 2009)

Figure 2.19 shows a screen capture of a transverse profile measured by the VRUT 3D system, with an illustration of the rut depth calculation for each wheel path. The green points are the measured coordinates of the profile, the white lines are virtual straightedges, and the red lines are the MRD at each profile.

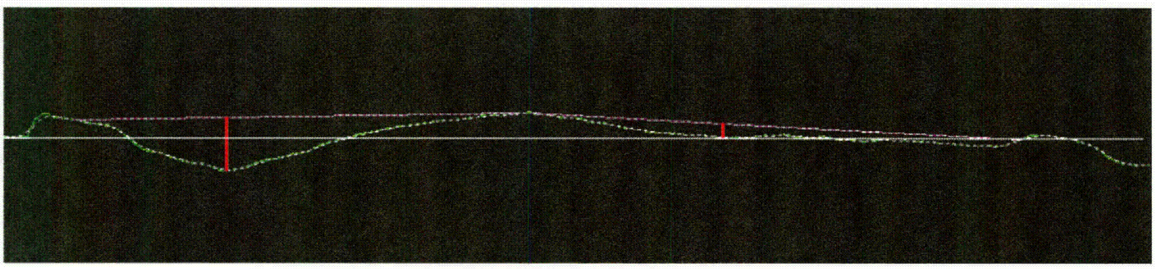


Figure 2.19: Transverse profile measured by the VRUT 3D system (Huang et al., 2009)

The TxDOT developers indicate that the accuracy of the system is not affected by the aggregate size due to the filtering effect of averaging 12 consecutive sample profiles. Selected VRUT system specifications include the following:

1. Number of laser profiles: 1
2. Number of 3D points per profile (max): 1,536
3. Vehicle speed: 10 to 70 mph (16 to 113km/h)
4. Height resolution: 0.03 inches (0.76 mm)
5. Transverse resolution: 0.11 inches (2.79 mm)
6. Longitudinal resolution: network level (1 inch); project level (adjustable)
7. Transversal field-of-view (nominal): 14 ft (4.27m)

Scanning lasers systems

Scanning lasers use Phase Measurement Laser Radar technology to measure the profile of a pavement. This technology consists of a laser sensor and a rotating polygonal mirror (Figure 2.20). The laser sensor consists of a transmitter and a detector to measure the distance to the pavement surface. The polygonal mirror changes the direction of the laser light while it rotates, measuring distances of consecutive points along a line. Thus, the scanner sweeps the profile of the pavement. These measurements are then sent to a computer that processes the data. Figure 2.20 shows a typical configuration of the scanner, which has a 90° field of view and, therefore, a scan line length equal to twice the polygon height.

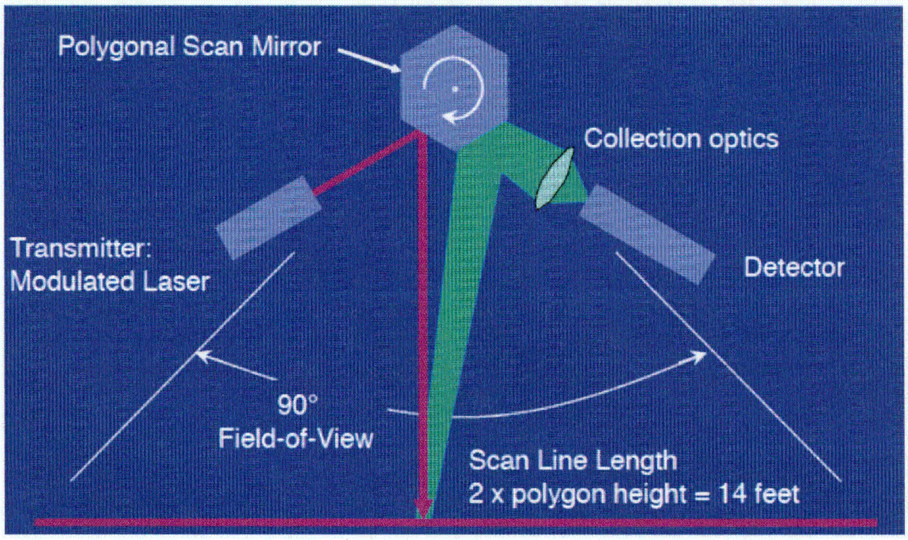


Figure 2.20: Scanning laser system scheme (Herr, 2001)

The orientation of the scanner plane of measurement will depend on the measurement desired (Figure 2.21). A transverse scanner will measure the transverse profile of the pavement, which is used for rut measurements. A longitudinal scanning might be used to calculate ride quality indexes such as the International Roughness Index (IRI) and Ride Number (RN).

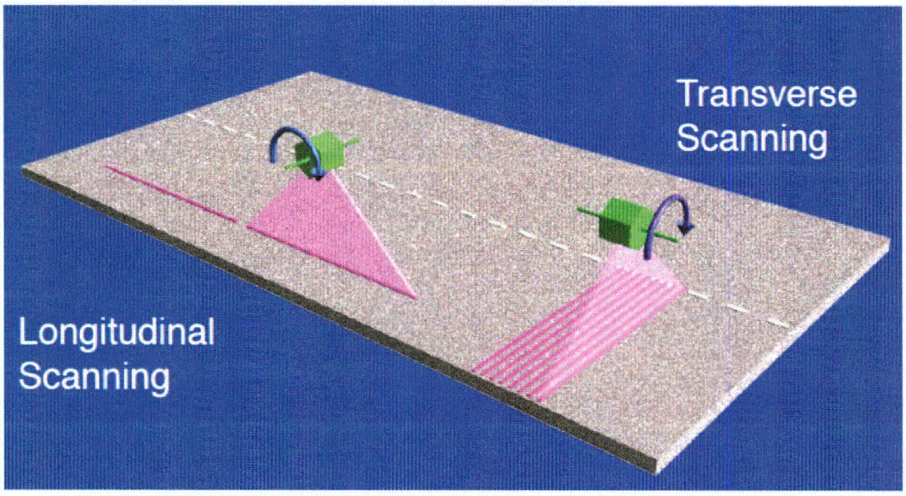


Figure 2.21: Scan orientation (Herr, 2001)

PSI Pavement Profile Scanner (PPS)

Phoenix Scientific Inc. (PSI) originally developed the Pavement Profile Scanner (PPS) for the Rolling Wheel Deflectometer (RWD), which was later adapted for obtaining pavement condition data such as rut and ride indexes. The PSI PPS scanner is mounted on the rear of the survey vehicle (Figure 2.22) at a height of at least half of the width that is needed to be measured. Mounted at 2.15 meters above the pavement, PPS measures a profile 4.3 meters wide in 0.75 milliseconds. The system takes 943 measurements per transverse profile spaced at a constant angle from the polygon, which are then converted to two-dimensional coordinates. The number and separation of points can be specified by the operator (PSI PPS White Paper, 2004).

Figure 2.22: PSI PPS scanner mounted on survey vehicle (Herr, 2009)

Following are the PPS 2005 specifications (PSI PPS-2005 Specifications):

1. **Data Rates and Structure:**
    a. Scan Rate (scan/second): 1,000 Hz
    b. Scan Separation, at 100 km/h: 2.8 cm
    c. Points per scan: 944 pts.
    d. Time per scan: 750 μsec
    e. Sample Rate: 1,258 MSPS
    f. Point spacing: center/average/edge 3.8/4.8/7.2 mm.
2. **Scan coverage**
    a. Field of view: ±45°
    b. Scan width: polygon centered at 2.15 m: 4.3 m
3. **Scan accuracy**
    a. Spot/line width, cross scan: 22 mm
    b. Spot width, along scan, instantaneous: 7 mm
    c. Precision, center/average/edge of scan (std. dev.): 0.07/0.15/0.25 mm
    d. Bias, overall: maximum/nominal average ±0.50/0.00 mm
4. **Mechanical**
    a. Scanner Dimensions: 47 (H) x 51 (D) x 69 (W) cm
    b. Scanner Weight: 54 Kg

2.3 Summary

The researchers conducted a thorough literature review that provides information about the state of the practice in automated transverse profile/rut measurements systems, which can be sub-divided into discrete point or continuous systems. The objective of the Phase I research study is to evaluate and compare the accuracy and precision of the TxDOT 3D optical system and vendor systems, which also provide continuous transverse profile data.

The literature review provided the researchers with information about the strengths and potential weaknesses of each system type when conducting transverse profile measurements on the range of pavement conditions found in Texas. Chapter 3 will discuss development of the experimental design, including the factors used to select sections and additional features that might challenge automated rut measurements systems to accurately measure a range of rut depths.

Based on the literature review and contacts with several vendors that provide network-level rut measurement data services for the majority of state Departments of Transportation, a list of potential study participants was prepared. This list was reviewed with the TxDOT Project Monitoring Committee to discuss how to proceed with invitations to participate in the field data collection (which will be discussed in Chapter 4). Due to a limited budget, the research team determined that all vendors who met minimum qualifications discussed in Chapter 1 would be invited to participate with the understanding that the available funds would be shared equally among the vendors.

Chapter 3. Experimental Design

3.1 Introduction

This chapter discusses the development of the experimental design for the evaluation of pavement rutting. The experimental design was developed to consider three primary variables identified by the research team after considering a large number of variables that affect rutting and its measurement. These primary variables are surface texture, lane width, and level of surface rutting. Due to a limitation in the number of test sections, including every different flexible pavement type encountered on Texas highways was not possible. The experiment did include a range of pavement factors and distress conditions that represent common conditions on Texas roadways as well as features typically problematic for automated rutting surveys. This chapter consists of two parts: 1) the determination of the critical variables that affect rutting measurements and how these variables are incorporated into the experimental design and (2) the development of the experimental design of test sections that achieves a representative sample of the Texas roadway network. Details of the rationale behind the selection of test sections, section location along with photographs, and summary statistics are presented in the next sections.

3.2 Experimental Variables

The primary objective of this research project was the evaluation of technologies that measure rutting and distresses and the assessment of their accuracy and reliability. Automated systems operating at highway speeds and static measurements were used for collecting rutting data on a range of different pavement surfaces representative of the Texas roadway network. In the Phase I study, a factorial experiment was developed to test different pavements including those with hot-mix asphalt surfaces and surface treatments that represent both coarse and fine pavement textures. Concrete pavements were initially considered for inclusion in the study to provide a baseline pavement condition of one or more pavements with no rutting and to evaluate how automated equipment would characterize concrete pavement tining and other concrete surface texture characteristics. However, due to the limited number of sections available in the study and safety concerns regarding manual collection on high-speed, high-volume concrete pavements in Austin, concrete sections were not included in the experiment. The accuracy and precision of the transverse profile and MRD measurements collected by the TxDOT and vendor automated systems were evaluated by comparing each set of results to the static measurements obtained by the researchers on the experimental sections. During Phase II, equipment for measuring various types of distresses will be evaluated. In this report, the focus will be rut and transverse profile measurements.

Prior to the selection of the experimental sections and the field measurements, the research team determined the critical variables that can affect rutting measurements. The variables that were considered are listed here.

1) Pavement surface type (asphalt concrete, surface treatment, cold mix patches)
2) Surface texture (coarse or fine)
3) Changes in surface texture within a single test section
4) Extreme changes in pavement surface color (light/dark) within a single test section
5) Pavement/lane width (wide 12 ft or narrow 9–11 ft)

6) Facility type (IH, US, SH, or FM road)
7) Level of rutting (i.e., No Rut, Shallow, Deep, Severe, and Failure)
8) Shoulder type (paved, unpaved)
9) Variable lane striping conditions (single dashed, solid double yellow, with/without edge stripe, etc.)
10) Wide versus narrow ruts
11) Presence of other distresses in addition to rutting on a single test section
12) Presence of longitudinal joints
13) Edge conditions including drop-offs, lane widening, or ragged (variable) lane edges
14) Horizontal curve or tangent section and associated cross slope transitions
15) Vertical crest or sag curves
16) Positive/negative grade
17) Presence of grass and vegetation at the pavement edge
18) Presence of utilities (i.e., man hole covers)
19) Variable or localized rutting within a section
20) Other anomalies: e.g., the effect of channelized traffic in narrow lanes, which produces rutting on the centerline; dual track in one wheel path from dual truck tires, etc.

In Phase I, the researchers focused on flexible pavements (hot mix asphalt [HMA] surfaces and surface treatment) because these constitute approximately 94% of the roadway network and rutting is a distress that occurs on these pavement types.

3.3 Test Section

3.3.1 Experimental Design

The selection of test sections was based on two main considerations: 1) meeting the goals of the experiment design, and 2) minimizing travel distance between sections so the automated equipment data could be collected within one working day. The research team visited and took photographs of specific roadway sections that exhibited different rutting severities, surface textures, asphalt mix types, combinations of rutting and other distresses, roadway geometric features, and other factors. In addition, the research team carefully considered all experimental variables described in Section 3.2 in the selection procedure.

The original plan of the experimental design was to identify 15 sections to cover the basic experimental design plus an additional 5 sections to address particular cases or anomalies. Thus, for the Phase I experiment, 20 sections were initially proposed to be evaluated. The final experiment involved field data collection on 26 sections of which 24 were included in the comparative analysis. The first two sections, Sections 1 and 2, FM 1660-1 and FM 1466, were later discarded because they were rehabilitated by the District. Therefore, the research team added two more sections that included severe to failure rutting and horizontal and vertical (crest) curves.

The research team sought to distribute the level of rutting in the selection of test sections. That is, we attempted to include sections with all levels of rutting based on TxDOT PMIS definitions. The 24 test sections were evaluated using the two static measurement systems, including 1) manual measurement with a 6-ft straightedge to obtain MRDs in the inside and outside wheel paths, and 2) manual measurement of transverse profiles with a Leica laser system. The manual measurements were conducted using pre-determined stationing format for each 550 ft long test section. The test section was marked using spray paint along the pavement center line on 5-ft intervals with a number station placed every 25 ft. Thus, 6-ft straightedge measurements were performed at 5-ft intervals along both inside and outside wheel paths, while the Leica laser measurement was performed at 25-ft intervals. Details of these two rutting measurements are described in Section 3.4.

3.3.2 Site Description

This section describes each site, including location, roadway geometry, shoulder characteristics, rutting severity, and other relevant conditions, along with photographs providing more details of the experimental variables. As mentioned previously, the selection of test sections was designed to minimize the travel time so that the automatic data collection could be completed in one day. The general location map that encompasses the experimental sections is shown in Figure 3.1.

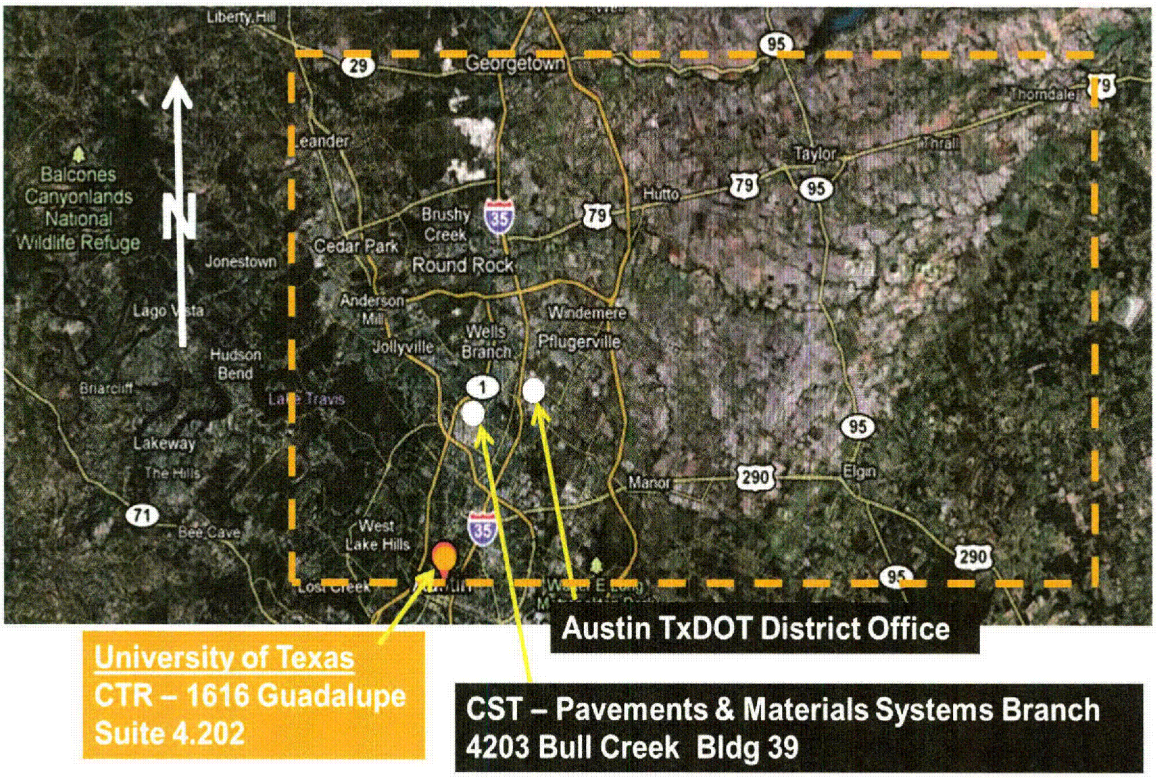


Figure 3.1: General location of test section for rutting measurement

During the visit to the different sites, the researchers took notes of the main characteristics of each section. The description of each test section is summarized below. In addition, the photographs of Sections 1 through 26 are presented in Figures 3.2 through 3.27, respectively.

(1) FM 1660-1: Section 1, later discarded due to rehabilitation

- coarse texture
- narrow lane width
- variation in rut depths, extensive sealed and unsealed wide cracks
- significant amount of sealed cracks (longitudinal and alligator)
- no shoulder and with grass encroachment
- tangent section
- patching
- variation in surface coloration
- solid yellow line on proposed test section side
- no pavement edge stripe

(2) FM 1466: Section 2, later discarded due to rehabilitation

- coarse texture
- narrow lane width
- variation in rut depths, extensive sealed and unsealed wide cracks
- no shoulder and edge drop-offs/edge failures
- severe surface condition (e.g., longitudinal cracking), unsealed cracks, variable edge demarcation
- tangent section
- short crest vertical curve with relatively steep grades
- double yellow center line stripe, no edge stripe

(3) US 79-1: Section 3

- HMA pavement (coarse texture) with several patches (fine to intermediate texture) with different shapes and locations
- wide lane (12 ft) and paved shoulder (11 ft)
- variation in rutting but primarily shallow
- elevation differences between patching and original pavement surface creates depressions that could be identified as ruts by automated equipment
- slightly uphill (positive grade) and horizontal curve
- dashed white centerline strip and solid edge stripe

(4) US 79-2: Section 4

- PFC surface: coarse (open) texture surface
- wide lane (12 ft, 2 in.) and wide shoulder (9 ft, 8 in.)
- new construction, little or no rutting, no cracking on the surface
- uniform dark surface
- rumble strip near lane edge
- tangent section with flat grade
- dashed white center line stripe with solid edge stripe

(5) FM 696 -1: Section 5

- seal coat of intermediate to coarse texture surface
- narrow lane (10 ft) and no shoulder
- uniform lane width
- edge condition good, little or no vegetative encroachment
- no major surface distresses, some bleeding and rutting along wheel paths, unsealed cracks (longitudinal)
- tangent section with flat grade

(6) FM 619-1: Section 6

- seal coat with coarse texture surface
- narrow lane (9 ft, 6 in.) and narrow shoulder
- primarily shallow rutting with no major distresses on the surface
- unusual cross slope condition with peak (roof top section) at mid lane
- relatively recent rehabilitation, uniform surface coloration
- no vegetative encroachment
- tangent section with flat grade
- double yellow center line stripe, solid white edge stripe

(7) FM 696-2: Section 7

- seal coat (coarse texture surface)
- narrow lane (10 ft, 2 in.) and narrow shoulder (2 ft)
- variable no rutting to shallow rutting
- no patches or cracks but some flushing along wheel paths (smooth texture)
- relatively flat, left hand horizontal curve

- relatively flat positive grade
- double yellow centerline stripe with solid white edge stripe

(8) FM 619-2: Section 8

- seal coat with coarse texture and patches with fine texture
- narrow lane varies (10 ft to 10 ft, 8 in.) with localized widening due to maintenance repairs
- variable rut depths but no severe or failure ruts
- no shoulder
- no major surface distresses
- localized vegetative encroachment at lane edge
- tangent section with flat grade
- double yellow center line strip, no edge stripe

(9) FM 619-3: Section 9

- seal coat (coarse texture) but some flushing along the wheel paths
- narrow lane (9 ft, 7 in.) and no shoulder
- variable rutting—however, no severe or failure rutting
- tangent section with slight positive grade
- no major surface cracks
- dashed yellow center line stripe, no edge stripe

(10) FM 619-4: Section 10

- seal coat (coarse texture) with flushing along the wheel paths
- narrow lane (9 ft, 7 in.) and no shoulder—but base-crown widening with trough
- variable rut depths
- little or no visual distress other than flushing
- slight positive grade
- tangent section
- double yellow center line stripe, no edge stripe

(11) FM 619-5: Section 11

- seal coat (coarse texture) with two major patches with fine texture
- narrow lane (width varies from 9 ft, 8 in. to 10 ft, 4 in.), no shoulder

- variable rutting including severe and failure
- localized patches and extensive sealed and unsealed longitudinal cracks
- localized flushing
- raveling along the lane centerline
- grass encroachment
- sharp, right-hand horizontal curve
- crest vertical curve with gentle grades
- double yellow center line stripe, no edge stripe

(12) FM 1063-1: Section 12

- surface treatment (coarse texture)
- intermediate lane width (11 ft) and no shoulder
- variable rutting including severe and failure ruts and wide ruts > 6 ft
- wheel paths shifted, outside wheel path in lane center, inside wheel path on center line
- roughness due to swelling clay, edge drop-off, several sealed and unsealed longitudinal cracks
- double yellow center line stripe, no edge stripe
- relatively flat right hand horizontal curve
- shallow sag vertical curve
- section start point just beyond a narrow load zoned bridge

(13) FM 1063-2: Section 13

- surface treatment with coarse texture
- narrow lane (10 ft) and no shoulder
- variable rutting including severe rutting along outer wheel path,
- sealed longitudinal cracks,
- grass encroachment,
- tangent section with flat grade,
- double yellow stripe with no edge stripe.

(14) FM 1660-2: Section 14

- coarse surface treatment (original pavement) with intermediate to coarse texture surface
- recently rehabilitated with maintenance fine texture HMA patches from Sta. 0 to Sta. 260
- wide lane (11 ft, 9 in.)
- no rutting on rehabilitated section, deep to severe rutting on untreated section
- curb and gutter (gutter width 1 ft, 5 in.)
- tangent section with relatively flat grade
- urban area (speed limit 30 mph)
- non-standard double yellow center line stripe, no edge stripe

(15) FM 112-1: Section 15

- seal coat (coarse texture) with severe flushing along the wheel paths
- narrow lane (widths vary from 9 to 10 ft)
- deep, severe and failure rutting in outside wheel path, shallow to deep rutting inside wheel path
- no shoulder—but base crown widening of variable width with grass encroachment
- extensive sealed longitudinal cracks
- sharp left-hand horizontal curve
- gentle positive grade
- double yellow centerline stripe and solid white edge line stripe

(16) FM 696-3: Section 16

- surface texture transition:
  - 0–300 ft: seal coat: coarse texture surface
  - 300–550 ft: HMA: fine texture surface
- lane width = 10 ft, 10 in.
- good condition, no surface crack and no significant rutting
- wide shoulder (10 ft)
- sag vertical curve
- left-hand horizontal curve with moderate grades
- double yellow centerline stripe and solid white edge stripe (variable width)

(17) FM 696-4: Section 17

- Variable surface texture including Type D ACP, coarse seal and fine texture full-width maintenance patch
- lane width varies (from 10 ft, 10 in. to 11 ft, 7 in.)
- variable rutting from no to shallow
- good condition, no surface distresses
- joint line between patch and original surface creates a trough that could be identified as a rut
- wide shoulder (10 ft)
- tangent section straight path with gentle positive grade
- variable centerline stripe includes solid yellow/dashed on test section side and a transition zone with three stripes; solid white edge stripe

(18) FM 973: Section 18

- new, dense hot mix asphalt with fine texture
- wide lane (12 ft) and wide paved shoulder
- no or localized shallow rutting
- no patches, no significant distresses, some sealed longitudinal cracks along the edge
- left-hand horizontal curve
- moderate negative grade
- dashed white centerline stripe and solid white edge stripe
- construction joint within lane creates a "v-notch" feature that could be identified as a rut

(19) FM 619-6: Section 19

- seal coat with coarse texture
- lane width varies (from 10 ft, 11 in. to 11 ft, 10 in.)
- variable rutting including deep, severe and localized failure
- no shoulder—but variable width base crown widening
- wheel path shifted with inside wheel path rut on top of centerline stripe
- longitudinal cracks including wide, failure cracks
- adjacent to Section 20
- tangent section with relatively flat grade
- dashed yellow center line stripe, no edge stripe

(20) FM 619-7: Section 20

- seal coat with coarse texture
- lane width varies (from 10 ft, 11 in. to 11 ft, 10 in.)
- variable rutting including deep, severe and localized failure
- no shoulder—but variable width base crown widening
- wheel path shifted with inside wheel path rut on top of centerline stripe
- longitudinal sealed cracks
- adjacent to Section 19
- tangent section with relatively flat grade
- dashed yellow center line stripe, no edge stripe

(21) US79-3: Section 21

- coarse texture PFC hot mix
- lane width = 11 ft, 3 in. and shoulder width = 10 ft, 10 in.
- new construction, no rutting
- immediately precedes Section 22
- gentle left-hand horizontal curve
- relatively flat grade
- good condition no surface distresses
- solid white dashed center line stripe, solid white edge stripe
- milled rumble strip along shoulder

(22) US79-4: Section 22

- dense graded, fine textured hot mix
- lane width = 11 ft, 3 in. and shoulder width = 10 ft, 10 in.
- new construction, no rutting
- immediately follows Section 21
- gentle left-hand horizontal curve
- relatively flat grade
- good condition no surface distresses
- solid white dashed center line stripe, solid white edge stripe
- milled rumble strip along shoulder

(23) FM1063-3: Section 23

- seal coat with coarse texture
- lane width varies (from 10 ft, 9 in. to 10 ft, 0 in.)
- variable rutting including deep, severe and localized failure
- no shoulder
- sealed and unsealed longitudinal cracks
- tangent section and relatively steep positive grade
- immediately adjacent to Section 24
- double yellow centerline stripe, no edge stripe

(24) FM1063-4: Section 24

- seal coat with coarse texture
- lane width varies (from 10 ft, 9 in. to 10 ft, 0 in.)
- variable rutting including deep, severe and localized failure
- no shoulder
- sealed and unsealed longitudinal cracks
- tangent section and relatively steep negative grade
- immediately adjacent to Section 23
- double yellow centerline stripe, no edge stripe

(25) FM112-2: Section 25

- coarse surface treatment with extensive fine texture hot mix patches
- lane width varies (from 10 ft, 4 in. to 11 ft, 3 in.)
- variable deep, severe and failure rutting
- immediately adjacent to Section 25
- wheel paths shifted, toward centerline, deep failure rutting with longitudinal cracking along lane centerline
- no shoulder, variable width base widening and edge patches
- roughness, extensive sealed and unsealed longitudinal cracks
- sharp right-hand horizontal curve
- crest vertical curve moderate grades
- double yellow centerline stripe, no edge stripe

(26) FM112-3: Section 26

- coarse surface treatment with extensive fine texture hot mix patches
- lane width varies (from 10 ft, 4 in. to 11 ft, 3 in.)
- variable deep, severe and failure rutting
- immediately adjacent to Section 26
- wheel paths shifted, toward centerline
- roughness, sealed and unsealed longitudinal cracks
- no shoulder, variable width base widening and edge patches
- sharp left-hand horizontal curve
- crest vertical curve moderate grades
- double yellow centerline stripe, no edge stripe

Figure 3.2: Section 1: FM 1660-1

Figure 3.3: Section 2: FM 1466

Figure 3.4: Section 3: US 79 Bypass

Figure 3.5: Section 4: US 79

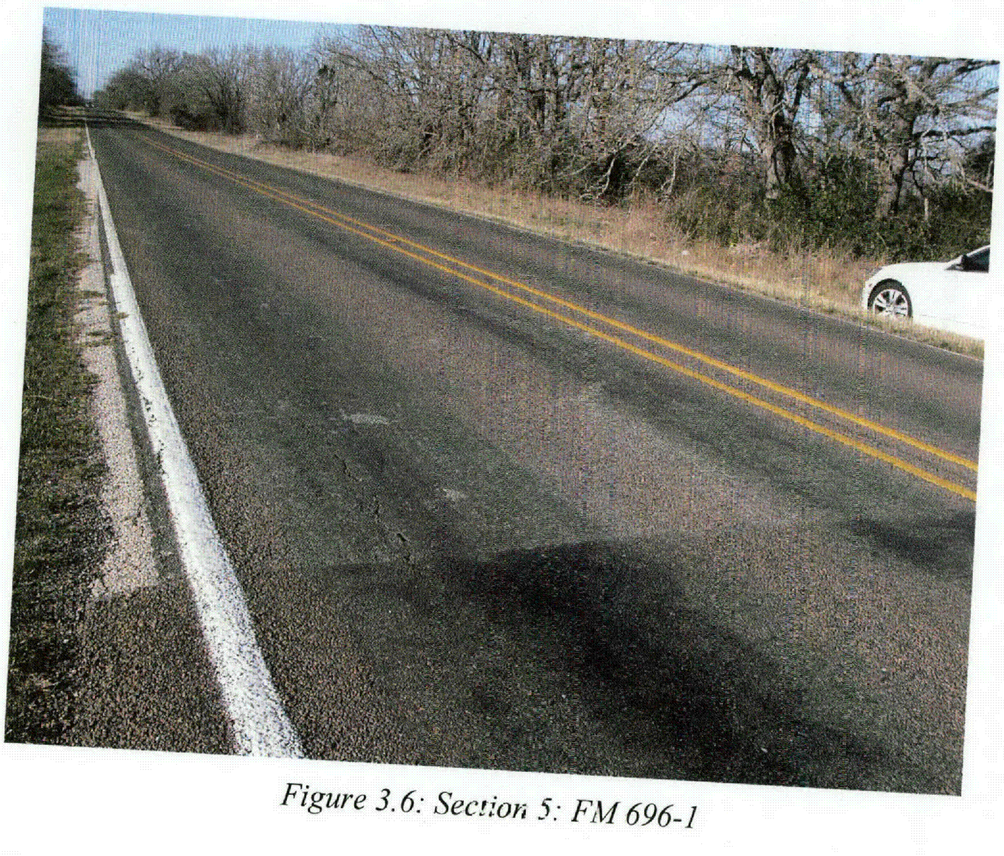


Figure 3.6: Section 5: FM 696-1

Figure 3.7: Section 6: FM 619-1

Figure 3.8: Section 7: FM 696-2

Figure 3.9: Section 8: FM 619 -2

Figure 3.10: Section 9: FM 619-3

Figure 3.11: Section 10: FM 619-4

Figure 3.12: Section 11: FM 619-5-HC

Figure 3.13: Section 12: FM1063-1

Figure 3.14: Section 13: FM 1063-2

Figure 3.15: Section 14: FM 1660-2

Figure 3.16: Section 15: FM 112-1

Figure 3.17: Section 16: FM 696-3

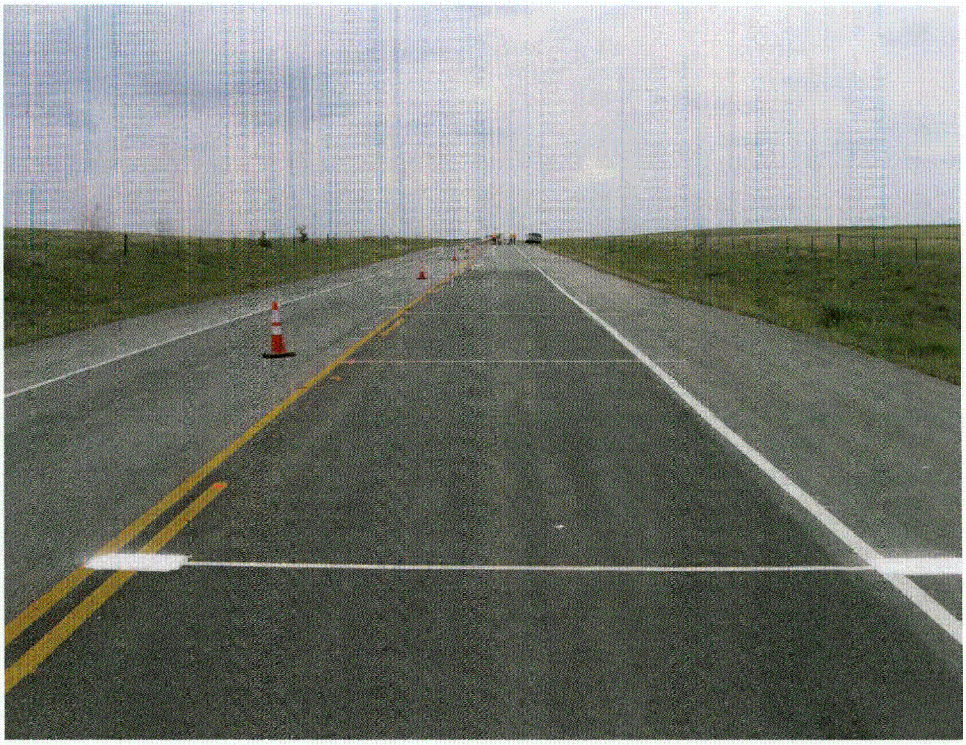


Figure 3.18: Section 17: FM 696-4

Figure 3.19: Section 18: FM 973

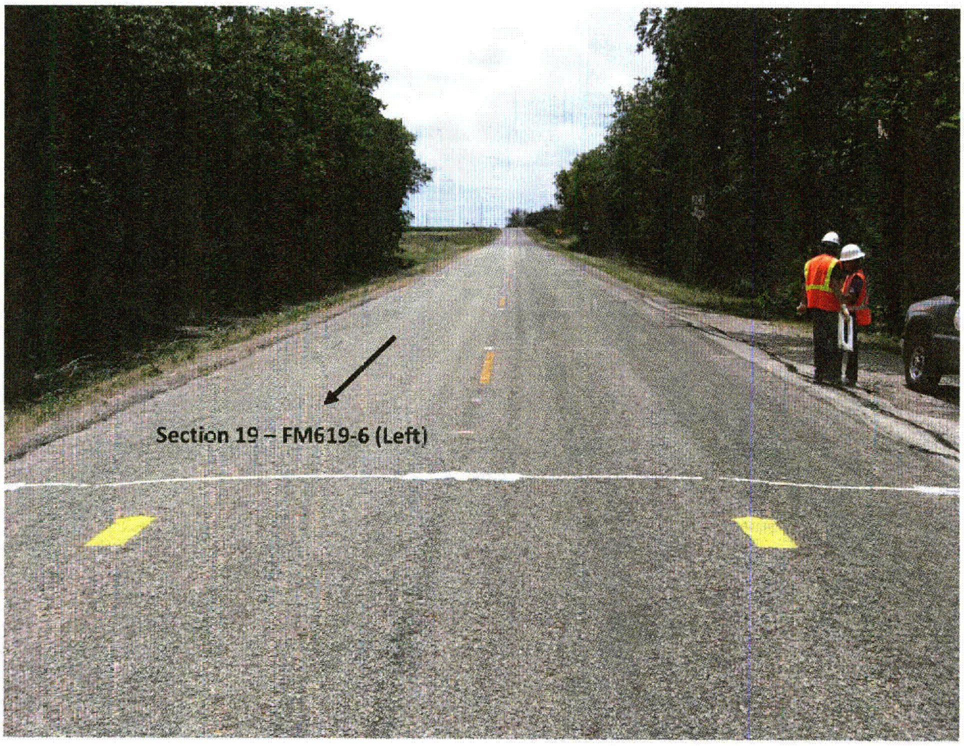


Figure 3.20: Section 19: FM 619-6

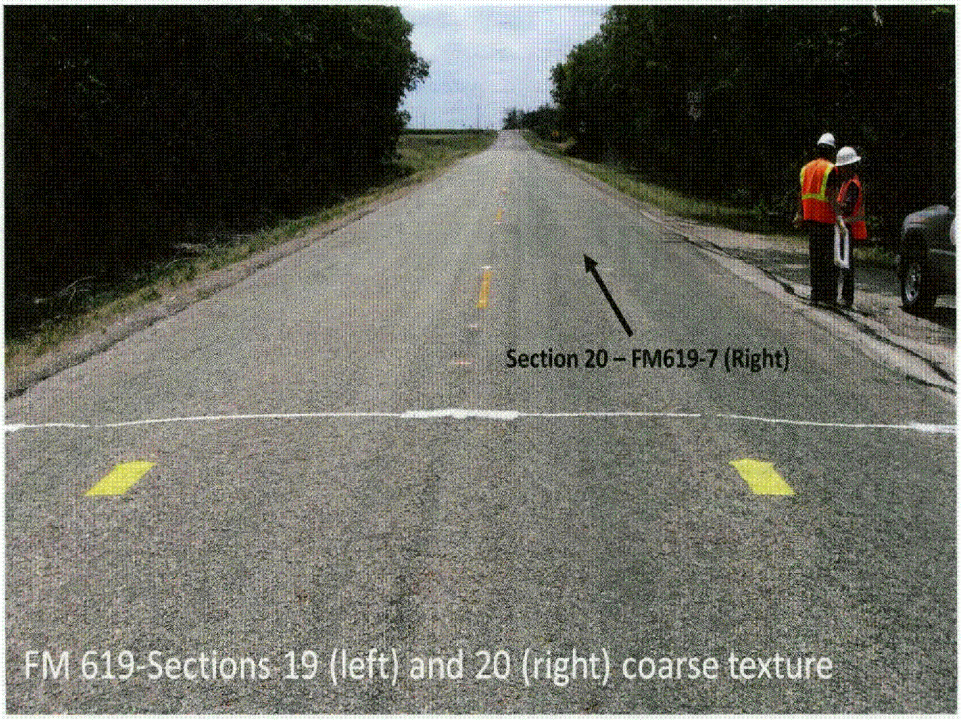


Figure 3.21: Section 20: FM 619-7

Figure 3.22: Section 21: US 79-3

Figure 3.23: Section 22: US 79-4

Figure 3.24: Section 23: FM 1063-3

Figure 3.25: Section 24: FM 1063-4

Figure 3.26: Section 25: FM 112-2

Figure 3.27: Section 26: FM 112-3

3.4 Rutting Measurement

Within each of the final 24 sections, a test segment of roadway spanning 550 ft was demarcated for rutting and transverse profile measurements. For ease of location and for relating the collected data to existing PMIS data, accurate GPS coordinates of the beginning and end of each section were recorded.

For the rutting measurement, manual measurements (performed by the research team) and measurements collected at highway speeds (by TxDOT and the vendors) were made on each of the 24 sections. The manual measurements included the collection of MRD with a 6-ft straightedge and rut wedge in the right and left wheel paths at 5-ft intervals and the Leica laser transverse profile measurements taken at 25-ft intervals. Please note that for this report, the term Maximum Rut Depth (MRD) is the same as the ASTM term rut-depth (ASTM E1703). The data collected using the two manual processes are referred to as GT data in this study. These measurements were compared to the data provided by TxDOT and the vendors, which included each participant's best estimate of the transverse profiles and MRDs matching the GT test locations.

The testing procedure for the static measurements is described next. With the 6-ft straightedge, the researchers measured maximum rutting at 5-ft intervals along both inside wheel path (IWP) and outside wheel path (OWP). Figure 3.28 shows the procedure for measuring a rut with the 6-ft straightedge and rut wedge. During the measurement procedure, two people worked in tandem to measure the maximum rutting for each wheel path while a third person recorded the rutting values. In this way, rut measurements for 111 test locations in each wheel path could be completed within an acceptable timeframe. The researchers used the ASTM standard as a guide for measuring the surface rutting (ASTM E1703M-10). Photographs of the rut wedge are shown in Figure 3.29. The rut wedge is 6 inches in length, 3 inches in height, and 1/4 inch in width. The rut wedge is delineated in gradations of 1/16 of an inch recorded as a whole number from 1 through 48 (as shown Figure 29b).

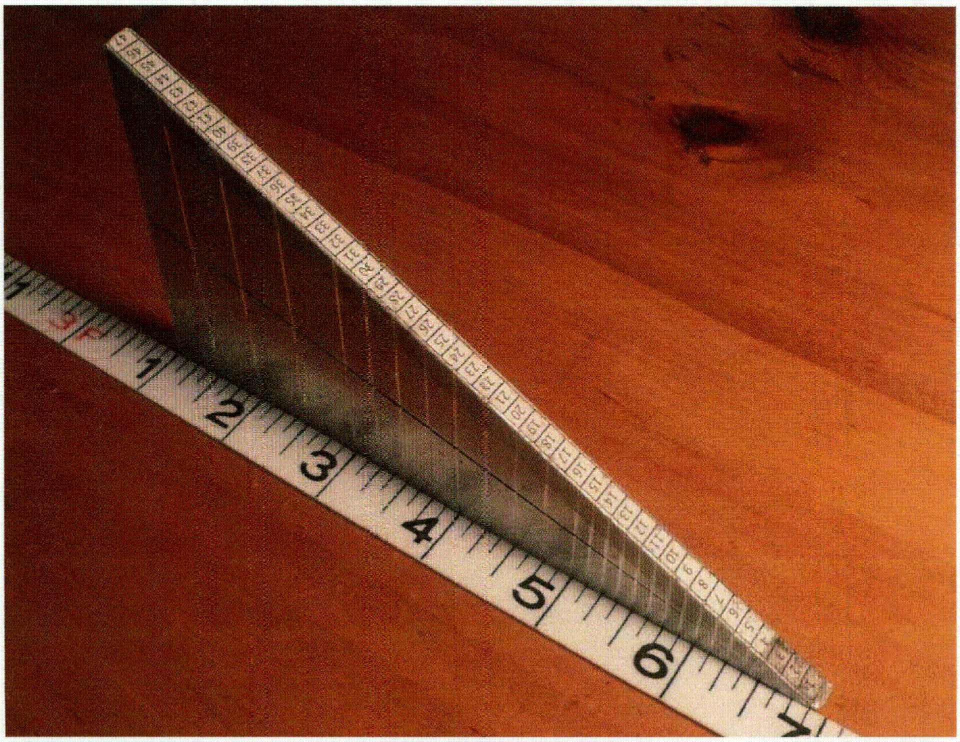
In addition, transverse profiles were measured with the Leica laser system every 25 ft. The original plan was to measure the transverse profiles using the TxDOT MLS transverse profile beam. However, the profile beam had mechanical problems; thus, the Leica laser system was adopted as an alternative due to time and cost constraints. The measurement procedure with the Leica laser system is shown in Figure 3.30.

Masking tape was placed at each transverse profile measurement location to minimize the effect of local anomalies such as large cracks and coarse aggregate. The aluminum "C" channel cross beam was placed on two tripods located at each end of the beam and a high-precision bubble level was used to level the beam to provide a horizontal reference plane for testing. The Leica laser sensor unit was placed on the beam, aiming the laser onto the tape on the pavement surface. The Leica laser sensor unit has a wireless Bluetooth connection that communicated with a laptop placed on a cart. When a test sequence was started, the Leica laser unit hung from the beam using a foldout clip and moved along the beam by the operator to each pre-determined measurement locations. As data collection progressed, the operator had 4 seconds to move the Leica system to the next test point before the unit would automatically take a measurement reading. The total length of the measurement path along the beam is 150 inches sub-divided into test points 6 inches apart. The distance from the laser to the pavement surface (tape on the surface) was measured by the Leica system and automatically recorded via Bluetooth connection in a pre-formatted Excel spreadsheet operating on the laptop.

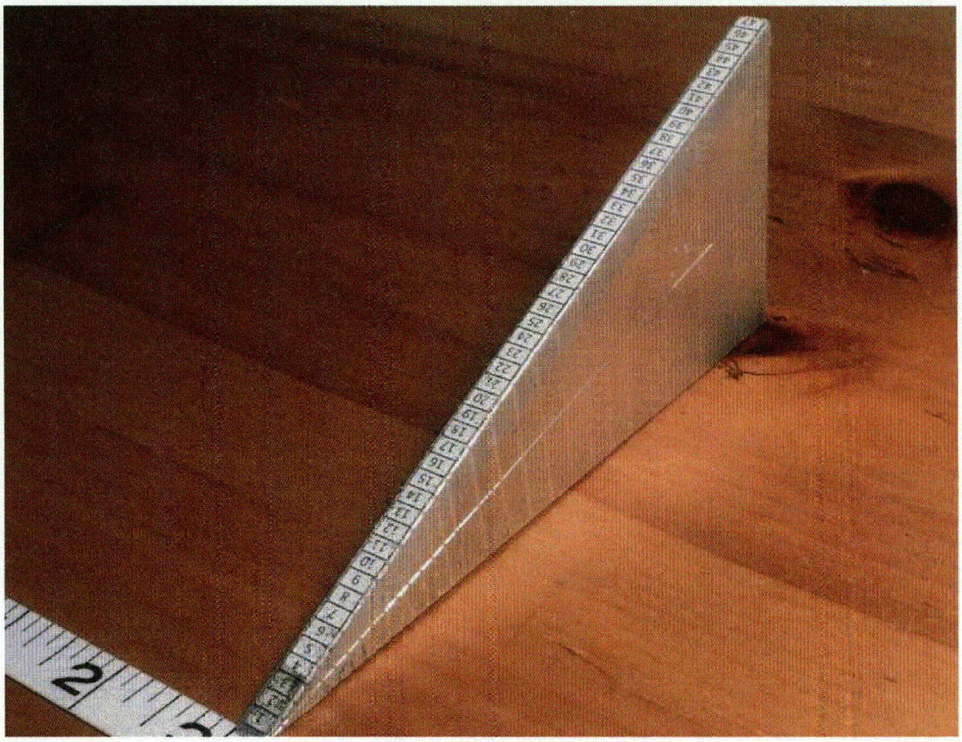
(a)

(b)

Figure 3.28: Static rutting measurement using the 6-ft straightedge and wedge



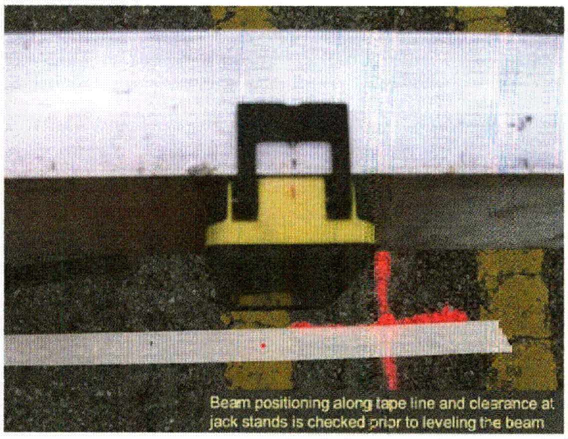
(a) Rut Wedge Length



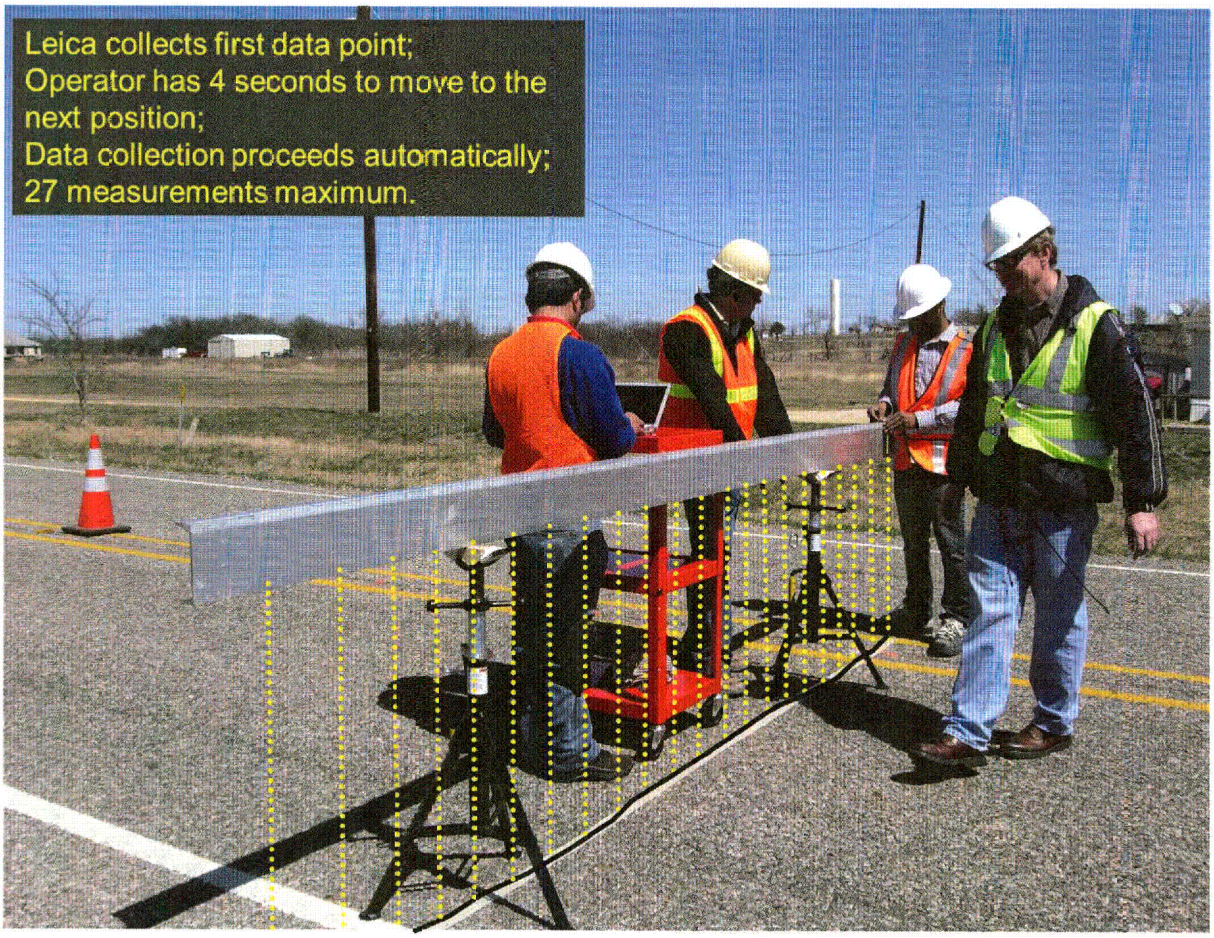
(b) Rut Wedge Width

Figure 3.29: Photographs of the rut wedge

a)



b)



c)

Figure 3.30: Rutting measurement using the Leica laser system

3.5 Summary of Tested Sections

The results of the manual maximum rut measurement on the selected sections was evaluated as testing progressed to help in selecting subsequent sections to ensure a representative sample. Two analyses were conducted to observe the rutting distribution: 1) rutting distribution for all sections, and 2) separate rutting distributions of the IWP and OWP. The results of the rutting distribution are shown in Figures 3.31 and 3.32. For TxDOT PMIS purposes, rutting is classified as follows.

1) No Rut: rutting less than 4/16 of an inch
2) Shallow: rutting between 4/16 and 7/16 inches
3) Deep: rutting between 8/16 and 15/16 inches
4) Severe: rutting from 16/16 to 31/16 inches
5) Failure: rutting deeper than 32/16 inches

The distribution shown in Figure 3.31 indicates a greater number of test locations with No Rut, Shallow, and Deep rutting, but fewer with Severe and Failure rutting. This result is to be expected because TxDOT maintenance places a priority on repairing sections with deep, severe, and failure rut conditions and the highest priority on locations with severe and failure rutting. Figure 3.32 shows the comparison between IWP and OWP with regard to rutting level. The IWP and OWP have almost same number with regard to No Rut and the IWP has a higher number of Shallow Rutting than the OWP. On the other hand, the OWP has higher number of Deep, Severe, and Failure rutting than the IWP. The FM road sections tended to have the greatest amount and highest severity of rutting whereas the US routes had little to no rutting.

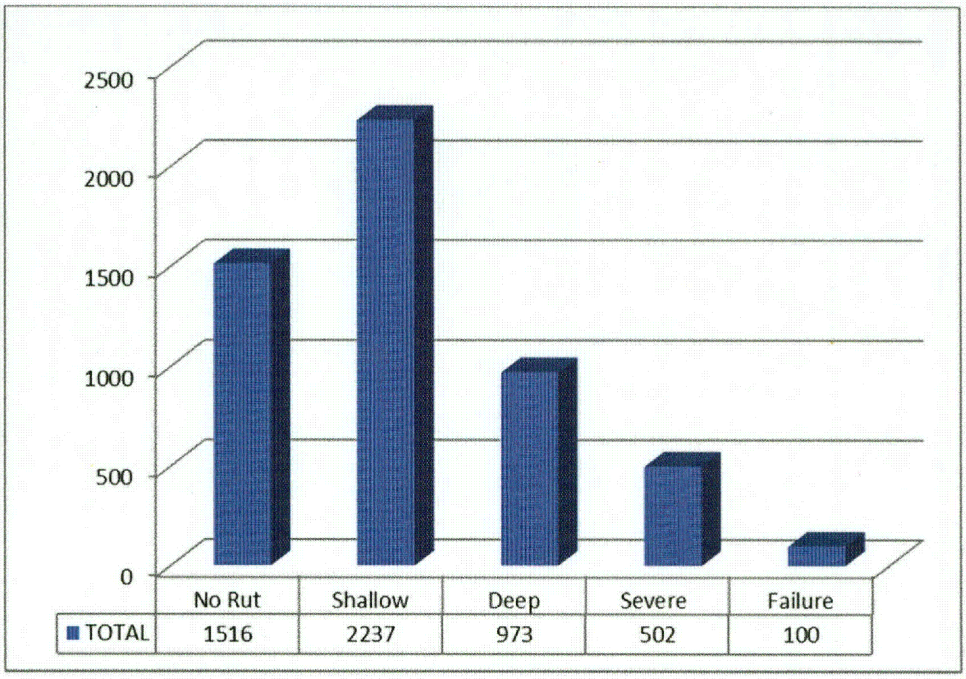
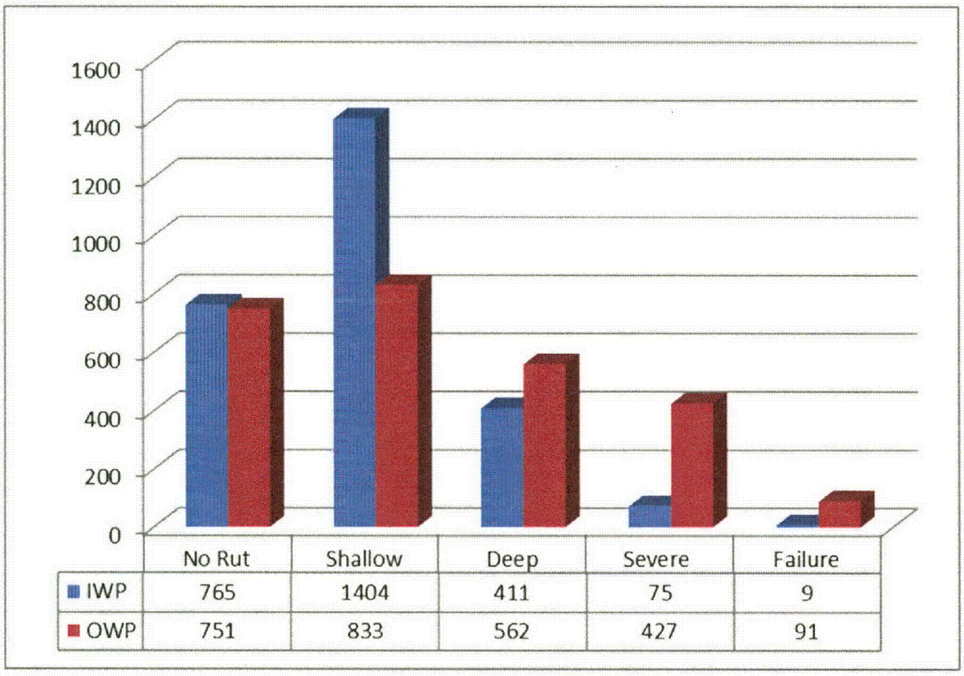


Figure 3.31: Rutting distribution using the 6-ft straightedge



	No Rut	Shallow	Deep	Severe	Failure
IWP	765	1404	411	75	9
OWP	751	833	562	427	91

Figure 3.32: Rutting distribution for the outer wheel path and inner wheel path

3.6 Summary

In this chapter, the Phase I experimental design for the rutting measurement was presented. The research team selected 24 sections based on the experimental variables that can potentially affect the results of automated rut data collection. The manual measurements were collected and analyzed. Details of the data analysis are presented in Chapter 4. Primary factors considered in the selection of test section include rutting level (No Rut, Shallow, Deep, Severe, and Failure), lane width (either narrow or wide lanes), and surface texture (either coarse or fine surface texture). In addition, the research team has selected the sections that have some combination of the following features:

1) Horizontal curve (left hand/right hand)
2) Tangent section (no horizontal curve)
3) Super-elevated section (with variable steep cross slopes as with FM 619 HC and FM 973)
4) Normal crown (non-super-elevated section)
5) With and without paved shoulders
6) Vertical (sag) curve (in either a tangent or horizontal curve)
7) Vertical (crest) curve (in either a tangent or horizontal curve)
8) Positive and negative grade
9) Variable lane width (within the same section and between sections)
10) Variable rut depths
11) Curb and gutter section

12) Variations in center line striping arrangements

13) With and without edge striping and with and without centerline reflectors

14) Presence or absence of other distress types:

    a. sealed cracks (longitudinal, transverse and alligator)

    b. unsealed cracks (longitudinal, transverse and alligator)

    c. asphalt patches

    d. strip seals in one or both wheel paths

    e. flushing

    f. presence of crack sealant with no cracks

    g. different levels of ride quality

15) Rutting located in wheel paths with traffic centered in the lane

16) Rutting located in wheel paths with traffic shifted toward the centerline

17) Depressions in pavement that may not be considered rutting

18) Variation in surface colors within a test section and between test sections

19) Local surface debris or anomalies such as lumps of clay, asphalt, sealant or localized pop-outs

20) Variable posted speeds

Chapter 4 discusses the analysis and comparison of manual GT measurements and the automated measurements made by TxDOT and the vendors.

Chapter 4. Data Analysis

This chapter reports the analysis performed on both the transverse profiles and MRD values measured by the TxDOT 3D system and the various vendor systems. The chapter is subdivided into two sections: 1) data processing and 2) transverse profile and rutting data comparisons.

Part 1 describes the processes applied to the transverse profiles required to permit direct comparisons with the GT measurements. These processes consisted of vertical and horizontal displacement and rotation of the profiles to match the orientation of the GT profiles, as none of the participants used a horizontal reference plane during data collection. In addition, a discussion is presented regarding processing of MRD values, which consisted only of converting the reported values from measurements reported in inches to the second decimal place to sixteenths of an inch reported as whole numbers. The rationale for this conversion is also presented.

Part 2 presents the statistics parameters selected by the researchers for the comparison of the participants' results with GT measurements. The statistics are presented for both the transverse profiles and the MRD values. The statistics were calculated for each test section and participant and used to rank the different systems. This chapter also contains a sample of the charts prepared to report the GT and participants results. The complete series of charts is contained in Appendixes A and B (due to document size—over 1,400 pages—these appendices are stored on the accompanying CD rather than contained in this report).

4.1 Data Processing

Each of the five participants reported their best estimate of the 23 transverse profiles and the 111 MRD values per wheel path per section for each of the 24 test sections. Therefore, 552 transverse profiles and 5,328 rut depth values were reported by each participant. However, due to 6 missed GT transverse profiles for Section 3, the total number of GT profiles available for the analysis and comparisons is 446 (99%).

In each case, the participants were requested to report their best estimate of the transverse profiles and MRDs at the predetermined GT station locations described in Chapter 3. The participants were free to use their own judgment and processes to calculate a reported profile as their best estimate. The participants were also free to use their choice of MRD algorithm to report the MRD values. The next section presents the processing of the transverse profile data reported by the participants.

4.1.1 Transverse Profiles Processing

Each automated rut measurement system produced data with different characteristics, such as the number and horizontal separation of transverse profile coordinates. Table 4.1 contains the main characteristics of the transverse profiles reported by each participant. TxDOT was the first participant to measure the transverse profiles and the other participants collected data in the order listed in the table. The participants were requested to report the values in inches to three decimal places. Thirty (30) points was the minimum number that could be reported by a participant based on criteria established prior to the vendor webinar; however, no limitations were placed on the maximum number of points to report, horizontal point spacing, or width of the transverse profile.

The second and third columns of Table 4.1 present how the participant reported the transverse profile data to the researchers, including the number of decimal places and units of the coordinates. The fourth column presents the horizontal separation between coordinates, which was consistent for all stations and sections, except in at a few cases when "skipped" coordinates occurred within the limits of a participant's profile. These cases apparently occurred due to out-of-range readings or other anomalies.

Because the lane width of the sections varied, and each participant used different methods to determine the starting and ending points of each reported transverse profile, the widths of the profile measurements and therefore the number of reported points per transverse profile were different for each participant at each station. The maximum width of a measured profile and the maximum number of coordinates reported by each participant are presented in the fifth and sixth columns.

The first (extreme left-most point in the direction of traffic) of each profile was defined as the "zero coordinate," and therefore the remaining profile points were recalculated by subtracting the coordinates of the first point. In addition, the values of all reported coordinates were converted to the same units for the comparison purposes.

Table 4.1: Format of the reported transverse profiles

Participant	Digits	Unit	Horizontal Separation of Coordinates		Maximum Width of Measured Profile		Maximum Number of Coordinates
			in.	mm	in.	mm	
TxDOT	0.1	mm	0.109	2.8	168	4267	1536
Pathway	0.010	in.	0.100	2.5	146	3706	1460
Dynatest	0.001	in.	0.100	2.5	157	3998	1575
Roadware	0.001	in.	0.800	20.3	118	3007	149
Applus	0.001	in.	0.079	2.0	153	3876	1939

The GT transverse profiles were measured using a leveled beam and therefore all GT profiles coordinates are referenced to a horizontal plane. However, none of the automated systems measured the transverse profile coordinates using a fixed reference plane. Therefore, the researchers had to rotate each of the participant's profiles to match the orientation of the corresponding GT profile so that a comparison could be made.

In addition, the "zero coordinate" for each GT profile was always measured at the center of the center line paint stripe closest to the test lane. However, the profiles measured by the participants presented different starting and ending point locations due to lateral wander of the vehicle and other factors. The researchers contacted each participant and learned that none of the participants were able to determine the position of the center of the inner stripe within their reported profiles. Therefore, the researchers had to apply horizontal and vertical displacements to the reported profiles in order to perform the comparison to GT profiles.

Figure 4.1 shows a reported profile before and after the rotation and displacement were applied. The black dots in the figure represent the GT coordinates, the green points are the coordinates reported by a given participant, and the blue line is the reported profile after applying the displacements and rotation.

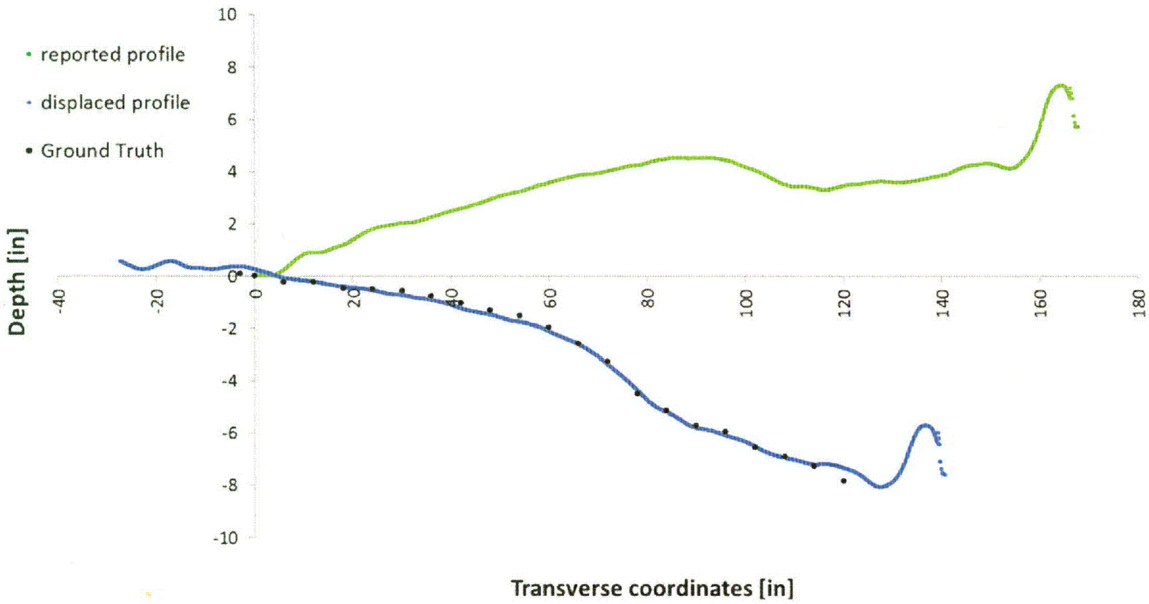


Figure 4.1: Reported (green points) and displaced (blue points) transverse profiles

The profiles presented in Figure 4.1 consist of the reported coordinates and appear to be a continuous line due to the high density of measured points and filtering applied by the participant's processing software. The horizontal and vertical displacements and the rotation of the profiles were determined such that the resulting sum of the squared residuals (SSE) was minimized. This process was developed to overcome the previously described referencing difficulties and to maintain an unbiased analysis by using the best possible interpretation of each participant's reported profile results when preforming the comparisons and analysis.

The residuals of each profile were defined as the vertical difference of the coordinates of the GT profile and the participant profile, as indicated in Figure 4.2.

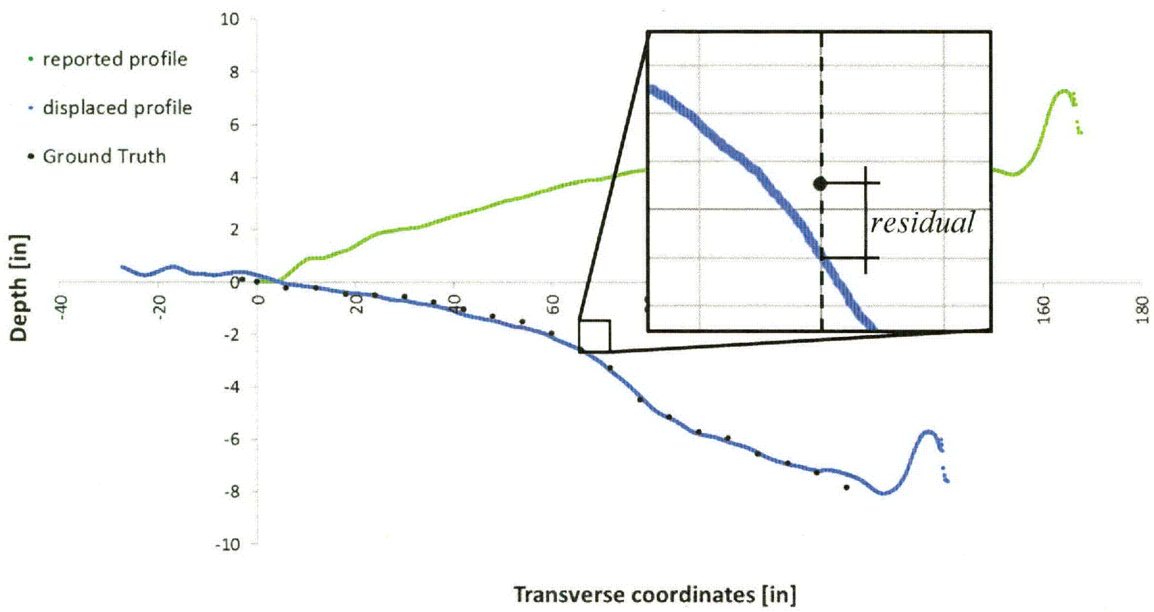


Figure 4.2: Comparison of transverse profiles

The residuals and the SSE of each profile were calculated as shown in Equation 4.1 and 4.2 respectively. The number of points compared for each profile, which is the number of residuals for the profile, could be equal to or less than the number of points of the GT profile. This is because not every profile provided by a participant extended the full width of the GT profile. Thus, no automated transverse profile point(s) may have been available to compare with every GT profile point, as shown, for example, in Figures 4.4 and 4.6. The researchers recognize that differences in the number of residuals calculated for each profile could introduce an unknown variability in the comparisons. However, the approach taken by the researchers maximized the number of residuals used in the analysis and comparison in every case.

$$residual_i = y_i^c - y_i^{GT}, \forall \text{ "i" } such\ that\ x_i^{GT} \in [x'_1; x'_N] \tag{4.1}$$

$$SSE = \textstyle\sum_R residual_i^2 \tag{4.2}$$

Where:

$residual_i$ = Residual of the point "i" of the displaced profile;
y_i^{GT} = Vertical coordinate of the point "i" the GT profile;
x_i^{GT} = Horizontal coordinates of the point "i" of the GT profile;
x'_1 = Horizontal coordinate of the first point of the displaced profile;
x'_N = Horizontal coordinate of the last point of the displaced profile;
SSE = Sum of the squared residuals; and
R = Number of residuals calculated in the profile.

As an example, Figures 4.3 to 4.7 show the displaced transverse profile measured by each participant along with the GT profile (black points) for Section 9, Station 375. The plots of the displaced profiles of each participant for all the stations are presented in Appendix A.

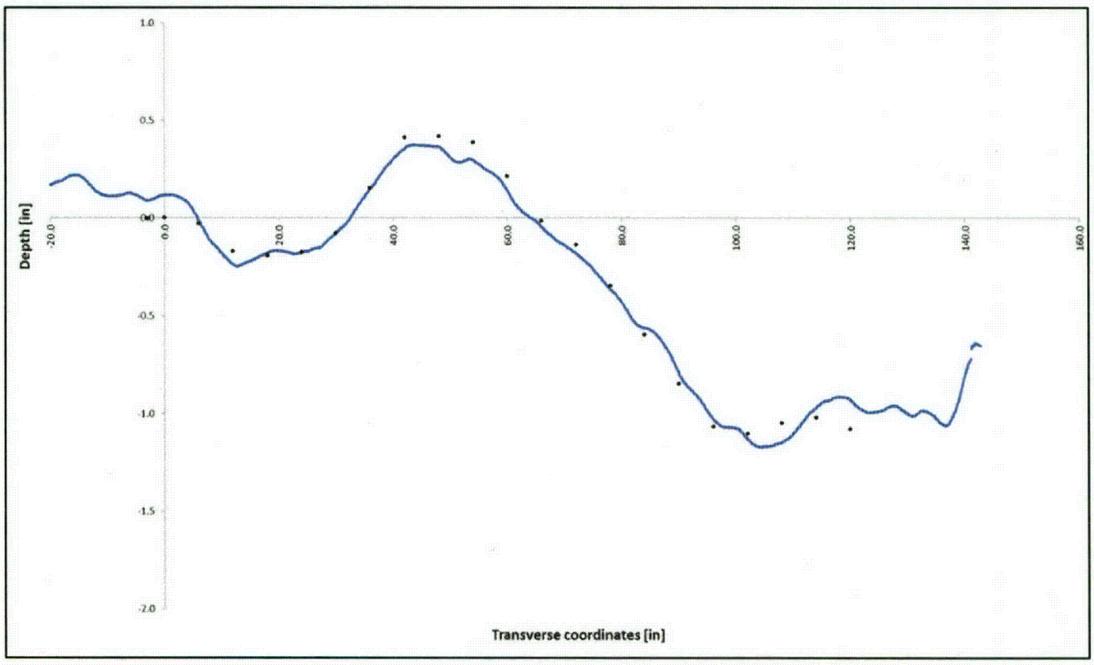


Figure 4.3: GT (black points) and TxDOT (blue points) coordinates

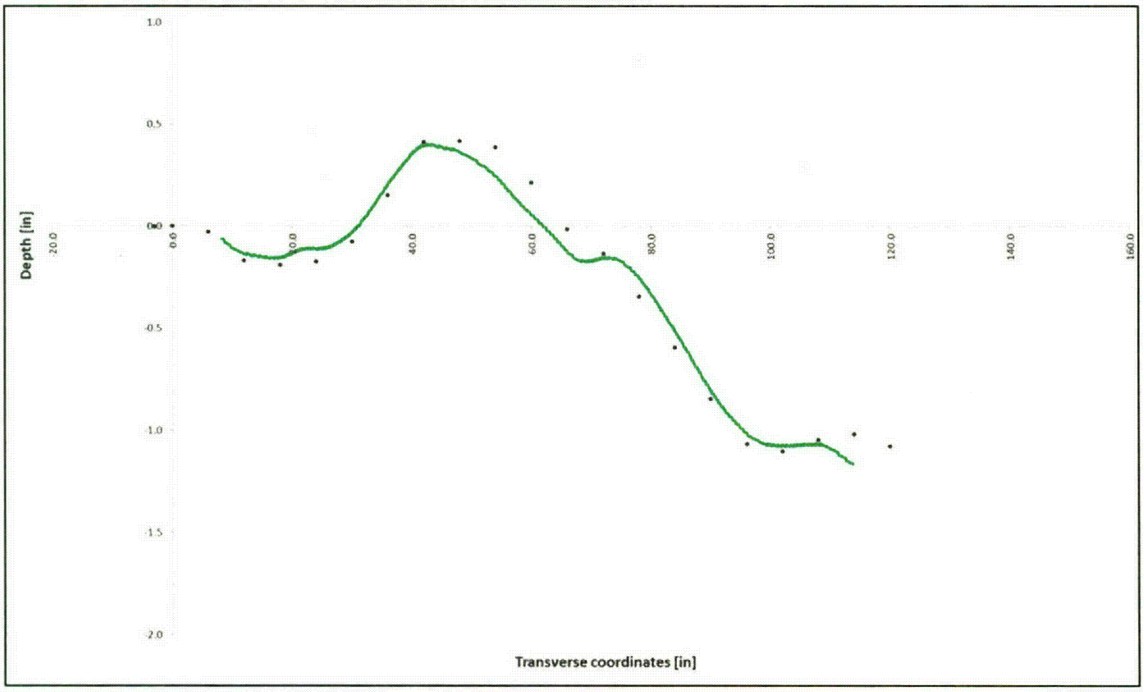


Figure 4.4: GT (black points) and Pathway (green points) coordinates

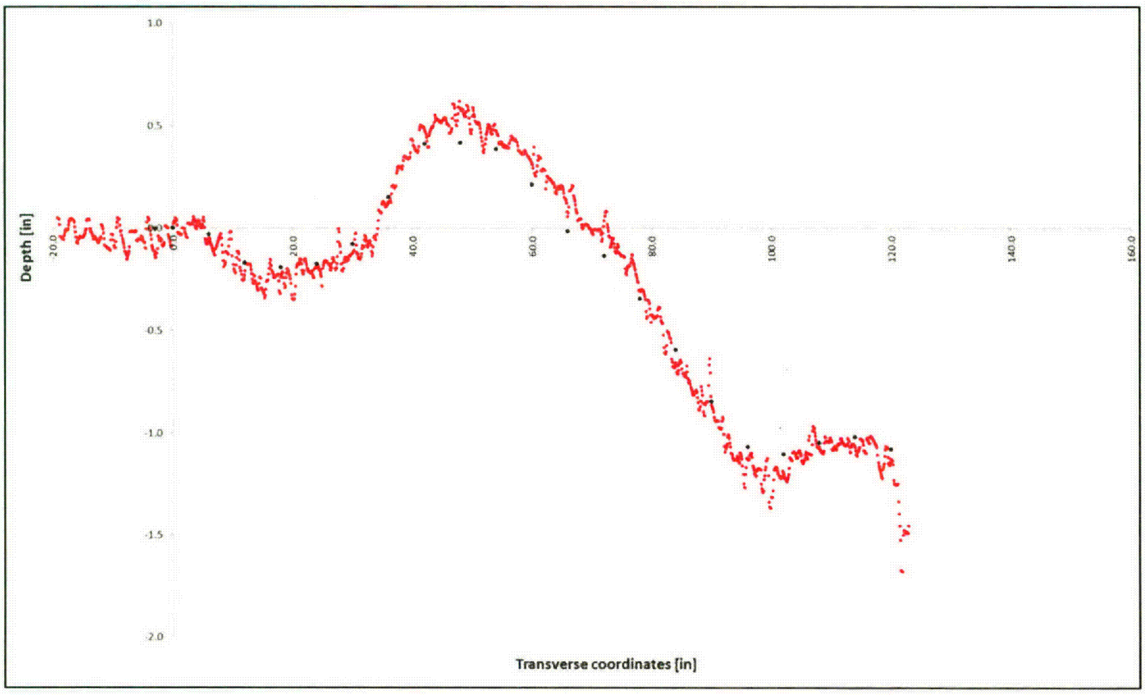


Figure 4.5: GT (black points) and Dynatest (red points) coordinates

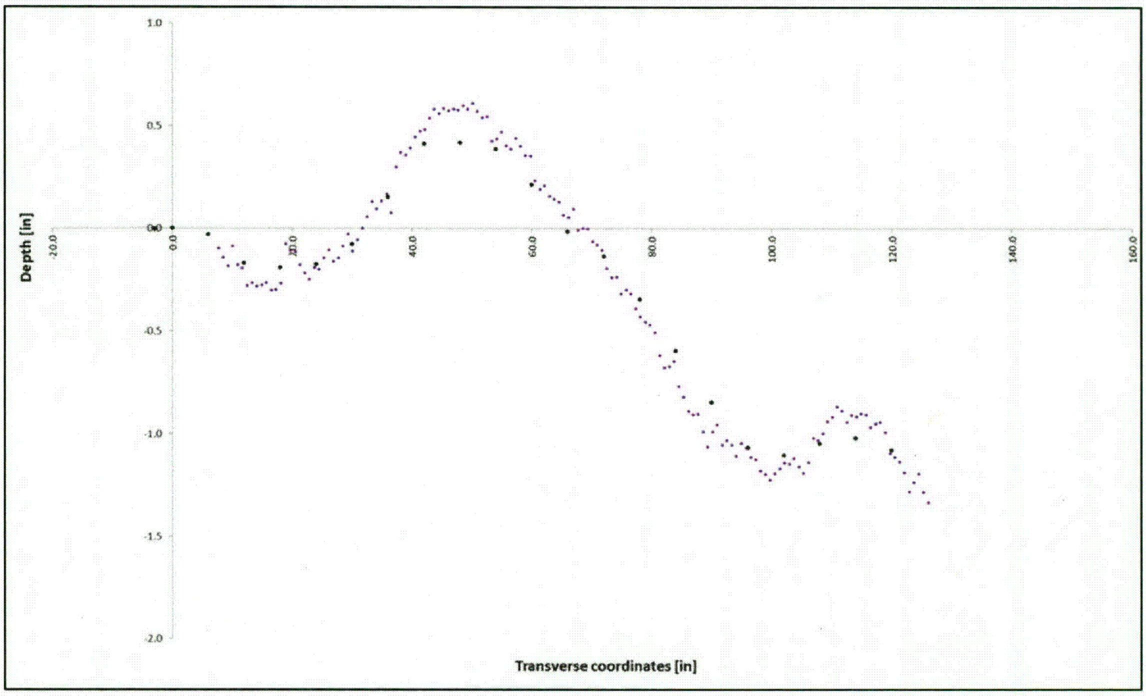


Figure 4.6: GT (black points) and Roadware (purple points) coordinates

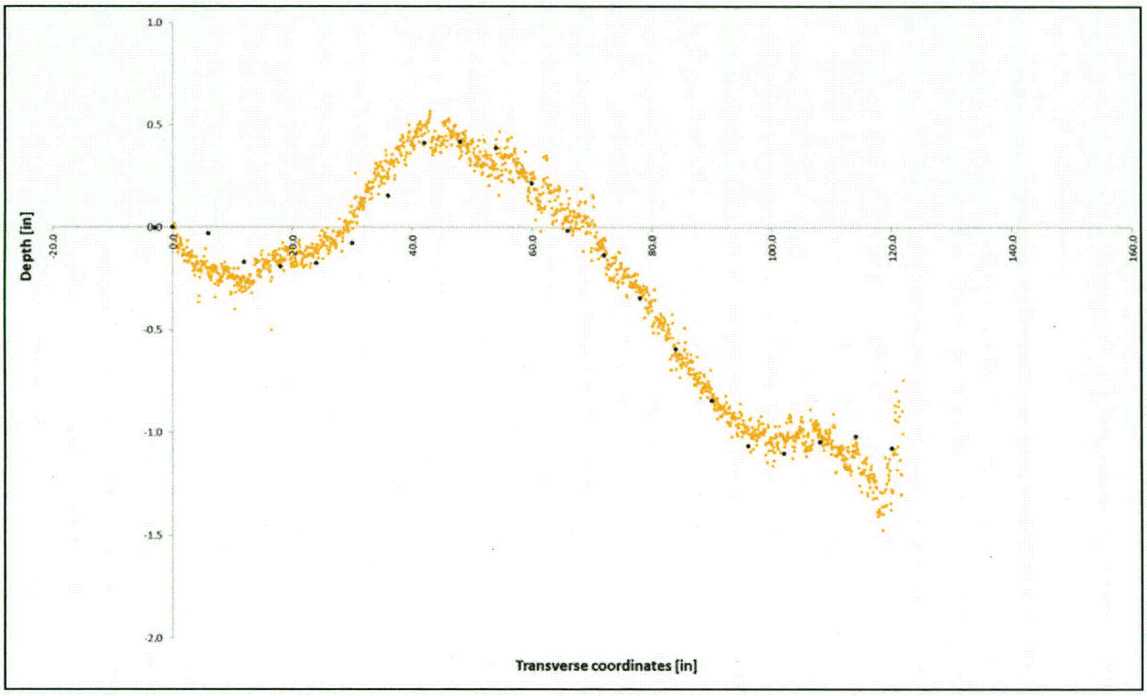


Figure 4.7: GT (black points) and Applus (yellow points) coordinates

As Figures 4.3 to 4.7 illustrate, the profiles provided by TxDOT and Pathway appear to be a solid line, whereas the profiles provided by the remaining participants consist of a cloud of points. Each participant processed their measurements using proprietary algorithms not provided to the researchers.

The first GT profile coordinate measuring from left to right (black dots in Figures 4.3 to 4.7), was located 3 inches to the left of the "zero coordinate" in the plots. The zero coordinate was always measured at the center of the centerline paint stripe closest to the test section lane. The GT coordinates to the right of the zero coordinate were measured every 6 inches until the pavement lane edge stripe or the last measurement point (150 inches) on the leveled profile beam was reached for cases in which no edge stripe existed. However, in no case was GT profile data collected beyond the pavement edge. Therefore, the last coordinate of the GT profile corresponds to the outer limit of the travel lane.

As the participant's transverse profiles were also used to characterize rutting, the width of the measured profiles should ideally be equal to, or greater than, the width of the lane. Further, if the transverse profile width is greater than the pavement lane width, the coordinates of the inner and outer limits of the lane should be properly located within the profile. For one particular section and station, TxDOT and Dynatest reported points located in both the adjacent lane and the test lane shoulder; the width of the profile presented by Pathway was shorter than the width of the test lane; and the width of the profile presented by both Roadware and Applus was similar to the width of the test lane. Note, however, that the researchers encountered IWP rutting that coincided with the centerline paint stripe or crossed the stripe and extended into the adjacent lane. This condition occurred on certain narrow FM roads. Thus, algorithms that truncate the left-most portion of the transverse profile within the test lane may introduce errors in measuring the MRD for the IWP.

4.1.2 MRD Processing

The participants provided their best estimate of the MRD values for each wheel path reported in inches to two decimal places. Please note that for this report, the term Maximum Rut Depth (MRD) is the same as the ASTM term rut-depth (ASTM E1703). Each of the participants calculated the MRD values applying their own algorithms to their measured transverse profiles. The algorithms used by the participants were not provided to the researchers. The methods and criteria adopted during the measurement of the GT MRD values were explained to the participants both during the webinar and on the day of testing prior to data collection.

The participants reported the MRD values for all the stations in the requested format of inches to two decimal places. The only processing applied by the researchers consisted of converting the reported values to sixteenths of an inch calculated to two decimal places, as all GT MRD values were recorded in these units. Once the conversion in units was applied to all the reported MRD values the comparison with the GT MRD values was performed.

As an example, Figures 4.8 to 4.19 show the longitudinal distribution of the reported MRD values in sixteenths of an inch, along with the GT values, for both the IWP and the OWP in Section 9. TxDOT reported two set of results for the MRD values, which were both calculated using the same measured transverse profiles but applying different filters and processing algorithms. The algorithms used to calculate both sets of results were not provided to the researchers. The first set of results was calculated with the filters that are currently used during for PMIS data collection and reporting, and therefore this set is referred to, by the researchers, as *TxDOT PMIS*. The filters used to produce the second set of results were introduced by TxDOT to account for the criteria used during the manual measurements of MRD values. Those criteria were based on the researchers' interpretation of the ASTM standard for determining the MRD using a 6-ft straightedge (ASTM E1703) and rut wedges as discussed during the webinar. This second set of results is referred to, by the researchers, as *TxDOT ASTM*.

The blue line in each of the following charts (Figures 4.8 to 4.19) connects the 111 GT values measured along each wheel path of the section. The dashed blue line connects the TxDOT PMIS values and the solid blue line connects the TxDOT ASTM values. The green line connects the values reported by Pathway, the red line connects values reported by Dynatest, the purple line connects values reported by Roadware, and lastly, the yellow line connects the points reported by Applus. Thus, where the participant's line coincides with the GT line, the MRD values were equal. When the participant's line falls below the GT line, their measurements underestimated the GT, and when the participant's line is above the GT line, their measurements overestimated the GT.

Because this study's motivation is the comparison of TxDOT's equipment to the vendors' equipment, both set of results reported by TxDOT were included in the vendor result charts. The complete series of charts with the participant's MRD values and the GT values for all the sections for both wheel paths are presented in Appendix B.

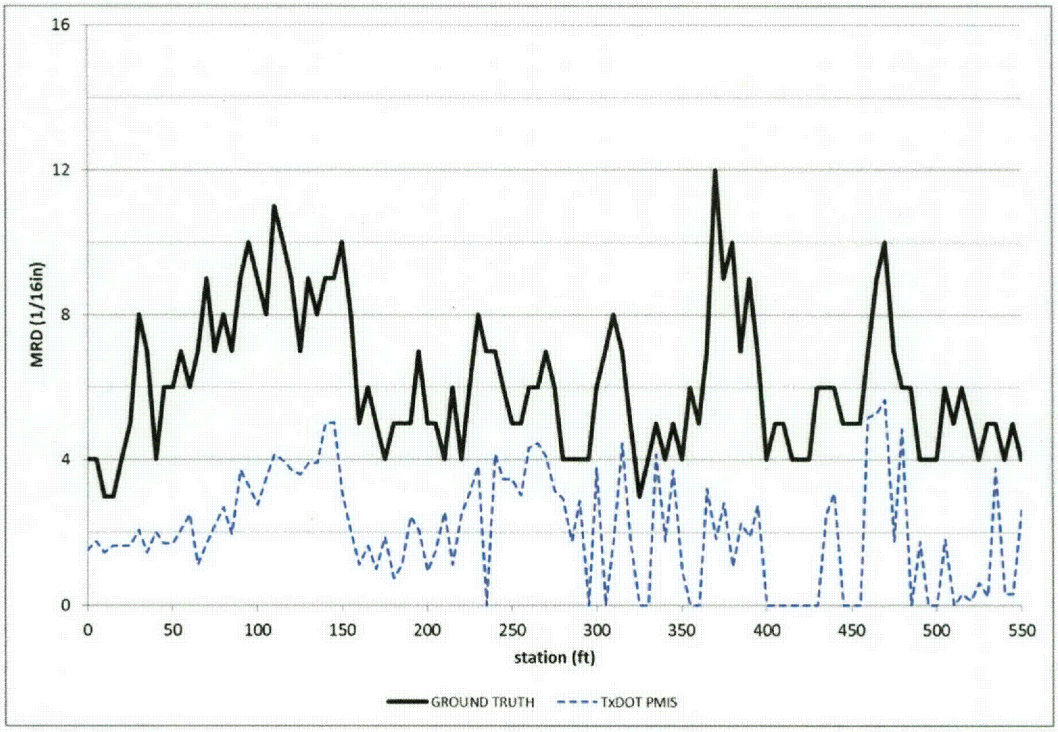


Figure 4.8: GT (black line) and TxDOT PMIS (dashed blue line) IWP MRD longitudinal distribution

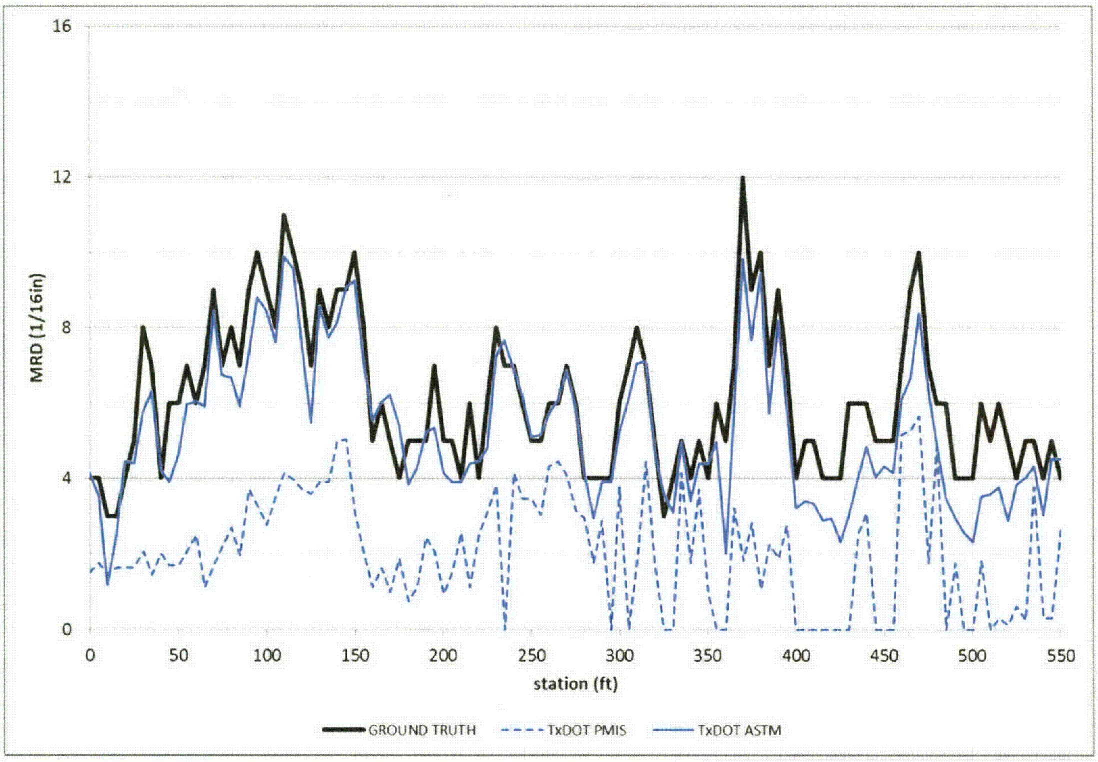


Figure 4.9: GT (black line), TxDOT PMIS (dashed blue line), and TxDOT ASTM (solid blue line) IWP MRD longitudinal distribution

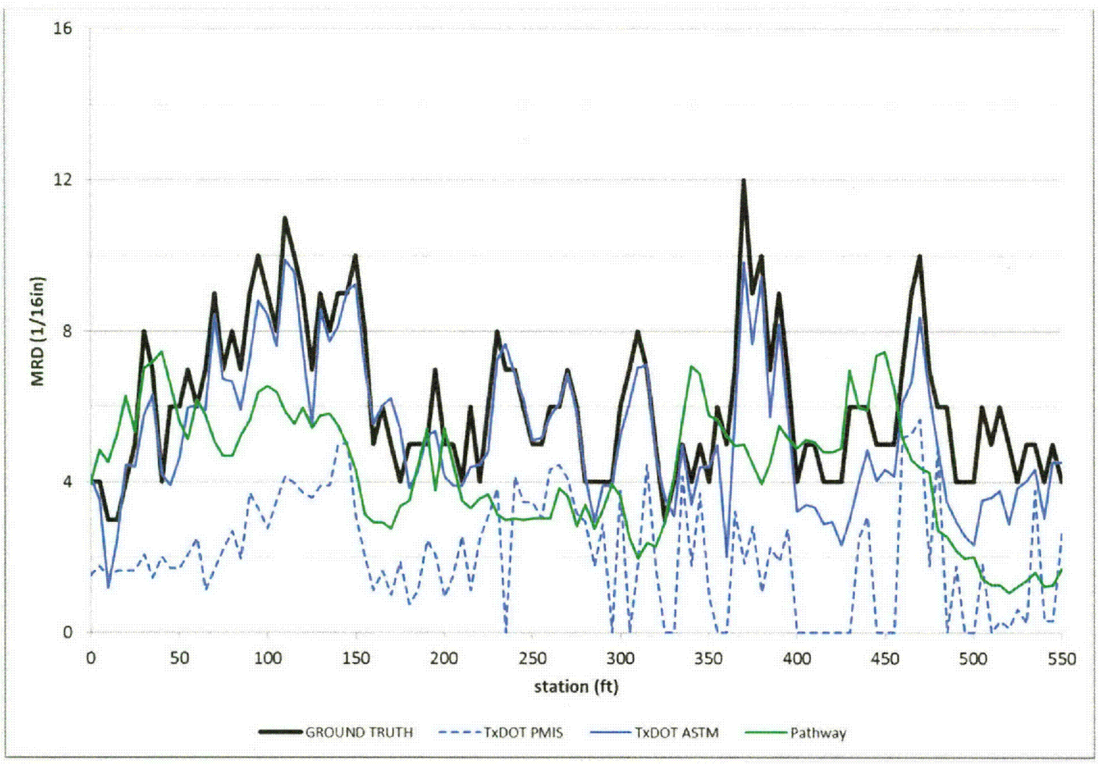


Figure 4.10: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Pathway (green line) IWP MRD longitudinal distribution

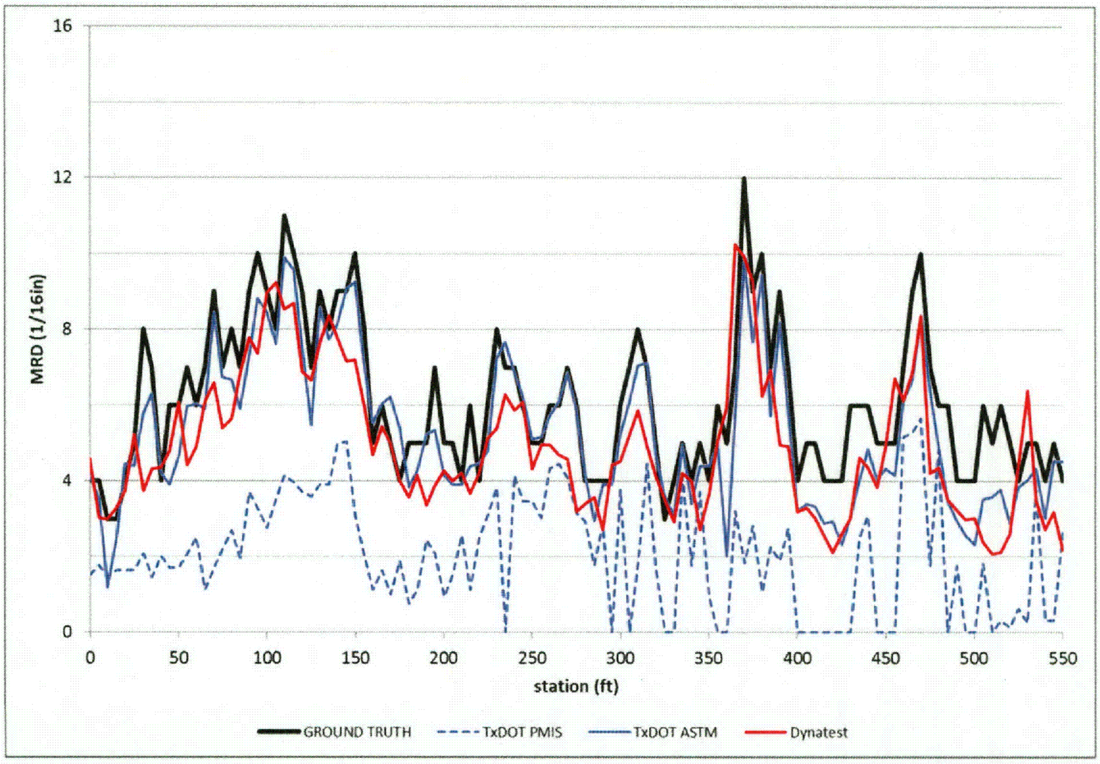


Figure 4.11: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Dynatest (red line) IWP MRD longitudinal distribution

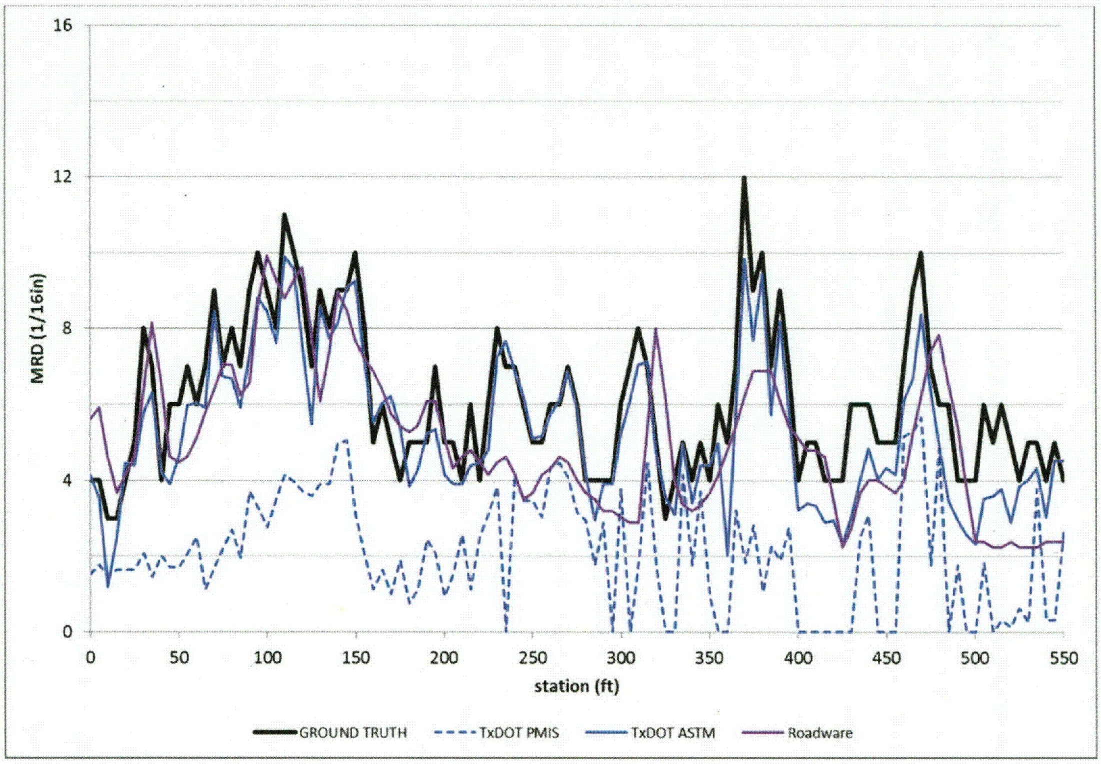


Figure 4.12: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Roadware (purple line) IWP MRD longitudinal distribution

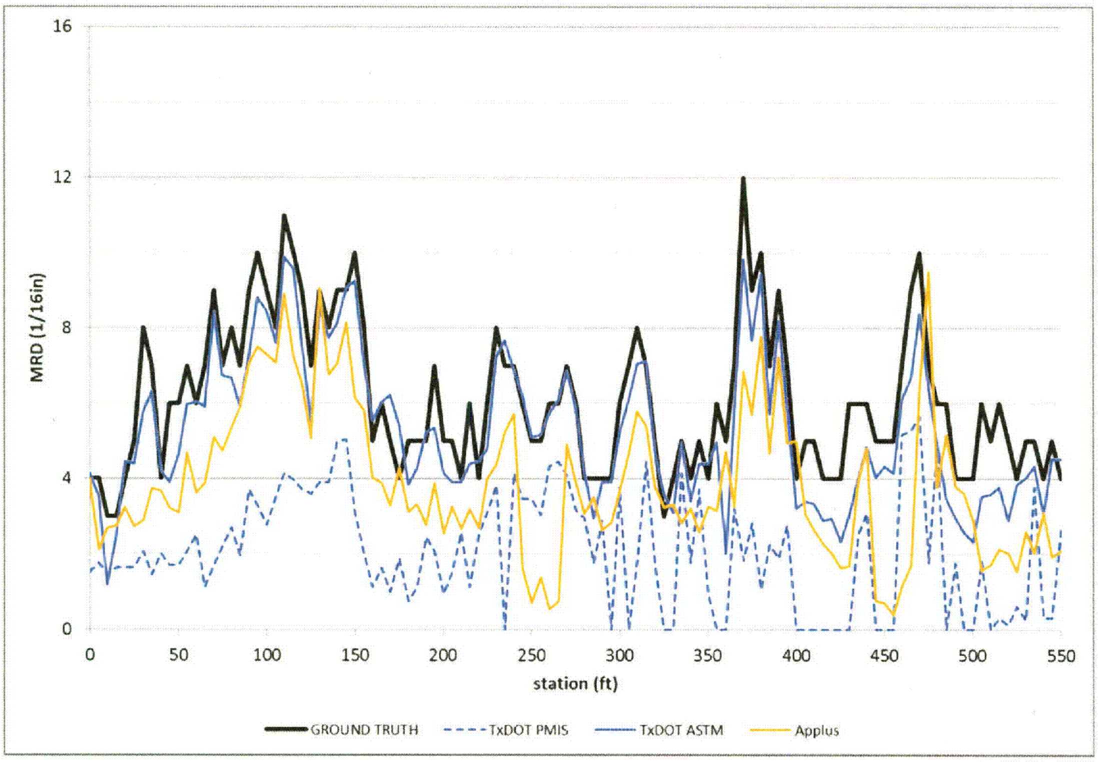


Figure 4.13: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Applus (yellow line) IWP MRD longitudinal distribution

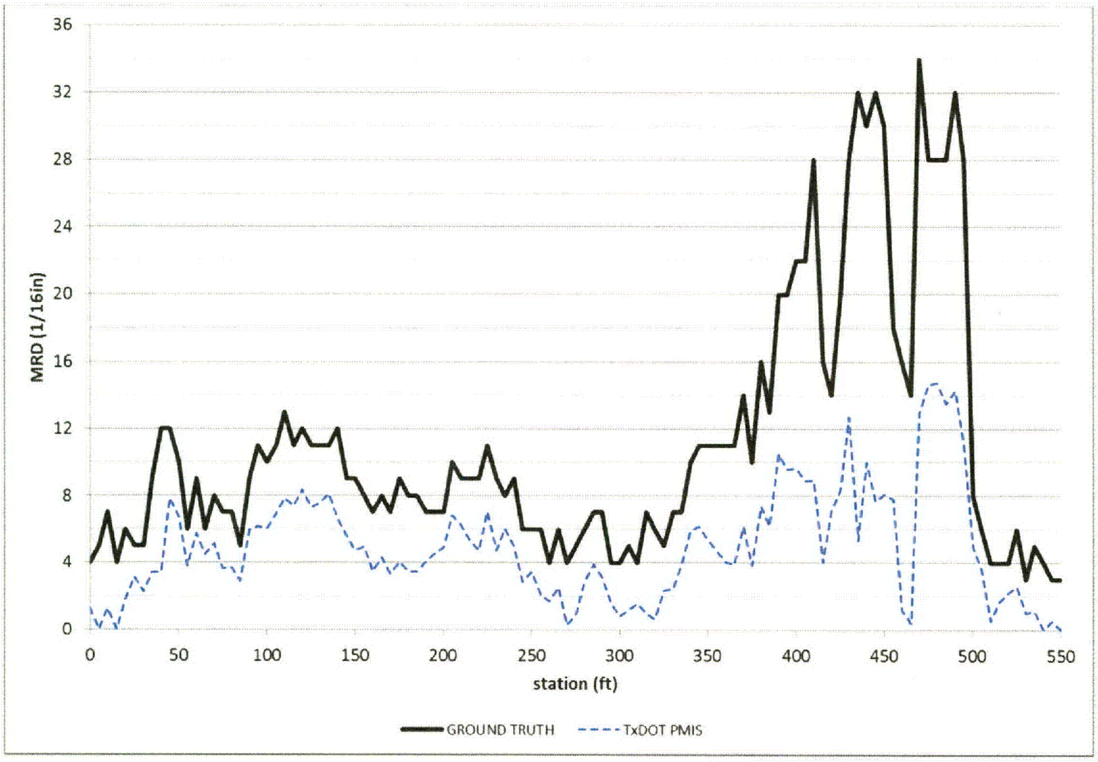


Figure 4.14: GT (black line) and TxDOT PMIS (dashed blue line) OWP MRD longitudinal distribution

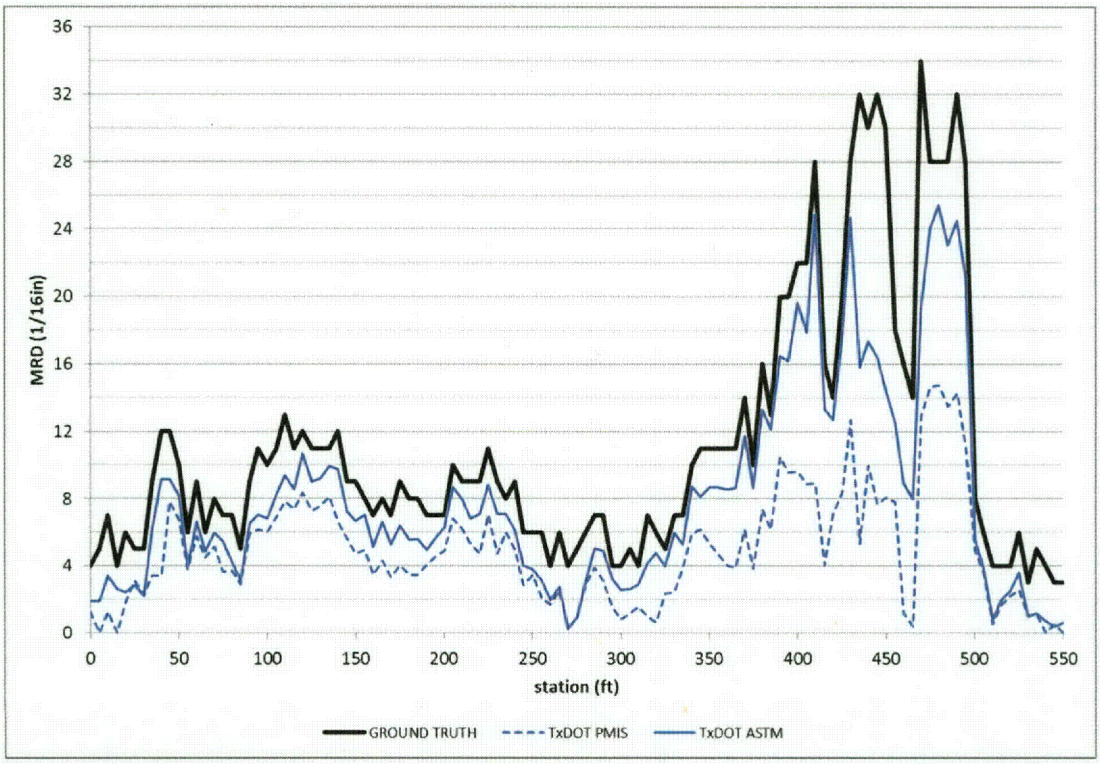


Figure 4.15: GT (black line), TxDOT PMIS (dashed blue line), and TxDOT ASTM (solid blue line) OWP MRD longitudinal distribution

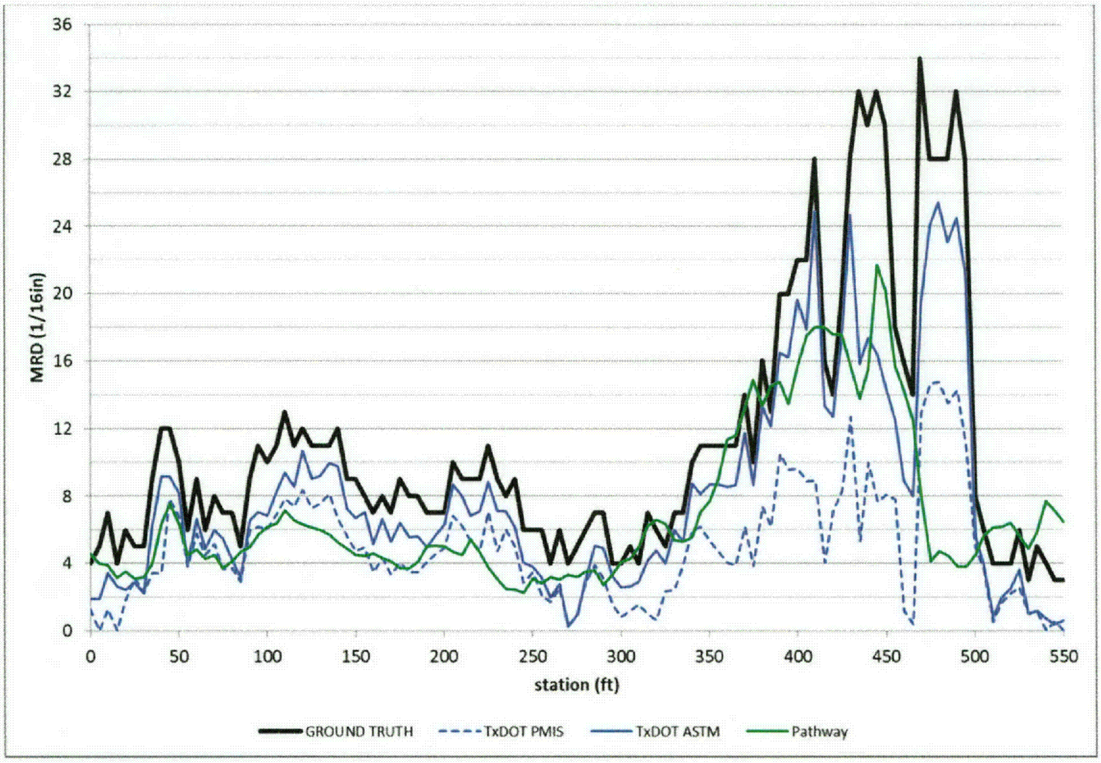


Figure 4.16: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Pathway (green line) OWP MRD longitudinal distribution

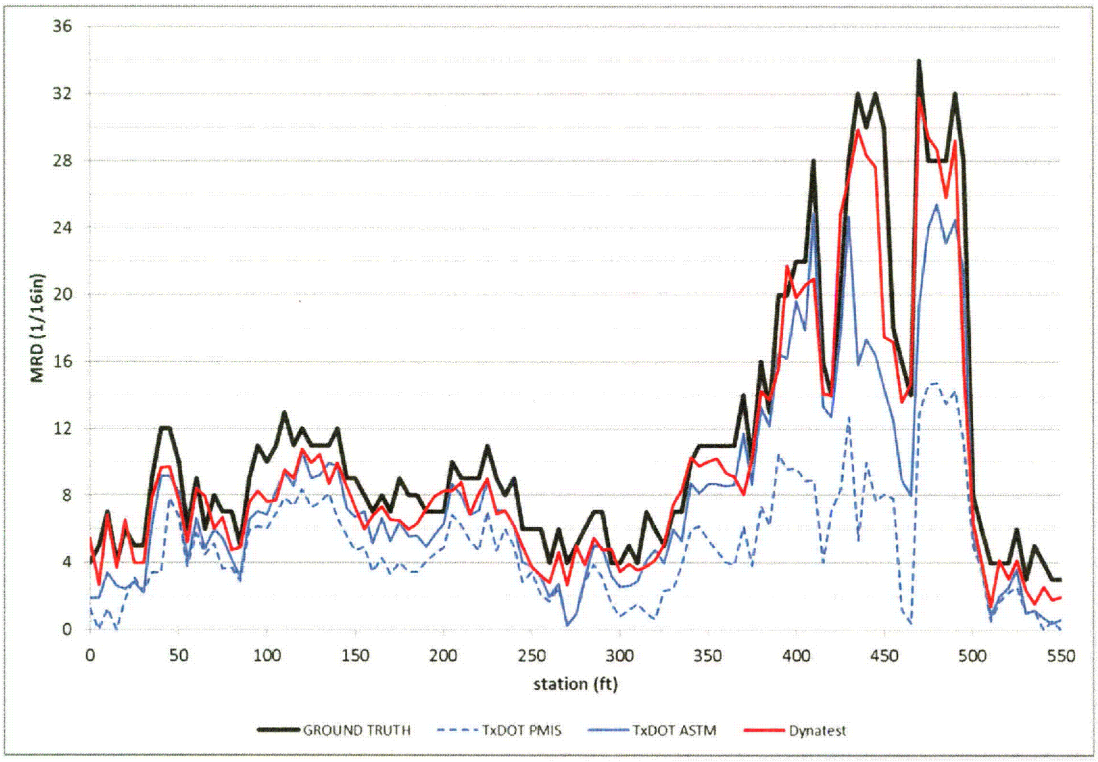


Figure 4.17: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Dynatest (red line) OWP MRD longitudinal distribution

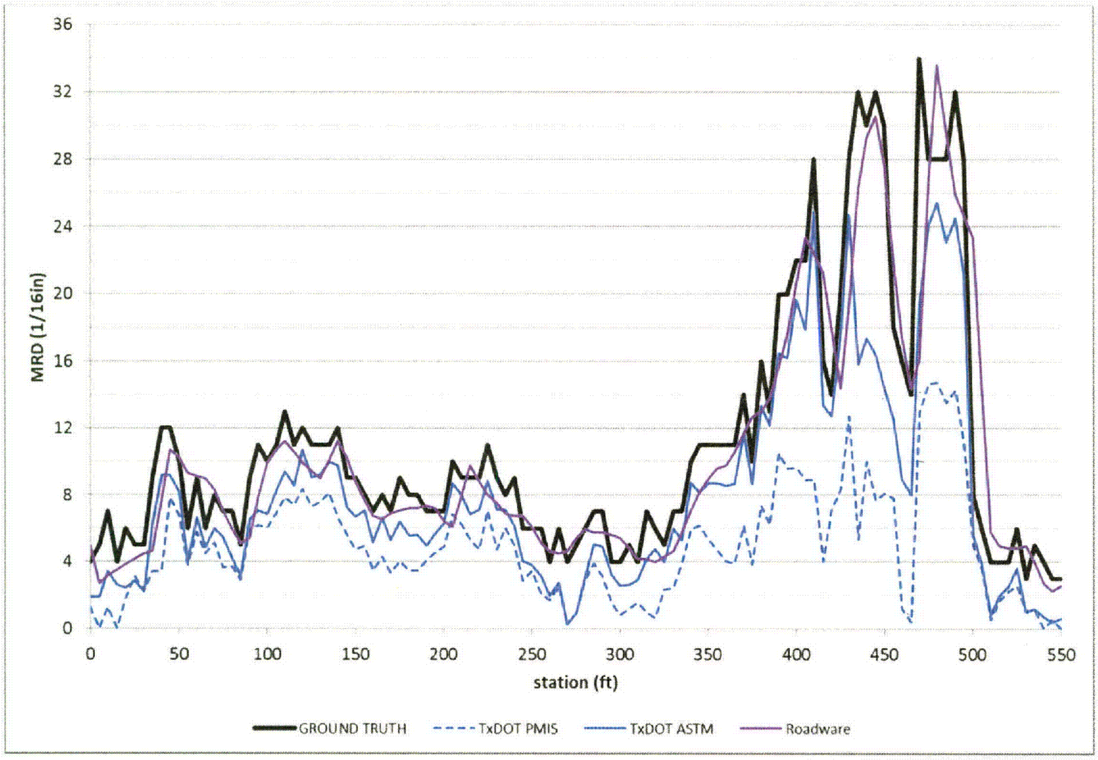


Figure 4.18: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Roadware (purple line) OWP MRD longitudinal distribution

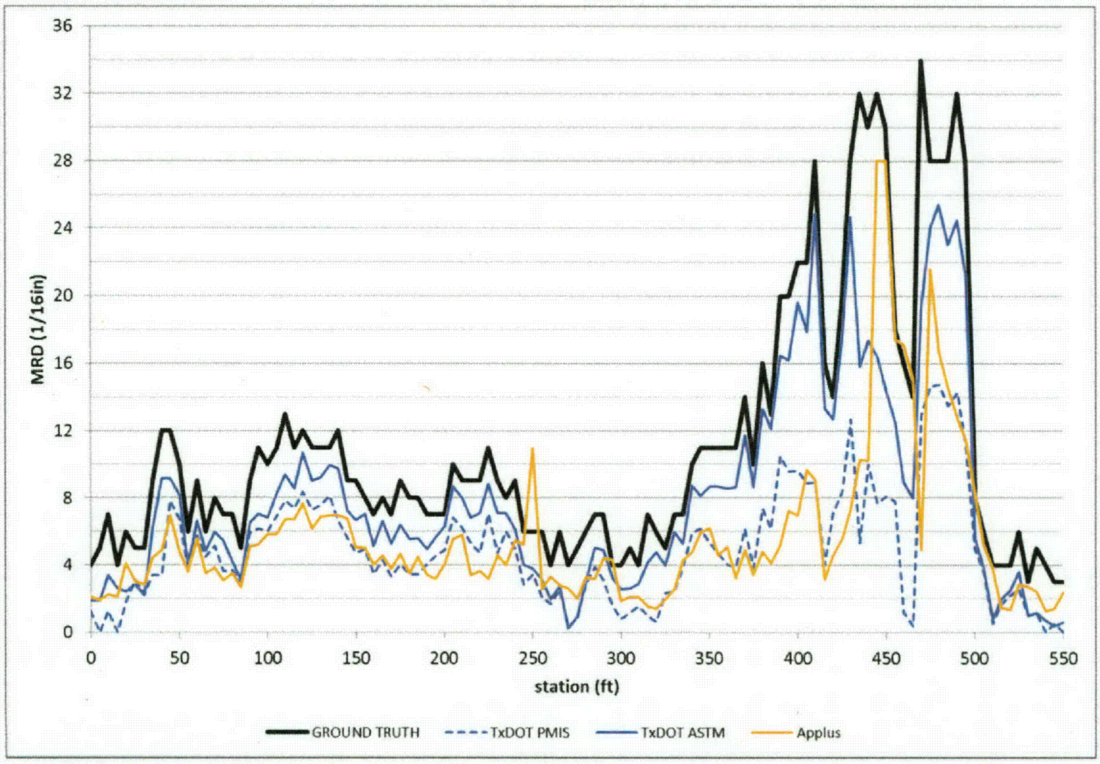


Figure 4.19: GT (black line), TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Applus (yellow line) OWP MRD longitudinal distribution

4.2 Transverse Profile and Rutting Data Comparisons

Once all the reported rutting data measurements were processed, the measurements were compared. This section describes the calculations performed as well as the results for both the transverse profiles and MRD values comparison.

4.2.1 Transverse Profiles Comparison

Each transverse profile measured by the participants was compared to the GT profile for the 552 stations of the study. Five statistical parameters were calculated for the comparison and used to rank the participants:

- Bias, defined as the mean of the residuals;
- Precision, defined as the standard deviation of the residuals;
- MSE, which accounts for both bias and precision;
- Average Sum of the Square Residuals (SSEn); and
- Correlation Coefficient (corr).

The five statistical parameters used for the comparison of the profiles were calculated using Equations 4.3 to 4.7.

$$Bias = \sum_R \frac{residual_i}{R} \tag{4.3}$$

$$Precision = \sqrt{\sum_R \frac{(residual_i - Bias)^2}{R-1}} \tag{4.4}$$

$$MSE = \sqrt{Bias^2 + Precision^2} \tag{4.5}$$

$$SSEn = \sqrt{\sum_R \frac{residual_i^2}{R}} \tag{4.6}$$

$$corr = \frac{\sum_R (y_i^{GT} - \overline{y^{GT}})(y_i^c - \overline{y^c})}{\sqrt{\sum_R (y_i^{GT} - \overline{y^{GT}})}\sqrt{\sum_R (y_i^c - \overline{y^c})}} \tag{4.7}$$

Where:

$\overline{y^{GT}}$ = Mean vertical coordinate of the GT profile;
$\overline{y^c}$ = Mean vertical coordinate of the interpolated points of the displaced profile;

Tables 4.2 to 4.26 present the values of the five statistical parameters calculated for each profile of each of the five participants. The first row (bold text) of each table lists the section stations and the first column (bold text) lists the sections in order by section number. Each cell of the tables contains the value of the respective parameter calculated for participant's transverse profiles. The cells in orange are stations where the GT profile was not collected and the ones in yellow indicate the stations for which the GT value was found to contain an error. The cells in red are stations for which the respective participant did not report measurements.

Therefore, from a total of 552 transverse profiles, TxDOT reported the measurements for all the stations; Pathway did not report measurements for one station (0.2%); Dynatest did not report measurements for 15 stations (2.7%); Roadware did not report measurements for 6 stations (1.1%); and Applus did not report measurements for 14 stations (2.5%).

Interestingly, for those cases in which Dynatest (section 17 – FM 696-4) and Roadware (section 23 – FM 1063-3) did not present measurements, the stations were consecutive. The section and stations for which Dynatest did not report data contained high OWP rut depths and sealed cracks. The section and stations for which Roadware did not report data contained variations in pavement color and texture; however, little distress and no deep, severe, or failure rutting occurred in this section. This development suggests to the researchers that once the system failed to provide measurements at one station, it could not measure the subsequent station, or the system needed to be reset to measure the following stations. As each participant was given the opportunity to run each section three times, it is puzzling that these participants were not able to provide data for these stations from at least one good run. However, these missed stations did comprise a very small percentage of the total number of profiles collected. The stations for which Applus did not report measurements are from sections that presented high values of rutting and severe distresses. Applus used the INO LCMS sensors mounted on a trailer. The last column of Tables 4.2 to 4.26 contains the average value of the respective statistical parameter for each section. The orange and red cells were not considered for calculating the average value of each section.

Tables 4.27 to 4.31 contain the average values of each parameter for every station, which were obtained from Tables 4.2 to 4.26. The last column of the tables indicates the participant that presented the best value for each section, which is the closest to zero for the case of Bias, Precision, MSE, and SSEn, and the closest to one for the case of the correlation coefficient. Additionally, the last rows of Tables 4.27 to 4.31 indicate the number (also expressed in percentage) of sections at which each participant presented the best value. The values of the statistical parameters in Tables 4.2 to 4.31 are reported to two decimals, but the comparison was carried out considering the values without rounding them.

Table 4.2: Bias between GT Profile and TxDOT Profile [16th in]

	Station																						
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00		0.00		0.00		0.00		0.00	**0.00**
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	0.00	0.00	0.00	0.00	0.00	**0.00**
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.24	0.00	**-0.01**
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
8	0.00	0.00	0.00	0.00	0.00	-0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
12	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.21	0.00	-0.16	0.00	0.00	0.00	-0.22	-0.16	-0.08	-0.19	0.00	**-0.04**
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.01	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	**0.01**
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
18	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.41	**-0.02**
20	-0.25	0.00	-0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.20	0.00	0.00	0.00	0.00	0.00	**-0.01**
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

Table 4.3: Bias between GT Profile and Pathway Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00		0.00		0.00		0.02		0.00	**0.00**
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
7	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	-0.53	0.00	0.00	0.00	0.00	0.00	**-0.02**
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.07**
12	-0.01	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	**0.01**
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	**0.01**
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.35	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	**-0.01**
15	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.24	0.00	0.00	0.80	0.32	0.00	0.00	0.00	0.00	0.00	0.00	-1.17	0.00	0.00	0.00	0.00	**0.01**
16	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
19	0.00	0.00	0.00	0.00	0.04	-0.71	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	**-0.03**
20	0.00	0.07	0.00	0.39	0.00	0.00	0.00	0.00	0.20	0.16	0.15	-0.66	0.00	0.38	-0.01	-0.08	0.00	0.26	0.00	0.00	0.00	0.00	0.00	**0.04**
21	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.14	0.00	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	**-0.01**
23	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	**0.00**
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	**0.00**
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.23	-0.14	0.00	0.10	0.00	**-0.01**
26	0.00	0.00	-0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	-0.79	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.05**

Table 4.4: Bias between GT Profile and Dynatest Profile [16th in]

Section	Station 0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00		0.00		0.00		0.00		0.00	**0.00**
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.25	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
10	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
11	0.00	0.00	-0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**
12	-0.02	0.01	0.28	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	**0.02**
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
15	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00																**0.00**
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.29	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**
21	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
22	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	**0.01**
23	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
24	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	-0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	**-0.01**
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.51	0.01	0.00	0.00	**0.04**
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

Table 4.5: Bias between GT Profile and Roadware Profile [16th in]

		Station																						
Section		0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	**Avg**
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00		-2.66		0.00		0.00		-0.01	**-0.16**
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	5	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	**0.02**
	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	7	0.00	0.00	0.00	0.00	-0.28	-0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	**-0.02**
	8	0.00	0.00	0.00	0.26	0.00	0.15	0.00	0.10	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.05	0.00	0.00	0.00	0.00	0.00	**0.06**
	9	0.00	0.00	0.00	0.00	0.00	-0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	10	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
	11	-0.27	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.00	0.52	0.00	0.00	0.00	-0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	**0.00**
	12	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.29	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**
	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.36	0.00	0.00	0.00	0.00	0.10	0.00	**-0.10**
	14	0.00	-0.02	0.00	0.00	0.00	-0.14	0.00	0.00	0.21	0.00	0.00	0.00	0.00	-0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-0.01**
	15	-0.02	-0.02	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	**0.00**
	17	-0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.05	**0.00**
	18	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	19	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.48	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	-0.01	-0.05	0.00	**0.00**
	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.01	0.00	-3.57	-0.36	0.00	0.00	0.00	0.00	**-0.17**
	21	0.00	0.00	-2.10	0.00	0.00	-1.07	-0.06	-1.39	-2.39	0.00	-2.88	-0.58	-2.83	-2.74	-2.75	-2.54	-2.30	-2.50	0.00	-1.44	-2.31	0.00	-1.41	**-1.36**
	22	0.15	0.00	0.00	-0.22	-2.01	-1.77	-3.15	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.66	-0.72	0.00	0.00	0.00	0.00	0.00	0.00	**-0.45**
	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						**0.00**
	24	-7.7	0.00	0.00	0.00	0.00	0.00	0.00	-4.19	-0.11	0.00	0.00	0.00	0.00	0.00	0.00	-3.20	0.00	0.01	0.00	0.00	-1.66	0.00	0.00	**-0.73**
	25	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.28	0.01	-20.69	0.00	0.00	-0.02	0.00	-0.55	0.00	0.00	0.00	-2.98	0.00	**-1.06**
	26	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.10	0.00	**0.00**

Table 4.6: Bias between GT Profile and Applus Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00		0.00		0.00		0.00		0.00		0.00	**0.00**
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
5	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
7	0.09	0.00	0.09	0.00	0.00	0.00	0.00	0.00	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	**0.01**
8	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**0.01**
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	**0.00**
10	0.00	0.00	0.00	0.00	-0.02	0.00	0.00	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	-0.02	0.00	0.00	**-0.01**
11	0.00	0.00	0.00	0.00	0.01	0.00	-0.04	-0.01	-0.05	0.00	0.12	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
12	0.09	0.01		0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	-0.06	0.01	0.00	0.00	0.00	0.00	0.04	0.00	-0.01	0.00	0.00	0.00	**0.01**
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	0.00	0.00	-0.01	0.00	-0.05	0.00	**0.00**
14	0.00	0.00	0.00	0.13	0.00	0.00	0.09	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.13	0.01	0.00	0.00	0.25	0.00	0.00	0.00	**0.03**
15	0.00	0.00	-0.01	0.01	-0.23	-0.02	-0.02	0.00	0.00	-0.02	0.00	-0.01	0.01	0.01	-0.02	-0.04	0.01	1.11	0.00	-0.01	0.00	-0.01	0.00	**0.03**
16	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
17	0.00	0.02	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	**0.00**
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.11	0.00	0.00	0.00	0.00	0.00	-0.07	0.00	**-0.01**
19	0.00	0.00	-0.03	0.00	0.00	0.00	-0.09	-0.23	-0.01		0.00	0.00	-0.01	0.00	0.00	0.00	0.00			-0.01	0.00	-0.02	0.00	**-0.02**
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00		0.01		0.00			0.00		**0.00**
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.09	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	-0.01	0.00	0.00	0.01	-0.01	-0.02	0.00	0.01	0.00	0.00	0.00		0.00	**0.00**
25	0.00	0.00	0.00	0.00	0.00		-0.01	0.00	0.01	0.00	-0.03		0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.32	0.00	0.00	**0.01**
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

Table 4.7: Precision between GT Profile and TxDOT Profile [16th in]

	Station																							
Section	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	2.23	3.13	1.93	1.91	1.70	2.10	2.30	2.43	3.03	2.97	2.29		1.74		1.78		2.04		1.49		1.79		1.29	**2.13**
4	2.52	2.37	1.93	2.19	1.99	2.15	2.00	1.97	2.68	2.00	2.11	2.10	2.12	2.18	1.77	2.10	1.95	2.44	2.10	2.14	1.96	2.94	2.30	**2.17**
5	1.42	1.29	1.26	1.20	2.04	1.77	1.20	1.44	1.68	1.48	1.63	1.71	2.56	1.64	1.70	1.49	1.52	1.68	2.27	1.68	2.35	2.08	2.21	**1.71**
6	1.85	2.37	1.78	2.08	1.89	1.62	2.14	1.97	2.32	2.27	2.22	2.02	2.09	1.57	1.75	2.14	2.18	1.95	2.38	3.01	1.97	2.54	2.60	**2.12**
7	2.21	2.12	1.39	2.93	1.98	1.81	1.71	1.42	1.34	1.47	1.38	1.17	1.91	1.46	1.66	1.74	1.95	1.82	2.09	1.97	1.56	1.91	1.78	**1.77**
8	1.19	1.53	1.27	2.48	1.45	1.97	1.49	1.92	1.69	1.46	1.60	2.09	2.09	2.32	2.33	2.17	2.04	2.25	1.54	1.70	1.63	2.46	1.26	**1.82**
9	1.01	1.08	1.44	1.60	1.47	1.87	3.23	2.50	2.13	1.45	1.80	2.54	1.68	1.43	1.54	1.05	1.58	1.57	1.53	2.14	1.31	1.22	1.62	**1.69**
10	1.65	1.41	1.77	2.31	2.41	1.74	1.55	1.22	1.83	1.59	1.63	1.51	1.36	1.64	1.51	2.14	1.27	1.57	2.06	2.22	1.51	1.46	1.57	**1.69**
11	1.20	1.35	2.02	2.66	1.78	1.67	3.44	3.10	6.56	4.85	2.67	1.23	0.85	1.46	1.33	1.56	1.94	2.12	1.48	1.38	1.18	1.38	1.22	**2.11**
12	4.39	0.89	2.08	2.35	1.76	3.02	1.45	2.91	4.57	1.09	3.01	2.34	1.68	2.02	1.55	2.34	1.61	1.27	1.25	1.95	1.60	2.20	2.65	**2.17**
13	1.45	2.06	1.58	1.34	1.96	1.88	3.29	2.51	2.62	3.19	2.80	2.58	2.14	1.82	3.34	1.60	1.56	1.57	1.43	1.33	1.36	1.35	2.05	**2.04**
14	1.56	1.24	1.42	1.36	1.44	1.91	1.40	1.93	1.65	1.60	2.04	2.30	2.17	2.90	1.94	2.56	2.32	2.94	2.73	2.27	1.61	2.56	2.30	**2.01**
15	1.81	2.39	1.27	1.18	0.88	2.06	1.11	1.93	1.94	2.17	2.69	3.65	3.43	1.18	1.70	1.35	2.71	4.23	0.79	2.37	0.81	0.99	1.11	**1.90**
16	2.51	1.84	2.02	1.52	1.30	1.69	1.80	1.55	2.28	1.66	1.85	2.13	2.12	1.72	2.03	1.93	2.08	1.42	1.64	1.93	1.84	1.77	1.53	**1.83**
17	1.35	1.47	1.28	1.57	2.11	1.78	1.61	1.57	1.29	2.31	1.80	1.51	1.64	1.79	2.29	1.51	2.05	1.55	1.71	1.66	1.61	1.81	2.12	**1.71**
18	1.83	1.30	2.39	2.33	1.98	1.92	2.04	1.75	1.08	0.99	1.40	1.19	1.80	1.63	1.40	1.68	1.60	1.76	1.62	1.75	1.37	1.51	1.36	**1.64**
19	1.98	1.86	3.92	2.06	2.24	3.05	3.68	3.25	5.15	3.97	4.30	2.65	3.42	2.01	2.15	2.85	1.69	3.75	3.57	5.72	2.67	2.58	4.19	**3.16**
20	2.60	2.22	3.34	2.64	2.83	2.05	2.08	2.50	2.63	2.43	2.09	2.35	4.44	3.41	2.12	7.41	6.16	5.67	2.73	3.58	1.99	2.49	2.15	**3.13**
21	1.55	1.81	1.72	1.84	1.51	1.70	1.60	1.43	1.38	1.29	1.35	1.48	1.25	1.60	1.48	1.39	1.43	1.75	1.66	1.93	2.49	2.36	1.91	**1.65**
22	1.59	1.59	2.36	1.52	1.64	1.49	1.23	1.02	1.45	0.94	0.91	0.91	1.32	1.45	1.81	1.45	1.63	2.05	1.92	2.11	1.98	1.65	1.40	**1.54**
23	4.12	3.29	4.65	3.66	5.47	3.25	3.99	3.53	4.04	4.32	3.60	3.93	3.64	2.82	2.35	1.94	1.30	1.32	1.67	1.41	3.55	4.56	1.88	**3.23**
24	3.01	2.84	1.90	1.95	1.55	3.71	1.67	2.93	3.48	4.77	4.24	3.32	2.85	4.51	3.98	4.65	3.70	3.55	2.29	2.77	6.35	3.97	4.50	**3.41**
25	1.94	2.34	3.09	2.46	2.00	1.49	1.22	1.46	1.67	1.75	3.51	2.05	2.06	2.46	2.60	1.38	2.06	2.34	2.72	2.93	2.16	2.17	1.51	**2.15**
26	2.01	1.79	2.23	2.29	1.94	1.77	2.07	2.21	1.96	2.23	3.03	3.55	1.95	2.44	2.51	1.96	1.73	1.82	2.07	1.62	1.56	1.69	1.64	**2.09**

Table 4.8: Precision between GT Profile and Pathway Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	1.93	2.08	1.45	1.52	1.69	1.32	1.83	2.54	1.43	2.37	1.01		1.09		1.59		1.25		2.06		1.99		1.88	**1.71**
4	1.73	1.30	1.56	2.08	1.42	1.58	1.71	1.75	1.30	1.48	1.60	2.04	1.66	1.72	1.48	1.91	1.49	1.68	1.89	1.48	1.55	1.43	1.78	**1.64**
5	1.14	1.23	1.39	1.47	1.01	1.24	1.73	1.35	1.21	1.43	1.28	1.65	1.56	1.93	1.56	1.37	1.02	1.16	1.07	1.63	0.94	1.33	1.91	**1.37**
6	1.37	1.18	1.01	1.43	1.21	1.25	0.99	1.21	1.71	1.29	1.95	1.35	1.41	1.32	1.21	1.11	1.27	1.94	1.32	1.41	1.44	1.23	1.20	**1.34**
7	0.89	1.39	0.80	0.74	0.99	0.74	1.48	1.23	2.57	1.08	0.95	1.11	1.02	0.98	0.99	1.32	1.16	1.32	1.28	1.12	1.05	1.02	1.32	**1.15**
8	2.32	1.24	1.10	1.00	1.04	1.61	1.25	1.71	1.67	1.14	1.21	1.60	1.15	1.16	1.31	1.34	1.30	1.38	1.28	1.45	1.71	1.48	1.74	**1.40**
9	1.49	1.53	1.70	1.32	1.21	1.12	1.12	1.40	1.47	1.36	1.55	1.19	1.59	1.64	1.14	1.20	4.20	4.64	0.89	3.15	1.36	1.19	1.26	**1.68**
10	1.65	1.22	1.86	1.52	1.44	1.16	1.39	1.54	1.69	1.59	1.48	1.75	1.63	1.93	1.70	1.59	1.57	1.55	1.64	1.61	1.55	1.50	1.85	**1.58**
11	2.68	4.09	0.93	1.33	1.13	1.67	3.81	5.09	7.02	4.85	3.35	1.19	1.03	1.36	7.11	1.86	1.63	1.52	1.51	2.26	1.45	1.86	2.81	**2.67**
12	7.33	3.20	9.54	1.86	2.55	3.84	6.78	1.61	2.48	1.47	3.81	1.39	2.92	2.18	1.87	2.33	1.88	1.90	3.69	2.75	2.27	1.69	1.41	**3.08**
13	1.51	1.59	1.37	1.85	1.69	2.50	3.23	1.73	7.07	2.62	4.73	1.99	2.09	1.62	1.99	1.44	1.24	1.62	1.61	1.64	1.35	0.86	1.29	**2.11**
14	1.38	1.40	1.26	1.18	1.46	1.32	1.42	1.27	1.76	1.38	1.86	1.16	2.08	1.61	1.40	1.15	1.64	1.79	1.02	1.09	1.00	0.98	1.40	**1.39**
15	1.40	0.92	1.35	0.63	0.62	2.39	0.69	1.62	0.94	4.38	5.01	4.93	3.17	3.79	2.61	2.31	2.05	4.94	7.92	2.42	7.55	1.07	1.27	**2.78**
16	0.86	1.10	1.01	1.15	1.10	1.20	1.14	1.21	1.20	1.19	1.24	1.03	1.20	0.98	0.96	1.05	1.17	1.22	1.00	1.09	1.20	1.15	0.99	**1.11**
17	1.17	0.93	1.13	1.13	1.40	1.38	1.31	1.02	0.79	0.89	1.22	0.88	0.87	0.73	0.93	0.75	1.32	1.19	1.31	1.17	1.45	1.00	0.99	**1.09**
18	1.36	1.21	1.37	1.29	0.85	1.04	1.13	1.18	1.15	1.27	1.11	1.14	1.15	1.24	1.25	1.49	1.20	1.36	1.14	1.41	1.02	1.69	1.37	**1.24**
19	6.27	3.42	3.43	1.88	1.52	3.67	1.21	1.87	4.31		1.35	1.26	2.11	2.61	1.08	1.15	1.00	3.54	4.60	8.78	4.64	1.34	3.06	**2.91**
20	1.58	1.38	1.24	2.27	1.37	1.58	1.06	1.34	1.73	1.67	1.86	6.51	9.45	4.25	14.50	15.66	8.88	7.45	7.79	6.88	5.76	1.85	4.22	**4.79**
21	1.16	1.13	1.21	1.01	1.23	0.89	1.34	0.86	0.92	0.92	0.89	1.00	1.06	1.10	1.22	1.09	0.82	1.03	1.19	0.93	1.10	1.10	1.09	**1.06**
22	1.22	1.13	1.79	1.12	1.14	1.27	1.06	1.12	1.38	1.29	1.35	0.98	1.17	1.08	1.12	1.20	1.05	1.12	1.21	1.04	1.01	1.12	1.21	**1.18**
23	1.62	4.93	2.83	3.25	10.23	1.73	9.91	1.75	1.66	14.36	5.46	3.86	2.79	1.35	1.28	1.31	1.57	1.61	1.18	1.40	1.73	1.55	1.37	**3.42**
24	8.15	1.39	2.87	1.54	1.27	1.55	1.40	1.78	3.50	4.61	1.75	0.96	5.49	6.65	6.07	2.23	2.47	7.74	3.11	4.61	7.99	3.12	1.67	**3.56**
25	4.18	1.61	1.31	1.13	1.52	4.91	2.17	5.38	2.65	3.63	1.46	0.98	5.56	2.38	4.77	2.36	4.93	2.01	3.44	8.09	5.05	2.06	2.65	**3.23**
26	1.38	1.47	3.30	0.97	1.03	0.88	1.47	2.07	1.96	10.77	4.03	3.30	2.54	1.67	7.30	3.03	1.71	1.43	1.82	1.25	4.21	1.46	1.48	**2.63**

Table 4.9: Precision between GT Profile and Dynatest Profile [16th in]

	Station																							
Section	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	1.20	1.64	0.61	0.98	0.80	2.20	1.02	1.88	0.72	1.66	0.99		0.64		0.94		0.90		0.47		1.02		1.05	**1.10**
4	1.59	0.99	1.52	1.46	1.22	1.57	1.20	1.36	1.00	1.08	1.20	1.47	1.65	1.12	1.30	1.17	0.96	1.46	1.28	1.00	1.13	2.14	1.36	**1.32**
5	0.55	0.68	0.79	0.97	0.78	1.42	0.78	0.61	0.70	0.76	0.89	1.21	0.76	2.11	0.95	0.74	0.60	0.86	1.29	0.91	0.72	0.54	1.72	**0.93**
6	1.15	1.36	0.99	1.01	1.46	1.34	0.89	1.15	1.22	1.69	1.50	1.28	1.14	1.86	0.90	1.05	1.66	0.92	1.10	1.20	1.09	1.45	1.73	**1.27**
7	0.79	0.77	0.83	1.47	1.59	1.07	1.18	0.78	1.55	0.84	1.29	1.39	1.02	1.52	0.99	1.47	1.41	0.87	0.52	1.12	0.96	0.95	0.78	**1.09**
8	1.70	1.01	1.63	0.78	1.44	2.54	1.34	1.48	2.52	1.28	1.31	2.72	1.92	0.86	1.18	1.34	2.00	1.25	1.18	1.86	1.86	1.66	2.16	**1.61**
9	0.57	1.19	0.93	0.92	0.92	0.68	0.86	1.09	1.24	1.14	1.52	1.51	1.60	1.55	2.04	1.27	2.96	1.70	1.35	1.38	1.25	1.17	0.65	**1.28**
10	0.81	0.61	1.02	0.79	1.43	1.22	1.48	0.79	1.14	0.62	0.82	0.71	1.24	1.25	1.25	1.33	1.54	0.97	1.47	1.14	0.74	0.60	1.09	**1.05**
11	1.16	0.89	2.03	1.62	1.21	1.55	3.38	4.60	7.09	3.97	2.32	0.67	0.71	1.52	1.64	1.63	1.86	1.57	1.18	2.25	0.76	1.18	0.83	**1.98**
12	4.73	6.89	3.71	2.83	3.88	2.47	1.53	2.58	1.89	0.87	3.24	1.70	0.96	1.58	1.17	1.06	0.96	1.57	2.60	1.54	1.87	1.95	0.83	**2.28**
13	2.29	1.33	1.56	2.18	2.92	2.13	1.92	1.90	1.01	1.42	1.94	3.45	1.17	1.17	1.04	0.84	1.63	1.74	1.56	2.12	1.88	2.95	1.03	**1.79**
14	0.70	0.59	0.64	0.39	0.48	0.62	0.56	0.38	0.52	0.53	0.55	1.60	1.19	1.33	1.05	0.79	1.37	2.00	0.71	1.83	1.33	0.86	1.04	**0.91**
15	1.34	2.49	1.17	4.61	1.25	2.29	1.44	1.35	1.36	1.82	3.10	3.92	2.37	1.61	2.04	1.11	1.91	2.70	1.27	4.28	1.14	0.72	0.70	**2.00**
16	0.54	0.75	0.87	0.63	0.48	0.63	0.49	0.53	1.13	0.54	0.74	0.73	0.71	0.47	0.39	0.35	0.33	0.59	0.50	0.45	0.33	0.39	0.28	**0.56**
17	0.70	0.55	0.56	0.38	0.37	0.94	0.40	0.50																**0.55**
18	0.57	0.77	0.67	0.67	0.53	0.82	0.74	0.49	0.74	0.40	0.68	0.83	0.67	0.55	0.66	0.69	0.46	0.82	0.63	0.54	0.86	1.10	0.58	**0.67**
19	1.95	1.19	1.75	1.01	1.36	1.32	1.37	2.28	2.73	1.90	2.37	1.46	1.82	2.09	0.93	2.13	1.95	1.80	3.20	2.17	1.52	1.84	2.42	**1.85**
20	0.83	1.41	1.14	1.04	0.98	1.04	1.12	1.26	1.15	1.27	2.07	1.98	2.08	1.70	2.65	4.43	3.18	4.01	2.55	1.77	0.80	2.53	2.91	**1.91**
21	0.78	1.02	0.95	0.76	0.75	0.85	1.07	0.52	0.57	0.54	1.11	0.48	0.53	0.62	3.71	0.66	0.88	0.78	0.79	0.93	0.66	0.78	0.79	**0.89**
22	1.02	0.45	0.99	0.54	0.33	0.41	0.42	0.30	0.32	0.30	0.73	0.39	0.42	0.34	0.46	0.32	0.61	0.72	0.58	0.50	0.47	0.33	0.58	**0.50**
23	1.91	0.87	1.35	0.77	0.84	1.27	1.41	1.02	1.45	2.09	1.22	0.99	1.33	1.22	1.24	0.76	0.97	0.57	0.92	1.45	1.49	1.14	1.08	**1.19**
24	1.59	1.30	1.12	1.27	0.89	1.69	0.77	3.32	1.64	2.24	1.15	1.45	1.38	2.08	1.16	1.87	2.15	1.53	1.68	3.03	2.60	1.70	3.08	**1.77**
25	2.34	1.39	0.92	0.83	0.96	0.91	1.37	0.88	0.81	0.88	3.46	1.44	1.58	0.84	1.24	1.19	2.21	0.89	1.36	3.31	1.55	1.18	1.19	**1.42**
26	0.93	0.85	1.09	0.93	1.30	0.78	1.22	1.03	1.30	2.89	2.01	2.24	1.68	1.22	1.81	0.83	1.16	1.42	0.86	0.96	0.56	0.63	0.92	**1.24**

Table 4.10: Precision between GT Profile and Roadware Profile [16th in]

Section	Station																						
	0	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	1.12	0.59	1.07	1.30	0.74	1.61	0.98	3.27	2.54	2.02	0.88		0.85		0.77		11.62		0.78		0.69		0.94	**1.87**
4	1.33	0.93	1.46	1.47	1.06	1.37	1.31	1.21	1.05	1.06	1.13	1.29	1.60	1.04	1.61	1.03	1.21	1.78	1.46	0.95	1.13	0.98	1.68	**1.27**
5	1.52	1.03	0.82	0.74	1.36	0.88	0.83	0.57	0.61	0.70	1.54	0.73	1.14	1.28	1.21	0.79	0.58	1.02	2.11	1.10	1.10	1.29	0.93	**1.04**
6	1.06	0.73	0.60	1.12	0.57	1.12	1.08	1.11	1.06	1.00	0.66	0.77	0.85	1.17	0.77	0.83	0.72	1.21	0.72	1.33	1.11	0.71	1.11	**0.93**
7	0.45	0.50	0.79	0.39	1.88	1.44	0.57	0.86	0.76	0.74	1.74	0.93	0.57	0.73	0.62	0.94	0.64	0.69	0.98	0.40	1.03	2.48	0.49	**0.90**
8	0.97	1.41	1.33	1.90	0.56	1.78	0.89	0.89	1.67	1.33	1.07	1.62	1.32	1.57	0.91	0.84	1.64	0.98	0.82	0.68	0.63	1.02	1.03	**1.17**
9	1.19	1.55	1.52	0.89	0.88	1.31	1.77	1.34	1.32	1.25	0.92	0.83	1.13	1.17	2.28	1.26	1.21	2.12	3.19	2.60	6.51	1.68	0.63	**1.68**
10	0.98	0.82	1.05	1.52	1.67	0.95	1.14	1.62	1.48	1.24	0.90	1.50	1.43	0.78	1.57	1.30	1.06	0.95	0.94	0.86	1.11	0.56	0.81	**1.14**
11	3.13	0.83	1.08	2.18	1.33	1.56	3.60	4.18	7.09	5.21	2.47	1.16	0.58	6.46	1.44	1.04	1.30	2.97	1.51	1.36	1.86	1.85	1.46	**2.42**
12	5.21	4.78	4.53	1.08	2.91	3.15	1.64	1.98	3.08	1.72	1.84	1.50	2.24	1.60	1.29	1.15	0.99	1.09	2.17	2.92	1.08	1.09	2.20	**2.23**
13	1.05	1.67	1.97	1.49	3.02	1.77	2.60	2.09	1.52	1.68	3.16	0.99	1.23	1.80	3.93	1.14	10.63	1.70	1.22	2.46	3.18	1.96	1.75	**2.35**
14	0.42	0.87	0.55	0.59	0.69	1.10	0.77	0.70	1.11	1.21	0.82	0.96	1.99	3.09	0.58	0.93	0.80	1.82	0.66	1.25	0.81	1.20	0.62	**1.02**
15	6.15	1.71	1.35	1.62	1.04	2.73	0.74	1.61	2.06	0.95	3.41	5.56	3.58	2.08	1.56	1.45	1.99	4.53	1.58	3.47	1.49	2.21	1.32	**2.36**
16	0.33	0.49	0.90	0.51	0.53	0.60	0.50	0.57	1.00	1.80	0.42	0.54	0.55	0.45	0.44	0.23	0.27	0.48	0.35	0.41	0.39	0.30	0.38	**0.54**
17	0.68	0.25	0.31	0.59	0.37	0.55	0.30	0.47	0.42	0.57	0.66	0.74	0.41	0.30	0.56	0.65	0.54	1.12	0.79	0.86	0.77	0.78	0.70	**0.58**
18	0.42	0.49	0.43	0.59	0.41	0.79	0.70	0.53	0.73	0.90	0.59	0.56	0.75	0.38	0.55	0.59	0.84	0.40	0.43	0.40	0.56	0.42	0.59	**0.57**
19	1.34	1.11	2.61	1.89	1.75	1.90	1.62	2.28	5.55	3.21	2.39	4.76	1.24	1.82	2.98	1.67	4.79	2.71	2.70	4.11	2.41	1.87	1.64	**2.54**
20	0.92	1.39	1.10	1.82	0.84	1.29	1.45	0.63	1.39	1.17	1.21	1.76	1.19	1.06	2.86	12.63	1.58	19.75	3.00	1.62	1.00	1.20	1.90	**2.73**
21	0.59	0.69	9.43	0.40	0.35	4.80	0.45	6.21	10.90	0.63	12.66	2.72	12.41	12.47	12.25	11.37	10.32	11.23	0.56	6.48	10.35	0.65	6.32	**6.27**
22	1.03	0.30	1.00	1.06	8.98	7.92	14.10	0.66	0.36	0.32	0.51	0.37	0.31	0.51	0.43	11.90	3.33	0.47	0.37	0.30	0.44	0.34	0.46	**2.41**
23	1.16	1.14	1.40	2.58	1.10	1.17	2.73		5.45	3.81	1.73	2.88	1.43	2.31	2.26	0.98	1.38	1.34						**2.05**
24	16.72	2.48	0.94	2.52	0.88	1.44	0.95	18.79	1.25	1.13	1.15	1.15	0.97	1.13	0.89	14.38	1.09	3.35	1.84	2.05	2.87	1.72	1.44	**3.53**
25	2.28	1.76	1.06	1.32	1.28	2.17	1.76	1.06	1.21	1.64	4.12	2.64	47.35	1.15	4.58	0.55	2.55	5.80	0.88	2.14	3.98	13.36	1.01	**4.59**
26	0.57	0.78	1.66	1.44	1.37	1.69	1.99	2.06	0.87	1.79	1.35	2.11	2.40	5.75	1.84	1.91	2.20	0.88	2.41	2.64	1.59	1.38	0.65	**1.80**

Table 4.11: Precision between GT Profile and Applus Profile [16th in]

	Station																							
Section	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	0.99	1.79	1.21	0.45	0.68	1.28	1.14	1.71	0.98	1.78	0.94		0.49		1.18		0.60		0.76		0.78		1.20	**1.06**
4	1.23	1.29	1.13	1.61	1.23	1.40	1.07	0.85	1.18	1.46	1.20	1.42	1.49	1.46	1.36	1.75	0.81	1.29	0.94	0.95	1.08	1.06	1.43	**1.25**
5	1.09	1.04	0.73	1.35	1.20	0.84	1.45	1.29	0.98	1.12	1.31	1.78	1.79	1.50	1.18	0.83	1.07	1.08	1.19	1.35	0.82	0.97	1.52	**1.19**
6	1.18	1.48	1.33	0.97	1.94	1.19	1.22	0.89	1.38	1.12	1.18	0.81	1.27	1.62	1.07	1.09	1.40	1.12	1.47	1.48	0.98	0.95	1.29	**1.24**
7	1.27	1.13	1.29	0.95	1.08	1.71	2.13	1.52	1.65	1.72	2.63	0.99	1.75	1.68	1.06	1.76	1.32	0.87	1.06	1.60	3.02	1.74	1.72	**1.55**
8	0.84	0.89	0.64	0.75	1.18	1.06	0.96	0.92	1.67	0.73	0.81	0.77	0.99	1.18	0.90	0.80	0.96	0.80	1.04	0.63	1.08	1.81	1.52	**1.00**
9	0.65	0.72	0.74	0.85	1.14	0.91	1.33	0.82	0.79	0.96	1.97	0.92	0.60	1.02	1.13	1.41	1.08	1.92	2.39	1.67	1.12	1.20	0.90	**1.14**
10	1.28	1.01	1.52	0.84	3.24	0.82	1.32	1.28	0.98	0.70	1.30	1.57	1.18	0.77	1.16	0.77	1.15	0.97	1.24	1.14	1.24	0.69	1.09	**1.19**
11	1.08	0.88	1.15	1.20	0.93	1.23	3.48	3.42	6.81	4.51	3.18	0.86	1.36	0.96	1.37	1.21	2.26	1.16	0.69	1.01	0.87	1.03	0.58	**1.79**
12	7.33	4.22		2.33	3.12	2.51	1.83	2.73	2.20	1.85	1.92	3.18	1.02	1.73	1.76	1.21	1.47	1.18	1.75	1.24	1.15	1.42	1.56	**2.21**
13	1.00	1.37	1.20	1.57	1.84	1.41	1.76	1.35	1.91	2.49	1.50	1.26	1.26	1.23	1.26	1.39	1.47	1.28	1.02	2.60	2.22	2.10	3.38	**1.65**
14	0.77	0.49	0.93	1.07	0.48	0.59	0.73	0.34	0.77	0.58	0.65	0.83	1.24	0.92	1.61	1.23	0.86	1.30	0.82	1.81	0.66	0.37	0.72	**0.86**
15	1.09	1.02	1.42	1.13	1.16	2.12	1.12	1.38	1.26	2.48	3.13	4.07	3.16	2.19	4.16	2.27	2.83	5.93	1.17	1.96	3.09	6.98	1.53	**2.46**
16	0.62	0.72	1.02	0.50	0.61	0.87	0.73	0.94	1.20	0.52	0.84	0.59	0.79	0.50	0.48	0.67	0.71	0.63	0.52	0.46	0.46	0.39	0.50	**0.67**
17	0.66	0.77	0.65	0.52	0.65	0.67		0.58	0.64	0.59	0.87	0.96	0.70	0.51	0.40	0.60	0.58	1.03	1.09	0.83	0.70	1.26	0.83	**0.73**
18	0.73	0.62	0.71	0.68	0.51	0.46	0.58	0.46	1.89	0.65	0.79	0.49	0.69	1.56	0.63	0.85	0.47	0.50	0.72	0.63	0.84	0.62	0.65	**0.73**
19	1.38	1.09	2.75	1.42	1.94	1.24	2.23	2.23	6.06		2.27	1.77	2.18	1.62	1.83	2.63	1.93			3.37	2.69	2.19	2.29	**2.26**
20	0.99	1.39	1.34	1.30	1.37	1.28	1.24	1.49	1.40	1.08	1.21	1.80	1.56	2.12	2.31		3.03		2.35			1.86		**1.62**
21	1.01	1.16	0.87	0.98	0.61	1.03	0.82	0.73	0.90	0.62	0.98	0.60	1.08	1.05	0.92	0.87	0.90	1.13	0.76	0.84	0.73	0.69	1.02	**0.88**
22	0.89	0.49	1.39	0.38	0.49	0.42	0.42	0.38	0.33	0.49	0.48	0.51	0.40	0.40	0.47	0.35	0.53	0.57	0.37	0.51	0.63	0.28	0.65	**0.51**
23	1.35	1.31	1.32	1.54	1.80	1.55	2.61	1.58	2.07	1.86	2.41	1.62	2.14	1.48	1.06	1.00	1.44	1.08	1.10	1.70	1.08	1.63	0.97	**1.55**
24	1.01	1.26	1.01	1.37	0.88	1.17	1.40	1.49	2.05	2.03	1.73	1.44	1.18	1.66	1.25	1.98	1.34	2.46	1.31	1.33	2.41		1.68	**1.52**
25	0.87	1.08	1.11	1.17	1.25		2.26	2.40	0.95	0.93	2.99		1.68	1.62	2.12	1.03	1.11	0.86	0.75	2.40	1.98	1.28	1.41	**1.49**
26	0.97	1.17	1.16	0.89	0.94	0.90	1.37	0.93	1.06	1.36	1.73	2.04	1.83	0.92	1.09		0.84	1.14	1.28	1.59	0.88	0.76	0.83	**1.17**

Table 4.12: MSE between GT Profile and TxDOT Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	2.23	3.13	1.93	1.91	1.70	2.10	2.30	2.43	3.03	2.97	2.29		1.74		1.78		2.04		1.49		1.79		1.29	**2.13**
4	2.52	2.37	1.93	2.19	1.99	2.15	2.00	1.97	2.68	2.00	2.11	2.10	2.12	2.18	1.77	2.10	1.95	2.44	2.10	2.14	1.96	2.94	2.30	**2.17**
5	1.42	1.29	1.26	1.20	2.04	1.77	1.20	1.44	1.68	1.48	1.63	1.71	2.56	1.64	1.70	1.49	1.52	1.68	2.27	1.68	2.35	2.10	2.21	**1.71**
6	1.85	2.37	1.78	2.08	1.89	1.62	2.14	1.97	2.32	2.27	2.22	2.02	2.09	1.57	1.75	2.14	2.18	1.95	2.38	3.01	1.97	2.54	2.60	**2.12**
7	2.21	2.12	1.39	2.93	1.98	1.81	1.71	1.42	1.34	1.47	1.38	1.17	1.91	1.46	1.66	1.74	1.95	1.82	2.09	1.97	1.56	1.91	1.78	**1.77**
8	1.19	1.53	1.27	2.48	1.45	1.97	1.49	1.92	1.69	1.46	1.60	2.09	2.09	2.32	2.33	2.17	2.04	2.25	1.54	1.70	1.63	2.46	1.26	**1.82**
9	1.01	1.08	1.44	1.60	1.47	1.87	3.23	2.50	2.13	1.45	1.80	2.54	1.68	1.43	1.54	1.05	1.58	1.57	1.53	2.14	1.31	1.22	1.62	**1.69**
10	1.65	1.41	1.77	2.31	2.41	1.74	1.55	1.22	1.83	1.59	1.63	1.51	1.36	1.64	1.51	2.14	1.27	1.57	2.06	2.22	1.51	1.46	1.57	**1.69**
11	1.20	1.35	2.02	2.66	1.78	1.67	3.44	3.10	6.56	4.85	2.67	1.23	0.85	1.46	1.33	1.56	1.94	2.12	1.48	1.38	1.18	1.38	1.22	**2.11**
12	4.39	0.89	2.08	2.35	1.76	3.02	1.45	2.91	4.57	1.09	3.01	2.34	1.68	2.02	1.55	2.34	1.61	1.27	1.25	1.95	1.60	2.20	2.65	**2.17**
13	1.45	2.06	1.58	1.34	1.96	1.88	3.29	2.51	2.62	3.19	2.80	2.58	2.14	1.82	3.34	1.60	1.56	1.57	1.43	1.33	1.36	1.35	2.05	**2.04**
14	1.56	1.24	1.42	1.36	1.44	1.91	1.40	1.93	1.65	1.60	2.04	2.30	2.18	2.90	1.95	2.56	2.32	2.94	2.74	2.27	1.62	2.57	2.30	**2.01**
15	1.81	2.39	1.27	1.18	0.88	2.06	1.11	1.93	1.94	2.17	2.69	3.65	3.43	1.18	1.70	1.35	2.71	4.23	0.79	2.37	0.81	0.99	1.11	**1.90**
16	2.51	1.84	2.02	1.52	1.30	1.69	1.80	1.55	2.28	1.66	1.85	2.13	2.12	1.72	2.03	1.93	2.08	1.42	1.64	1.93	1.84	1.77	1.53	**1.83**
17	1.35	1.47	1.28	1.57	2.11	1.78	1.61	1.57	1.29	2.31	1.80	1.51	1.64	1.79	2.29	1.51	2.05	1.55	1.71	1.66	1.61	1.81	2.12	**1.71**
18	1.83	1.30	2.39	2.33	1.98	1.92	2.04	1.75	1.08	0.99	1.40	1.19	1.80	1.63	1.40	1.68	1.60	1.76	1.62	1.75	1.37	1.51	1.36	**1.64**
19	1.98	1.86	3.92	2.06	2.24	3.05	3.68	3.25	5.15	3.97	4.30	2.65	3.42	2.01	2.15	2.85	1.69	3.75	3.57	5.72	2.67	2.58	4.21	**3.16**
20	2.61	2.22	3.35	2.64	2.83	2.05	2.08	2.50	2.63	2.43	2.09	2.35	4.44	3.41	2.12	7.41	6.16	5.68	2.73	3.58	1.99	2.49	2.15	**3.13**
21	1.55	1.81	1.72	1.84	1.51	1.70	1.60	1.43	1.38	1.29	1.35	1.48	1.25	1.60	1.48	1.39	1.43	1.75	1.66	1.93	2.49	2.36	1.91	**1.65**
22	1.59	1.59	2.36	1.52	1.64	1.49	1.23	1.02	1.45	0.94	0.91	0.91	1.32	1.45	1.81	1.45	1.63	2.05	1.92	2.11	1.98	1.65	1.40	**1.54**
23	4.12	3.29	4.65	3.66	5.47	3.25	3.99	3.53	4.04	4.32	3.60	3.93	3.64	2.82	2.35	1.94	1.30	1.32	1.67	1.41	3.55	4.56	1.88	**3.23**
24	3.01	2.84	1.90	1.95	1.55	3.71	1.67	2.93	3.48	4.77	4.24	3.32	2.85	4.51	3.98	4.65	3.70	3.55	2.29	2.77	6.35	3.97	4.50	**3.41**
25	1.94	2.34	3.09	2.46	2.00	1.49	1.22	1.46	1.67	1.75	3.51	2.05	2.06	2.46	2.60	1.38	2.06	2.34	2.72	2.93	2.16	2.17	1.51	**2.15**
26	2.01	1.79	2.23	2.29	1.94	1.77	2.07	2.21	1.96	2.23	3.03	3.55	1.95	2.44	2.51	1.96	1.73	1.82	2.07	1.62	1.56	1.69	1.64	**2.09**

Table 4.13: MSE between GT Profile and Pathway Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	1.93	2.08	1.45	1.52	1.69	1.32	1.83	2.54	1.43	2.37	1.01		1.09		1.59		1.25		2.06		1.99		1.88	**1.71**
4	1.73	1.30	1.56	2.08	1.42	1.58	1.71	1.75	1.30	1.48	1.60	2.04	1.66	1.72	1.48	1.91	1.49	1.68	1.89	1.48	1.55	1.43	1.78	**1.64**
5	1.14	1.23	1.39	1.47	1.01	1.24	1.73	1.35	1.21	1.43	1.28	1.65	1.56	1.93	1.56	1.37	1.02	1.16	1.07	1.63	0.94	1.33	1.91	**1.37**
6	1.37	1.18	1.01	1.43	1.21	1.25	0.99	1.21	1.71	1.29	1.95	1.35	1.41	1.32	1.21	1.11	1.27	1.94	1.32	1.41	1.44	1.23	1.20	**1.34**
7	0.89	1.39	0.81	0.74	0.99	0.74	1.48	1.23	2.57	1.08	0.95	1.11	1.02	0.98	0.99	1.32	1.16	1.32	1.28	1.12	1.05	1.02	1.32	**1.15**
8	2.32	1.24	1.10	1.00	1.04	1.61	1.25	1.71	1.67	1.14	1.21	1.60	1.15	1.16	1.31	1.34	1.30	1.38	1.28	1.45	1.71	1.48	1.74	**1.40**
9	1.49	1.53	1.70	1.32	1.21	1.12	1.12	1.40	1.47	1.36	1.55	1.19	1.59	1.64	1.14	1.20	4.20	4.67	0.89	3.15	1.36	1.19	1.26	**1.68**
10	1.65	1.22	1.86	1.52	1.44	1.16	1.39	1.54	1.69	1.59	1.48	1.75	1.63	1.93	1.70	1.59	1.57	1.55	1.64	1.61	1.55	1.50	1.85	**1.58**
11	2.68	4.09	0.93	1.33	1.13	1.67	3.81	5.09	7.02	4.85	3.35	1.19	1.03	1.36	7.26	1.86	1.63	1.52	1.51	2.26	1.45	1.86	2.81	**2.68**
12	7.33	3.20	9.54	1.86	2.55	3.84	6.78	1.61	2.48	1.47	3.81	1.39	2.92	2.18	1.87	2.33	1.88	1.90	3.69	2.75	2.27	1.69	1.41	**3.08**
13	1.51	1.59	1.37	1.85	1.69	2.50	3.23	1.73	7.07	2.62	4.73	1.99	2.09	1.62	1.99	1.44	1.24	1.62	1.61	1.64	1.35	0.86	1.29	**2.11**
14	1.38	1.40	1.26	1.18	1.46	1.32	1.42	1.27	1.80	1.38	1.86	1.16	2.08	1.62	1.40	1.15	1.64	1.79	1.02	1.09	1.01	0.98	1.40	**1.39**
15	1.40	0.92	1.35	0.63	0.62	2.39	0.69	1.64	0.94	4.38	5.08	4.94	3.17	3.79	2.61	2.31	2.05	4.94	8.01	2.42	7.55	1.07	1.27	**2.79**
16	0.86	1.10	1.01	1.15	1.10	1.20	1.14	1.21	1.20	1.19	1.24	1.03	1.20	0.98	0.96	1.05	1.17	1.22	1.00	1.09	1.20	1.15	0.99	**1.11**
17	1.17	0.93	1.13	1.13	1.40	1.38	1.31	1.02	0.79	0.89	1.22	0.88	0.87	0.73	0.93	0.75	1.32	1.19	1.31	1.17	1.45	1.00	0.99	**1.09**
18	1.36	1.21	1.37	1.29	0.85	1.04	1.13	1.18	1.15	1.27	1.11	1.14	1.15	1.24	1.25	1.49	1.20	1.36	1.14	1.41	1.02	1.69	1.37	**1.24**
19	6.27	3.42	3.43	1.88	1.52	3.73	1.21	1.87	4.31		1.35	1.26	2.11	2.61	1.08	1.15	1.00	3.54	4.60	8.78	4.64	1.34	3.06	**2.92**
20	1.58	1.38	1.24	2.30	1.37	1.58	1.06	1.34	1.74	1.68	1.86	6.54	9.45	4.26	14.50	15.66	8.88	7.45	7.79	6.88	5.76	1.85	4.22	**4.80**
21	1.16	1.13	1.21	1.01	1.23	0.89	1.38	0.86	0.92	0.92	0.89	1.00	1.06	1.10	1.22	1.09	0.82	1.03	1.19	0.93	1.10	1.10	1.09	**1.06**
22	1.22	1.13	1.79	1.12	1.14	1.27	1.06	1.12	1.38	1.29	1.36	0.98	1.17	1.08	1.12	1.20	1.05	1.12	1.21	1.04	1.01	1.12	1.21	**1.18**
23	1.62	4.93	2.83	3.25	10.23	1.73	9.91	1.75	1.66	14.36	5.46	3.86	2.79	1.35	1.28	1.31	1.57	1.62	1.18	1.40	1.73	1.55	1.37	**3.42**
24	8.15	1.39	2.87	1.54	1.27	1.55	1.40	1.78	3.50	4.61	1.75	0.96	5.49	6.65	6.07	2.23	2.47	7.74	3.11	4.61	7.99	3.12	1.67	**3.56**
25	4.18	1.61	1.31	1.13	1.52	4.91	2.17	5.38	2.65	3.63	1.46	0.98	5.56	2.38	4.77	2.36	4.93	2.01	3.44	8.09	5.05	2.07	2.65	**3.23**
26	1.38	1.47	3.35	0.97	1.03	0.88	1.47	2.07	1.96	10.77	4.03	3.30	2.54	1.67	7.34	3.03	1.71	1.43	1.82	1.25	4.21	1.46	1.48	**2.64**

Table 4.14: MSE between GT Profile and Dynatest Profile [16th in]

	Station																						
Section	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	1.20	1.64	0.61	0.98	0.80	2.20	1.02	1.88	0.72	1.66	0.99		0.64		0.94		0.90		0.47		1.02		1.05	**1.10**
4	1.59	0.99	1.52	1.46	1.22	1.57	1.20	1.36	1.00	1.08	1.20	1.47	1.65	1.12	1.30	1.17	0.96	1.46	1.28	1.00	1.13	2.14	1.36	**1.32**
5	0.55	0.68	0.79	0.97	0.78	1.42	0.78	0.61	0.70	0.76	0.89	1.21	0.76	2.11	0.95	0.74	0.60	0.86	1.29	0.91	0.72	0.54	1.72	**0.93**
6	1.15	1.36	0.99	1.01	1.46	1.34	0.89	1.15	1.22	1.69	1.50	1.28	1.14	1.86	0.90	1.05	1.68	0.92	1.10	1.20	1.09	1.45	1.73	**1.27**
7	0.79	0.77	0.83	1.47	1.59	1.07	1.18	0.78	1.55	0.84	1.29	1.39	1.02	1.52	0.99	1.47	1.41	0.87	0.52	1.12	0.96	0.95	0.78	**1.09**
8	1.70	1.01	1.63	0.78	1.44	2.54	1.34	1.48	2.52	1.28	1.31	2.72	1.92	0.86	1.18	1.34	2.00	1.25	1.18	1.86	1.86	1.66	2.16	**1.61**
9	0.57	1.19	0.93	0.92	0.92	0.68	0.86	1.09	1.24	1.14	1.52	1.51	1.60	1.55	2.04	1.27	2.96	1.70	1.35	1.38	1.25	1.17	0.65	**1.28**
10	0.81	0.61	1.02	0.79	1.43	1.22	1.48	0.79	1.14	0.62	0.82	0.71	1.24	1.25	1.25	1.33	1.54	0.97	1.47	1.14	0.74	0.60	1.09	**1.05**
11	1.16	0.89	2.04	1.62	1.21	1.55	3.38	4.60	7.09	3.97	2.32	0.67	0.71	1.52	1.64	1.63	1.86	1.57	1.18	2.25	0.76	1.18	0.83	**1.98**
12	4.73	6.89	3.72	2.83	3.88	2.47	1.53	2.58	1.89	0.87	3.24	1.70	0.96	1.58	1.17	1.06	0.96	1.58	2.60	1.54	1.87	1.95	0.83	**2.28**
13	2.29	1.33	1.56	2.18	2.92	2.13	1.92	1.90	1.01	1.42	1.94	3.45	1.17	1.17	1.04	0.84	1.63	1.74	1.56	2.12	1.88	2.95	1.03	**1.79**
14	0.70	0.59	0.64	0.39	0.48	0.62	0.56	0.38	0.52	0.53	0.55	1.60	1.19	1.33	1.05	0.79	1.37	2.00	0.71	1.83	1.33	0.86	1.04	**0.91**
15	1.34	2.49	1.17	4.69	1.25	2.29	1.44	1.35	1.36	1.82	3.10	3.92	2.37	1.61	2.04	1.11	1.96	2.70	1.27	4.28	1.14	0.72	0.70	**2.01**
16	0.54	0.75	0.87	0.63	0.48	0.63	0.49	0.53	1.13	0.54	0.74	0.73	0.71	0.47	0.39	0.35	0.33	0.59	0.50	0.45	0.33	0.39	0.28	**0.56**
17	0.70	0.55	0.56	0.38	0.37	0.94	0.40	0.50																**0.55**
18	0.57	0.77	0.67	0.67	0.53	0.82	0.74	0.49	0.74	0.40	0.68	0.83	0.67	0.55	0.66	0.69	0.46	0.82	0.63	0.54	0.86	1.10	0.58	**0.67**
19	1.95	1.19	1.75	1.01	1.36	1.32	1.37	2.28	2.73	1.90	2.37	1.46	1.82	2.09	0.93	2.13	1.95	1.80	3.20	2.17	1.52	1.84	2.42	**1.85**
20	0.83	1.41	1.14	1.04	0.98	1.04	1.12	1.26	1.15	1.27	2.07	1.98	2.08	1.70	2.65	4.43	3.19	4.01	2.55	1.77	0.80	2.53	2.91	**1.91**
21	0.78	1.02	0.95	0.76	0.75	0.85	1.07	0.52	0.57	0.54	1.11	0.48	0.53	0.62	3.71	0.66	0.88	0.78	0.79	0.93	0.66	0.78	0.79	**0.89**
22	1.02	0.45	0.99	0.54	0.33	0.41	0.42	0.30	0.32	0.30	0.73	0.39	0.42	0.34	0.46	0.32	0.61	0.72	0.58	0.50	0.47	0.33	0.58	**0.50**
23	1.91	0.87	1.35	0.77	0.84	1.27	1.41	1.02	1.45	2.09	1.22	0.99	1.33	1.22	1.24	0.76	0.97	0.57	0.92	1.45	1.49	1.14	1.08	**1.19**
24	1.59	1.30	1.13	1.27	0.89	1.69	0.77	3.33	1.64	2.24	1.15	1.45	1.38	2.08	1.16	1.87	2.15	1.53	1.68	3.03	2.60	1.70	3.08	**1.77**
25	2.34	1.39	0.92	0.83	0.96	0.91	1.37	0.88	0.81	0.88	3.47	1.44	1.58	0.84	1.24	1.19	2.21	0.89	1.36	3.35	1.55	1.18	1.19	**1.42**
26	0.93	0.85	1.09	0.93	1.30	0.78	1.22	1.03	1.30	2.89	2.01	2.24	1.68	1.22	1.81	0.83	1.16	1.42	0.86	0.96	0.56	0.63	0.92	**1.24**

Table 4.15: MSE between GT Profile and Roadware Profile [16th in]

	Station																							
Section	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	1.12	0.59	1.07	1.30	0.74	1.61	0.98	3.27	2.54	2.02	0.88		0.85		0.77		11.92		0.78		0.69		0.94	**1.89**
4	1.33	0.93	1.46	1.47	1.06	1.37	1.31	1.21	1.05	1.06	1.13	1.29	1.60	1.04	1.61	1.03	1.21	1.78	1.46	0.95	1.13	0.98	1.68	**1.27**
5	1.53	1.03	0.82	0.74	1.36	0.88	0.83	0.57	0.61	0.70	1.56	0.73	1.14	1.28	1.21	0.79	0.58	1.02	2.11	1.11	1.10	1.29	0.93	**1.04**
6	1.06	0.73	0.60	1.12	0.57	1.12	1.08	1.11	1.06	1.00	0.66	0.77	0.85	1.17	0.77	0.83	0.72	1.21	0.72	1.33	1.11	0.71	1.11	**0.93**
7	0.45	0.50	0.79	0.39	1.90	1.47	0.57	0.86	0.76	0.74	1.74	0.93	0.57	0.73	0.62	0.94	0.64	0.69	0.98	0.40	1.03	2.48	0.49	**0.90**
8	0.97	1.41	1.33	1.92	0.56	1.78	0.89	0.90	1.70	1.33	1.07	1.62	1.32	1.57	0.91	0.84	1.71	0.98	0.82	0.68	0.63	1.02	1.03	**1.17**
9	1.19	1.55	1.52	0.89	0.88	1.31	1.77	1.34	1.32	1.25	0.92	0.83	1.13	1.17	2.28	1.26	1.22	2.12	3.19	2.60	6.51	1.68	0.63	**1.68**
10	0.98	0.82	1.05	1.52	1.67	0.95	1.14	1.62	1.48	1.24	0.90	1.50	1.43	0.78	1.57	1.30	1.06	0.95	0.94	0.86	1.11	0.56	0.81	**1.14**
11	3.14	0.83	1.08	2.18	1.33	1.56	3.60	4.18	7.09	5.24	2.47	1.16	0.58	6.46	1.44	1.04	1.30	2.97	1.51	1.36	1.86	1.85	1.46	**2.42**
12	5.21	4.78	4.53	1.08	2.91	3.15	1.64	1.98	3.08	1.75	1.84	1.50	2.24	1.60	1.29	1.15	0.99	1.09	2.17	2.92	1.08	1.09	2.20	**2.23**
13	1.05	1.67	1.97	1.49	3.02	1.77	2.60	2.09	1.52	1.68	3.16	0.99	1.23	1.80	3.93	1.14	10.89	1.70	1.22	2.46	3.18	1.97	1.75	**2.36**
14	0.42	0.87	0.55	0.59	0.69	1.11	0.77	0.70	1.13	1.21	0.82	0.96	1.99	3.09	0.58	0.93	0.80	1.82	0.66	1.25	0.81	1.20	0.62	**1.02**
15	6.15	1.71	1.35	1.62	1.04	2.74	0.74	1.61	2.06	0.95	3.41	5.56	3.58	2.08	1.56	1.45	1.99	4.53	1.58	3.47	1.49	2.21	1.32	**2.36**
16	0.33	0.49	0.90	0.51	0.53	0.60	0.50	0.57	1.00	1.80	0.42	0.54	0.55	0.45	0.44	0.23	0.27	0.48	0.35	0.41	0.39	0.30	0.38	**0.54**
17	0.68	0.25	0.31	0.59	0.37	0.55	0.30	0.47	0.42	0.57	0.66	0.74	0.41	0.30	0.56	0.65	0.54	1.12	0.79	0.86	0.77	0.79	0.70	**0.58**
18	0.42	0.49	0.43	0.59	0.41	0.79	0.70	0.53	0.73	0.90	0.59	0.56	0.75	0.38	0.55	0.59	0.84	0.40	0.43	0.40	0.56	0.42	0.59	**0.57**
19	1.34	1.11	2.61	1.89	1.75	1.90	1.62	2.28	5.55	3.21	2.39	4.79	1.24	1.82	2.98	1.67	4.80	2.71	2.70	4.11	2.41	1.87	1.64	**2.54**
20	0.92	1.39	1.10	1.82	0.84	1.29	1.45	0.63	1.39	1.17	1.21	1.77	1.19	1.06	2.86	12.63	1.58	20.07	3.02	1.62	1.00	1.20	1.90	**2.74**
21	0.59	0.69	9.66	0.40	0.35	4.92	0.45	6.37	11.16	0.63	12.98	2.78	12.73	12.76	12.55	11.65	10.57	11.50	0.56	6.64	10.61	0.65	6.48	**6.42**
22	1.04	0.30	1.00	1.08	9.20	8.11	14.45	0.67	0.36	0.32	0.51	0.37	0.31	0.51	0.43	12.19	3.41	0.47	0.37	0.30	0.44	0.34	0.46	**2.46**
23	1.16	1.14	1.40	2.58	1.10	1.17	2.73		5.45	3.81	1.73	2.88	1.43	2.31	2.26	0.98	1.38	1.34						**2.05**
24	18.40	2.48	0.94	2.52	0.88	1.44	0.95	19.25	1.26	1.13	1.15	1.15	0.97	1.13	0.89	14.73	1.09	3.35	1.84	2.05	3.32	1.72	1.44	**3.66**
25	2.28	1.76	1.06	1.32	1.28	2.17	1.76	1.06	1.21	1.64	4.13	2.64	51.68	1.15	4.58	0.55	2.55	5.82	0.88	2.14	3.98	13.69	1.01	**4.80**
26	0.57	0.78	1.66	1.44	1.37	1.69	1.99	2.06	0.87	1.79	1.35	2.11	2.40	5.75	1.84	1.91	2.20	0.88	2.41	2.64	1.59	1.39	0.65	**1.80**

Table 4.16: MSE between GT Profile and Applus Profile [16th in]

Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
	Station																							
3	0.99	1.79	1.21	0.45	0.68	1.28	1.14	1.71	0.98	1.78	0.94		0.49		1.18		0.60		0.76		0.78		1.20	**1.06**
4	1.23	1.29	1.13	1.61	1.23	1.40	1.07	0.85	1.18	1.46	1.20	1.42	1.49	1.46	1.36	1.75	0.81	1.29	0.94	0.95	1.08	1.06	1.43	**1.25**
5	1.09	1.04	0.73	1.36	1.20	0.84	1.45	1.29	0.98	1.12	1.31	1.78	1.79	1.50	1.18	0.83	1.07	1.08	1.19	1.35	0.82	0.97	1.52	**1.19**
6	1.18	1.48	1.33	0.97	1.94	1.19	1.22	0.89	1.38	1.12	1.18	0.81	1.27	1.62	1.07	1.09	1.40	1.12	1.47	1.48	0.98	0.95	1.29	**1.24**
7	1.27	1.13	1.29	0.95	1.08	1.71	2.13	1.52	1.65	1.72	2.63	0.99	1.75	1.68	1.06	1.76	1.32	0.87	1.07	1.60	3.02	1.74	1.72	**1.55**
8	0.84	0.89	0.64	0.75	1.21	1.06	0.96	0.92	1.67	0.73	0.81	0.77	0.99	1.18	0.90	0.80	0.96	0.80	1.04	0.63	1.08	1.81	1.52	**1.00**
9	0.65	0.72	0.74	0.85	1.14	0.91	1.33	0.82	0.79	0.96	1.97	0.92	0.60	1.02	1.13	1.41	1.08	1.92	2.39	1.67	1.12	1.20	0.90	**1.14**
10	1.28	1.01	1.52	0.84	3.24	0.82	1.32	1.29	0.98	0.70	1.30	1.57	1.18	0.77	1.16	0.77	1.15	0.97	1.24	1.14	1.24	0.69	1.09	**1.19**
11	1.08	0.88	1.15	1.20	0.93	1.23	3.48	3.42	6.81	4.51	3.18	0.86	1.36	0.96	1.37	1.21	2.26	1.16	0.69	1.01	0.87	1.03	0.58	**1.79**
12	7.34	4.22		2.33	3.12	2.51	1.83	2.73	2.20	1.85	1.92	3.18	1.02	1.73	1.76	1.21	1.47	1.19	1.75	1.24	1.15	1.42	1.56	**2.21**
13	1.00	1.37	1.20	1.57	1.84	1.41	1.76	1.35	1.91	2.49	1.50	1.26	1.26	1.23	1.26	1.39	1.47	1.28	1.02	2.60	2.22	2.10	3.38	**1.65**
14	0.77	0.49	0.93	1.08	0.48	0.59	0.74	0.34	0.77	0.58	0.65	0.83	1.24	0.92	1.61	1.24	0.86	1.30	0.82	1.83	0.66	0.37	0.72	**0.86**
15	1.09	1.02	1.42	1.13	1.18	2.12	1.12	1.38	1.26	2.48	3.13	4.07	3.16	2.19	4.16	2.27	2.83	6.03	1.17	1.96	3.09	6.98	1.53	**2.47**
16	0.62	0.72	1.02	0.50	0.61	0.87	0.73	0.94	1.20	0.52	0.84	0.59	0.79	0.50	0.48	0.67	0.71	0.63	0.52	0.46	0.46	0.39	0.50	**0.67**
17	0.66	0.77	0.65	0.52	0.65	0.67		0.58	0.64	0.59	0.87	0.96	0.70	0.51	0.40	0.60	0.58	1.03	1.09	0.83	0.70	1.26	0.83	**0.73**
18	0.73	0.62	0.71	0.68	0.51	0.46	0.58	0.46	1.89	0.65	0.79	0.49	0.69	1.56	0.63	0.86	0.47	0.50	0.72	0.63	0.84	0.62	0.65	**0.73**
19	1.38	1.09	2.75	1.42	1.94	1.24	2.23	2.24	6.06		2.27	1.77	2.18	1.62	1.83	2.63	1.93			3.37	2.69	2.19	2.29	**2.26**
20	0.99	1.39	1.34	1.30	1.37	1.28	1.24	1.49	1.40	1.08	1.21	1.80	1.56	2.12	2.31		3.03		2.35			1.86		**1.62**
21	1.01	1.16	0.87	0.98	0.61	1.03	0.82	0.73	0.90	0.62	0.98	0.60	1.08	1.05	0.92	0.87	0.90	1.13	0.76	0.84	0.73	0.69	1.02	**0.88**
22	0.89	0.49	1.39	0.38	0.49	0.42	0.42	0.38	0.33	0.49	0.48	0.51	0.40	0.40	0.47	0.35	0.53	0.57	0.37	0.51	0.63	0.28	0.65	**0.51**
23	1.35	1.31	1.32	1.54	1.80	1.55	2.61	1.58	2.07	1.86	2.41	1.62	2.14	1.48	1.06	1.00	1.44	1.08	1.10	1.70	1.08	1.63	0.97	**1.55**
24	1.01	1.26	1.01	1.37	0.88	1.17	1.40	1.49	2.05	2.03	1.73	1.44	1.18	1.66	1.25	1.98	1.34	2.46	1.31	1.33	2.41		1.68	**1.52**
25	0.87	1.08	1.11	1.17	1.25		2.26	2.40	0.95	0.93	2.99		1.68	1.62	2.12	1.03	1.11	0.86	0.75	2.40	2.00	1.28	1.41	**1.49**
26	0.97	1.17	1.16	0.89	0.94	0.90	1.37	0.93	1.06	1.36	1.73	2.04	1.83	0.92	1.09		0.84	1.14	1.28	1.59	0.88	0.76	0.83	**1.17**

Table 4.17: SSEn between GT Profile and TxDOT Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	2.19	3.07	1.89	1.88	1.66	2.06	2.26	2.38	2.97	2.92	2.24		1.71		1.74		2.00		1.47		1.75		1.26	**2.09**
4	2.47	2.32	1.89	2.14	1.95	2.11	1.96	1.93	2.63	1.96	2.07	2.06	2.08	2.14	1.73	2.06	1.91	2.39	2.06	2.10	1.92	2.89	2.26	**2.13**
5	1.38	1.26	1.23	1.17	1.99	1.73	1.17	1.41	1.64	1.45	1.59	1.68	2.51	1.60	1.66	1.46	1.48	1.64	2.22	1.64	2.30	2.05	2.16	**1.67**
6	1.81	2.33	1.75	2.03	1.85	1.58	2.09	1.93	2.28	2.23	2.18	1.98	2.04	1.54	1.71	2.10	2.13	1.91	2.33	2.95	1.94	2.49	2.55	**2.08**
7	2.16	2.07	1.37	2.87	1.94	1.78	1.68	1.39	1.31	1.44	1.35	1.15	1.87	1.43	1.62	1.70	1.91	1.78	2.05	1.93	1.53	1.87	1.75	**1.74**
8	1.16	1.50	1.24	2.42	1.42	1.93	1.46	1.88	1.65	1.43	1.57	2.04	2.04	2.28	2.29	2.12	2.00	2.20	1.51	1.66	1.59	2.40	1.23	**1.78**
9	0.99	1.06	1.41	1.56	1.44	1.82	3.15	2.44	2.08	1.42	1.76	2.48	1.64	1.39	1.51	1.02	1.55	1.53	1.50	2.10	1.28	1.19	1.58	**1.65**
10	1.61	1.38	1.73	2.26	2.35	1.70	1.51	1.19	1.79	1.56	1.60	1.48	1.33	1.60	1.47	2.09	1.24	1.53	2.01	2.17	1.48	1.43	1.53	**1.65**
11	1.18	1.31	1.98	2.60	1.74	1.64	3.36	3.02	6.41	4.74	2.61	1.20	0.83	1.43	1.30	1.52	1.90	2.08	1.44	1.35	1.15	1.34	1.19	**2.06**
12	4.30	0.87	2.03	2.30	1.72	2.96	1.42	2.84	4.48	1.07	2.95	2.29	1.65	1.98	1.52	2.30	1.58	1.24	1.23	1.91	1.57	2.15	2.60	**2.13**
13	1.41	2.02	1.55	1.31	1.92	1.84	3.21	2.46	2.57	3.12	2.74	2.53	2.09	1.78	3.27	1.56	1.53	1.54	1.40	1.30	1.33	1.32	2.01	**1.99**
14	1.53	1.22	1.39	1.33	1.41	1.87	1.37	1.90	1.61	1.57	2.00	2.25	2.14	2.84	1.91	2.51	2.27	2.88	2.69	2.23	1.59	2.52	2.26	**1.97**
15	1.77	2.34	1.25	1.15	0.86	2.02	1.09	1.89	1.90	2.13	2.63	3.57	3.35	1.16	1.66	1.32	2.65	4.14	0.78	2.32	0.79	0.97	1.09	**1.86**
16	2.46	1.81	1.98	1.49	1.27	1.65	1.77	1.52	2.24	1.63	1.81	2.09	2.08	1.68	1.99	1.89	2.04	1.39	1.60	1.90	1.81	1.73	1.50	**1.80**
17	1.33	1.44	1.25	1.54	2.07	1.75	1.58	1.54	1.27	2.26	1.77	1.48	1.60	1.76	2.24	1.48	2.01	1.52	1.68	1.62	1.58	1.77	2.08	**1.68**
18	1.79	1.27	2.34	2.28	1.94	1.88	1.99	1.71	1.06	0.97	1.37	1.17	1.76	1.60	1.37	1.64	1.57	1.73	1.58	1.72	1.34	1.48	1.33	**1.60**
19	1.94	1.83	3.84	2.02	2.20	3.00	3.62	3.18	5.05	3.90	4.22	2.61	3.36	1.97	2.11	2.80	1.65	3.68	3.50	5.61	2.62	2.53	4.13	**3.10**
20	2.56	2.17	3.29	2.59	2.78	2.01	2.04	2.46	2.58	2.39	2.05	2.31	4.36	3.34	2.08	7.26	6.05	5.56	2.68	3.52	1.95	2.44	2.11	**3.07**
21	1.52	1.77	1.68	1.81	1.48	1.66	1.57	1.40	1.35	1.27	1.33	1.45	1.23	1.57	1.45	1.36	1.40	1.71	1.63	1.89	2.44	2.32	1.87	**1.62**
22	1.56	1.56	2.32	1.49	1.61	1.46	1.20	1.00	1.42	0.92	0.90	0.89	1.30	1.42	1.78	1.43	1.59	2.01	1.88	2.07	1.94	1.61	1.37	**1.51**
23	4.04	3.22	4.55	3.58	5.35	3.17	3.90	3.45	3.96	4.22	3.52	3.83	3.55	2.76	2.30	1.90	1.27	1.29	1.63	1.38	3.48	4.46	1.84	**3.16**
24	2.94	2.77	1.85	1.90	1.51	3.63	1.63	2.86	3.40	4.66	4.15	3.24	2.78	4.41	3.89	4.55	3.62	3.47	2.24	2.71	6.22	3.88	4.40	**3.34**
25	1.90	2.29	3.02	2.40	1.96	1.46	1.19	1.43	1.64	1.71	3.45	2.01	2.02	2.41	2.55	1.35	2.02	2.29	2.66	2.87	2.12	2.13	1.48	**2.10**
26	1.96	1.75	2.18	2.25	1.90	1.74	2.03	2.16	1.91	2.18	2.97	3.48	1.91	2.39	2.46	1.92	1.69	1.78	2.03	1.59	1.52	1.65	1.60	**2.05**

Table 4.18: SSEn between GT Profile and Pathway Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	1.87	2.03	1.41	1.48	1.65	1.29	1.78	2.47	1.39	2.30	0.98		1.06		1.55		1.22		2.01		1.94		1.84	**1.66**
4	1.69	1.27	1.52	2.03	1.39	1.54	1.67	1.71	1.27	1.45	1.57	1.99	1.62	1.68	1.45	1.87	1.45	1.64	1.85	1.44	1.51	1.40	1.74	**1.60**
5	1.11	1.20	1.35	1.43	0.99	1.20	1.68	1.32	1.18	1.39	1.24	1.60	1.52	1.87	1.52	1.33	0.99	1.13	1.04	1.59	0.92	1.29	1.86	**1.34**
6	1.33	1.15	0.98	1.39	1.18	1.22	0.96	1.18	1.66	1.25	1.90	1.31	1.37	1.29	1.17	1.08	1.23	1.88	1.28	1.37	1.40	1.20	1.17	**1.30**
7	0.86	1.35	0.79	0.72	0.96	0.72	1.44	1.19	2.50	1.05	0.92	1.08	0.99	0.95	0.97	1.29	1.13	1.29	1.25	1.09	1.02	0.99	1.28	**1.12**
8	2.25	1.20	1.07	0.97	1.02	1.57	1.22	1.67	1.62	1.11	1.18	1.56	1.12	1.13	1.28	1.31	1.26	1.34	1.25	1.42	1.67	1.44	1.69	**1.36**
9	1.45	1.48	1.65	1.28	1.18	1.09	1.09	1.36	1.43	1.32	1.51	1.16	1.54	1.59	1.10	1.17	4.08	4.54	0.87	3.06	1.32	1.15	1.22	**1.64**
10	1.60	1.19	1.81	1.48	1.40	1.12	1.35	1.49	1.65	1.54	1.44	1.70	1.58	1.88	1.65	1.55	1.52	1.51	1.60	1.57	1.51	1.46	1.80	**1.54**
11	2.60	3.98	0.90	1.29	1.10	1.63	3.72	4.95	6.84	4.72	3.26	1.16	1.00	1.32	7.09	1.81	1.58	1.48	1.47	2.20	1.41	1.80	2.72	**2.61**
12	7.11	3.11	9.30	1.81	2.47	3.75	6.61	1.57	2.42	1.43	3.72	1.35	2.84	2.13	1.82	2.27	1.83	1.85	3.59	2.68	2.21	1.65	1.37	**3.00**
13	1.46	1.54	1.33	1.80	1.65	2.43	3.13	1.68	6.88	2.55	4.60	1.93	2.03	1.58	1.93	1.40	1.20	1.57	1.56	1.59	1.32	0.84	1.25	**2.06**
14	1.34	1.37	1.24	1.16	1.42	1.29	1.38	1.24	1.76	1.35	1.82	1.13	2.04	1.58	1.37	1.13	1.60	1.75	0.99	1.07	0.98	0.95	1.36	**1.36**
15	1.36	0.90	1.31	0.62	0.60	2.32	0.67	1.60	0.91	4.25	4.94	4.81	3.08	3.68	2.54	2.25	1.99	4.81	7.80	2.35	7.36	1.04	1.23	**2.71**
16	0.84	1.08	0.99	1.12	1.08	1.17	1.11	1.18	1.17	1.16	1.21	1.00	1.17	0.95	0.94	1.02	1.14	1.19	0.97	1.06	1.17	1.12	0.97	**1.08**
17	1.14	0.91	1.10	1.11	1.36	1.35	1.28	1.00	0.77	0.87	1.20	0.86	0.85	0.72	0.91	0.73	1.29	1.16	1.28	1.14	1.42	0.98	0.97	**1.06**
18	1.33	1.18	1.33	1.26	0.83	1.02	1.10	1.16	1.12	1.24	1.08	1.12	1.12	1.21	1.22	1.45	1.17	1.33	1.12	1.38	1.00	1.65	1.34	**1.21**
19	6.12	3.34	3.35	1.83	1.48	3.65	1.18	1.83	4.19		1.31	1.22	2.06	2.54	1.06	1.12	0.97	3.44	4.49	8.55	4.52	1.31	2.99	**2.84**
20	1.55	1.35	1.21	2.25	1.33	1.54	1.03	1.30	1.70	1.64	1.82	6.39	9.21	4.16	14.13	15.28	8.66	7.27	7.60	6.71	5.62	1.81	4.12	**4.68**
21	1.13	1.10	1.18	0.98	1.19	0.86	1.34	0.83	0.90	0.90	0.87	0.98	1.03	1.07	1.19	1.06	0.80	1.00	1.16	0.91	1.08	1.08	1.07	**1.03**
22	1.19	1.10	1.74	1.09	1.11	1.24	1.04	1.09	1.35	1.26	1.33	0.95	1.14	1.06	1.09	1.17	1.02	1.09	1.18	1.02	0.98	1.09	1.19	**1.15**
23	1.58	4.79	2.76	3.17	9.97	1.69	9.67	1.71	1.62	13.98	5.32	3.75	2.72	1.31	1.24	1.28	1.53	1.57	1.15	1.36	1.69	1.51	1.34	**3.33**
24	7.92	1.35	2.78	1.49	1.24	1.51	1.36	1.73	3.41	4.48	1.70	0.93	5.34	6.47	5.91	2.17	2.40	7.53	3.03	4.48	7.77	3.03	1.63	**3.46**
25	4.07	1.56	1.27	1.10	1.47	4.77	2.11	5.24	2.58	3.53	1.42	0.96	5.42	2.32	4.65	2.30	4.81	1.96	3.36	7.90	4.92	2.01	2.59	**3.14**
26	1.34	1.43	3.27	0.94	1.00	0.85	1.43	2.02	1.91	10.48	3.92	3.22	2.47	1.62	7.16	2.96	1.67	1.39	1.78	1.21	4.10	1.42	1.44	**2.57**

Table 4.19: SSEn between GT Profile and Dynatest Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	1.17	1.61	0.60	0.96	0.78	2.15	1.00	1.84	0.70	1.63	0.97		0.62		0.92		0.88		0.46		0.99		1.03	**1.08**
4	1.55	0.97	1.49	1.43	1.19	1.54	1.17	1.33	0.98	1.06	1.17	1.44	1.62	1.10	1.27	1.14	0.94	1.43	1.26	0.97	1.11	2.10	1.33	**1.29**
5	0.54	0.66	0.77	0.94	0.76	1.38	0.76	0.59	0.68	0.74	0.87	1.18	0.74	2.05	0.93	0.72	0.59	0.84	1.25	0.88	0.70	0.52	1.67	**0.90**
6	1.11	1.32	0.96	0.99	1.42	1.31	0.86	1.11	1.19	1.65	1.46	1.25	1.11	1.81	0.87	1.02	1.64	0.90	1.07	1.17	1.06	1.41	1.69	**1.23**
7	0.77	0.75	0.82	1.43	1.55	1.05	1.15	0.76	1.51	0.82	1.26	1.36	1.00	1.49	0.96	1.44	1.37	0.85	0.50	1.09	0.93	0.93	0.76	**1.07**
8	1.66	0.99	1.59	0.76	1.41	2.49	1.31	1.45	2.47	1.25	1.28	2.66	1.88	0.85	1.15	1.31	1.96	1.22	1.15	1.82	1.81	1.62	2.11	**1.57**
9	0.55	1.16	0.91	0.90	0.90	0.66	0.84	1.06	1.21	1.12	1.48	1.47	1.56	1.51	1.99	1.24	2.89	1.65	1.32	1.35	1.22	1.14	0.63	**1.25**
10	0.79	0.60	1.00	0.77	1.40	1.19	1.45	0.77	1.11	0.60	0.80	0.70	1.21	1.22	1.22	1.30	1.51	0.94	1.43	1.11	0.72	0.58	1.06	**1.02**
11	1.13	0.87	1.99	1.59	1.18	1.51	3.30	4.47	6.90	3.86	2.26	0.65	0.69	1.48	1.60	1.59	1.81	1.52	1.15	2.19	0.73	1.14	0.81	**1.93**
12	4.61	6.73	3.62	2.76	3.78	2.41	1.49	2.52	1.85	0.84	3.16	1.66	0.93	1.54	1.14	1.04	0.94	1.54	2.55	1.50	1.82	1.90	0.81	**2.22**
13	2.23	1.30	1.52	2.13	2.85	2.08	1.87	1.86	0.99	1.39	1.89	3.37	1.14	1.14	1.01	0.82	1.59	1.70	1.51	2.07	1.83	2.88	1.00	**1.75**
14	0.68	0.58	0.62	0.38	0.47	0.61	0.54	0.37	0.51	0.52	0.54	1.57	1.17	1.31	1.03	0.77	1.34	1.96	0.70	1.79	1.30	0.84	1.01	**0.90**
15	1.31	2.43	1.14	4.58	1.22	2.24	1.41	1.32	1.32	1.78	3.02	3.82	2.31	1.56	1.99	1.08	1.91	2.65	1.24	4.18	1.11	0.70	0.69	**1.96**
16	0.53	0.73	0.85	0.62	0.47	0.61	0.48	0.52	1.11	0.52	0.72	0.71	0.70	0.46	0.38	0.34	0.32	0.57	0.49	0.44	0.33	0.38	0.27	**0.55**
17	0.68	0.54	0.54	0.37	0.37	0.92	0.39	0.49																**0.54**
18	0.56	0.75	0.65	0.66	0.52	0.81	0.72	0.48	0.72	0.39	0.67	0.81	0.66	0.54	0.64	0.68	0.45	0.80	0.62	0.52	0.85	1.07	0.57	**0.66**
19	1.91	1.17	1.72	0.99	1.33	1.29	1.35	2.22	2.66	1.86	2.32	1.43	1.78	2.05	0.91	2.09	1.90	1.76	3.13	2.12	1.48	1.81	2.38	**1.81**
20	0.82	1.39	1.12	1.01	0.96	1.02	1.10	1.24	1.12	1.24	2.03	1.94	2.04	1.67	2.60	4.34	3.13	3.92	2.48	1.73	0.78	2.48	2.85	**1.87**
21	0.77	1.00	0.93	0.74	0.73	0.83	1.05	0.51	0.56	0.53	1.09	0.47	0.52	0.61	3.64	0.64	0.87	0.76	0.78	0.91	0.65	0.76	0.77	**0.87**
22	1.00	0.44	0.96	0.52	0.32	0.40	0.41	0.29	0.31	0.29	0.72	0.38	0.41	0.34	0.45	0.32	0.60	0.70	0.57	0.49	0.46	0.33	0.57	**0.49**
23	1.87	0.84	1.32	0.75	0.82	1.24	1.37	1.00	1.42	2.04	1.19	0.96	1.30	1.20	1.21	0.74	0.95	0.55	0.89	1.41	1.46	1.11	1.05	**1.16**
24	1.55	1.26	1.10	1.24	0.87	1.65	0.75	3.25	1.60	2.19	1.13	1.42	1.34	2.03	1.13	1.83	2.10	1.50	1.64	2.95	2.54	1.66	3.01	**1.73**
25	2.28	1.36	0.90	0.81	0.93	0.88	1.34	0.86	0.79	0.86	3.40	1.41	1.54	0.82	1.21	1.16	2.16	0.87	1.33	3.28	1.51	1.15	1.16	**1.39**
26	0.91	0.83	1.06	0.91	1.27	0.76	1.20	1.01	1.28	2.83	1.97	2.19	1.64	1.20	1.77	0.81	1.14	1.38	0.84	0.94	0.55	0.61	0.90	**1.22**

Table 4.20: SSEn between GT Profile and Roadware Profile [16th in]

Section	Station																							
	0	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	1.09	0.57	1.04	1.26	0.72	1.57	0.96	3.19	2.47	1.97	0.85		0.83		0.75		11.62		0.76		0.67		0.92	**1.84**
4	1.29	0.91	1.42	1.43	1.03	1.33	1.28	1.18	1.02	1.03	1.10	1.25	1.56	1.01	1.56	1.01	1.18	1.74	1.42	0.93	1.10	0.95	1.64	**1.23**
5	1.49	1.00	0.80	0.72	1.32	0.86	0.81	0.55	0.59	0.68	1.52	0.71	1.11	1.24	1.18	0.77	0.57	0.99	2.06	1.08	1.07	1.26	0.91	**1.01**
6	1.03	0.71	0.58	1.09	0.55	1.09	1.06	1.08	1.03	0.98	0.64	0.75	0.83	1.14	0.75	0.81	0.70	1.18	0.70	1.29	1.08	0.69	1.08	**0.91**
7	0.44	0.49	0.77	0.38	1.85	1.43	0.56	0.83	0.74	0.72	1.69	0.91	0.56	0.71	0.60	0.91	0.63	0.68	0.96	0.39	1.01	2.41	0.48	**0.88**
8	0.94	1.37	1.30	1.87	0.55	1.74	0.87	0.87	1.66	1.30	1.04	1.57	1.29	1.53	0.89	0.82	1.67	0.96	0.80	0.67	0.61	0.99	1.01	**1.14**
9	1.16	1.51	1.48	0.86	0.85	1.27	1.73	1.30	1.28	1.22	0.89	0.81	1.10	1.14	2.22	1.23	1.19	2.06	3.10	2.53	6.34	1.63	0.62	**1.63**
10	0.95	0.80	1.03	1.48	1.63	0.92	1.11	1.58	1.44	1.21	0.88	1.46	1.39	0.76	1.53	1.27	1.03	0.92	0.92	0.83	1.08	0.55	0.79	**1.11**
11	3.05	0.81	1.05	2.12	1.30	1.52	3.51	4.08	6.90	5.10	2.40	1.13	0.56	6.29	1.40	1.01	1.27	2.89	1.47	1.32	1.81	1.80	1.42	**2.36**
12	5.08	4.65	4.40	1.05	2.84	3.07	1.59	1.93	3.00	1.70	1.79	1.46	2.18	1.55	1.26	1.12	0.96	1.06	2.12	2.84	1.05	1.06	2.15	**2.17**
13	1.02	1.62	1.91	1.45	2.94	1.72	2.53	2.04	1.48	1.64	3.08	0.96	1.20	1.75	3.83	1.11	10.62	1.66	1.19	2.39	3.10	1.92	1.70	**2.30**
14	0.41	0.85	0.53	0.58	0.68	1.08	0.75	0.68	1.10	1.18	0.80	0.93	1.94	3.02	0.56	0.90	0.78	1.77	0.64	1.22	0.79	1.16	0.60	**1.00**
15	6.00	1.67	1.31	1.57	1.01	2.67	0.72	1.57	2.00	0.93	3.32	5.42	3.49	2.02	1.52	1.41	1.94	4.41	1.54	3.38	1.45	2.15	1.29	**2.30**
16	0.32	0.47	0.87	0.50	0.51	0.58	0.49	0.55	0.98	1.76	0.41	0.53	0.54	0.44	0.43	0.22	0.26	0.47	0.34	0.40	0.38	0.29	0.37	**0.53**
17	0.66	0.24	0.31	0.58	0.36	0.54	0.29	0.46	0.40	0.55	0.64	0.72	0.40	0.29	0.55	0.63	0.53	1.09	0.77	0.84	0.75	0.77	0.68	**0.57**
18	0.41	0.48	0.42	0.57	0.40	0.77	0.68	0.51	0.71	0.87	0.58	0.54	0.73	0.37	0.53	0.57	0.82	0.39	0.42	0.39	0.55	0.41	0.58	**0.55**
19	1.30	1.08	2.54	1.84	1.70	1.85	1.58	2.22	5.40	3.13	2.33	4.67	1.21	1.78	2.90	1.63	4.67	2.65	2.63	4.00	2.35	1.82	1.60	**2.47**
20	0.89	1.35	1.07	1.78	0.81	1.26	1.42	0.61	1.36	1.14	1.17	1.72	1.16	1.03	2.79	12.31	1.54	19.58	2.94	1.58	0.97	1.17	1.85	**2.67**
21	0.58	0.67	9.43	0.39	0.34	4.80	0.44	6.21	10.89	0.62	12.65	2.71	12.41	12.46	12.25	11.37	10.32	11.23	0.54	6.48	10.35	0.63	6.32	**6.26**
22	1.01	0.29	0.97	1.06	8.98	7.92	14.10	0.66	0.35	0.31	0.50	0.36	0.30	0.50	0.42	11.90	3.33	0.46	0.36	0.29	0.43	0.33	0.45	**2.40**
23	1.13	1.12	1.36	2.51	1.07	1.14	2.66		5.31	3.71	1.69	2.81	1.39	2.25	2.19	0.95	1.34	1.30						**2.00**
24	18.01	2.42	0.91	2.46	0.86	1.40	0.93	18.79	1.23	1.10	1.13	1.12	0.94	1.11	0.87	14.38	1.06	3.26	1.80	2.00	3.26	1.67	1.40	**3.57**
25	2.22	1.71	1.03	1.29	1.25	2.12	1.71	1.03	1.18	1.60	4.02	2.57	50.58	1.12	4.46	0.54	2.48	5.68	0.86	2.08	3.87	13.36	0.99	**4.68**
26	0.55	0.76	1.62	1.40	1.33	1.65	1.94	2.00	0.85	1.74	1.32	2.05	2.34	5.60	1.79	1.86	2.14	0.85	2.35	2.58	1.55	1.35	0.64	**1.75**

Table 4.21: SSEn between GT Profile and Applus Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	0.97	1.75	1.19	0.44	0.67	1.25	1.11	1.67	0.96	1.75	0.92		0.48		1.16		0.58		0.75		0.77		1.18	**1.04**
4	1.20	1.26	1.10	1.58	1.20	1.37	1.05	0.83	1.16	1.43	1.18	1.39	1.45	1.43	1.33	1.71	0.79	1.27	0.92	0.93	1.06	1.04	1.40	**1.22**
5	1.07	1.01	0.71	1.33	1.17	0.82	1.42	1.26	0.96	1.10	1.28	1.74	1.75	1.46	1.15	0.81	1.05	1.06	1.16	1.32	0.80	0.95	1.48	**1.17**
6	1.15	1.45	1.30	0.95	1.90	1.17	1.20	0.87	1.35	1.10	1.15	0.80	1.24	1.58	1.04	1.07	1.37	1.10	1.44	1.44	0.96	0.93	1.27	**1.21**
7	1.24	1.10	1.27	0.93	1.06	1.68	2.08	1.48	1.61	1.69	2.57	0.97	1.71	1.64	1.04	1.72	1.29	0.85	1.05	1.56	2.95	1.70	1.68	**1.52**
8	0.82	0.87	0.62	0.74	1.18	1.03	0.94	0.90	1.63	0.71	0.80	0.75	0.96	1.15	0.88	0.78	0.93	0.78	1.01	0.61	1.05	1.76	1.48	**0.97**
9	0.63	0.70	0.73	0.83	1.11	0.88	1.30	0.79	0.77	0.93	1.92	0.89	0.59	0.99	1.10	1.37	1.05	1.87	2.33	1.62	1.09	1.17	0.87	**1.11**
10	1.24	0.98	1.48	0.82	3.17	0.80	1.28	1.26	0.96	0.68	1.27	1.53	1.15	0.75	1.13	0.75	1.12	0.95	1.20	1.11	1.21	0.67	1.06	**1.16**
11	1.05	0.86	1.12	1.17	0.91	1.20	3.39	3.33	6.63	4.39	3.10	0.84	1.33	0.93	1.33	1.18	2.21	1.13	0.68	0.98	0.85	1.00	0.57	**1.75**
12	7.17	4.11		2.28	3.05	2.45	1.79	2.66	2.15	1.80	1.87	3.10	0.99	1.69	1.72	1.18	1.43	1.16	1.71	1.21	1.12	1.39	1.53	**2.16**
13	0.97	1.34	1.17	1.53	1.79	1.38	1.71	1.32	1.86	2.43	1.46	1.23	1.22	1.20	1.23	1.35	1.43	1.25	0.99	2.53	2.17	2.05	3.30	**1.61**
14	0.76	0.48	0.91	1.06	0.47	0.58	0.72	0.34	0.76	0.56	0.64	0.81	1.22	0.90	1.57	1.21	0.84	1.28	0.81	1.79	0.64	0.36	0.71	**0.84**
15	1.07	1.00	1.38	1.11	1.15	2.07	1.10	1.34	1.23	2.42	3.05	3.97	3.08	2.14	4.05	2.22	2.76	5.89	1.14	1.92	3.02	6.81	1.49	**2.41**
16	0.60	0.71	1.00	0.49	0.60	0.85	0.71	0.92	1.18	0.51	0.83	0.58	0.77	0.49	0.46	0.66	0.70	0.62	0.51	0.45	0.45	0.38	0.49	**0.65**
17	0.65	0.76	0.63	0.51	0.64	0.66		0.57	0.62	0.58	0.85	0.94	0.69	0.50	0.39	0.59	0.57	1.01	1.07	0.81	0.69	1.23	0.81	**0.72**
18	0.71	0.60	0.70	0.66	0.50	0.45	0.56	0.44	1.84	0.63	0.77	0.48	0.67	1.53	0.61	0.84	0.46	0.49	0.70	0.62	0.82	0.60	0.64	**0.71**
19	1.35	1.07	2.70	1.39	1.90	1.21	2.19	2.20	5.93		2.22	1.73	2.13	1.59	1.79	2.57	1.89			3.30	2.63	2.15	2.24	**2.21**
20	0.97	1.36	1.31	1.27	1.34	1.25	1.22	1.46	1.37	1.06	1.18	1.76	1.52	2.08	2.26		2.96		2.30			1.82		**1.58**
21	0.99	1.13	0.85	0.96	0.60	1.01	0.80	0.71	0.88	0.61	0.96	0.59	1.06	1.03	0.91	0.85	0.88	1.11	0.74	0.82	0.72	0.68	1.00	**0.86**
22	0.87	0.48	1.36	0.37	0.48	0.41	0.41	0.37	0.33	0.48	0.47	0.50	0.39	0.39	0.46	0.35	0.52	0.56	0.36	0.50	0.61	0.27	0.64	**0.50**
23	1.31	1.28	1.29	1.50	1.76	1.51	2.55	1.54	2.02	1.81	2.35	1.58	2.09	1.44	1.03	0.98	1.40	1.05	1.07	1.66	1.05	1.59	0.94	**1.51**
24	0.98	1.22	0.99	1.34	0.86	1.14	1.37	1.45	2.01	1.98	1.69	1.40	1.15	1.62	1.22	1.93	1.31	2.41	1.28	1.29	2.35		1.64	**1.48**
25	0.85	1.05	1.09	1.14	1.23		2.21	2.34	0.93	0.91	2.93		1.65	1.58	2.08	1.00	1.08	0.84	0.74	2.34	1.96	1.26	1.38	**1.46**
26	0.95	1.15	1.14	0.87	0.92	0.88	1.34	0.91	1.04	1.33	1.69	1.99	1.79	0.89	1.06		0.83	1.11	1.25	1.55	0.86	0.74	0.81	**1.14**

Table 4.22: Correlation between GT Profile and TxDOT Profile [16th in]

	Station																							
Section	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00		1.00		1.00		1.00		1.00		1.00	**1.00**
4	0.99	0.99	1.00	0.99	1.00	0.99	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.99	**0.99**
5	0.96	0.97	0.97	0.99	0.87	0.91	0.93	0.96	0.90	0.95	0.93	0.97	0.93	0.97	0.94	0.94	0.94	0.92	0.92	0.99	0.97	0.99	0.99	**0.95**
6	0.99	0.99	1.00	0.99	0.99	1.00	0.99	1.00	0.99	0.99	0.99	1.00	0.99	1.00	0.99	0.98	0.99	1.00	0.99	0.99	1.00	0.99	0.99	**0.99**
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.98	0.98	0.98	0.97	0.91	0.92	0.78	0.80	0.91	0.89	0.88	**0.96**
8	1.00	1.00	1.00	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
9	1.00	1.00	0.99	0.99	0.99	0.98	0.95	0.98	0.98	1.00	0.99	0.98	0.99	0.99	0.99	0.99	1.00	1.00	1.00	0.99	1.00	0.99	0.99	**0.99**
10	0.83	0.94	0.74	0.92	0.99	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.99	1.00	0.99	0.99	0.99	0.98	0.98	**0.96**
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	**1.00**
12	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
13	0.99	0.99	1.00	1.00	0.99	0.99	0.98	1.00	0.99	0.99	0.99	0.99	1.00	1.00	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	**0.99**
14	0.98	0.99	0.99	0.99	0.99	0.98	0.99	0.99	0.97	0.98	0.96	0.98	0.92	0.87	0.96	0.98	0.98	0.98	0.99	0.99	1.00	0.98	0.99	**0.98**
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	**1.00**
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
17	0.87	0.79	0.95	0.99	0.96	0.97	0.99	0.99	0.98	0.92	0.99	1.00	1.00	1.00	0.99	1.00	0.98	0.98	0.98	0.99	0.99	0.98	0.97	**0.97**
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
19	1.00	1.00	0.99	0.99	1.00	0.99	0.99	0.99	0.98	0.99	0.99	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.99	1.00	1.00	0.99	**0.99**
20	0.94	0.91	0.92	0.97	0.96	0.95	0.97	0.98	0.94	0.98	0.97	0.98	0.97	0.99	1.00	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	**0.97**
21	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	1.00	0.99	0.99	0.99	0.99	0.99	0.99	**0.99**
22	1.00	1.00	0.99	1.00	1.00	0.99	0.79	0.98	0.98	1.00	0.99	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	**0.99**
23	0.97	0.98	0.98	0.98	0.96	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.97	0.97	0.97	0.95	0.88	0.96	**0.97**
24	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	0.99	0.99	1.00	0.99	0.99	0.98	0.99	0.99	**0.99**
25	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.94	0.98	0.99	0.98	0.90	**0.99**

Table 4.23: Correlation between GT Profile and Pathway Profile [16th in]

	Station																							
Section	**0**	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00		1.00		1.00		1.00		0.99		0.99	**1.00**
4	0.99	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	**0.99**
5	0.98	0.97	0.96	0.98	0.96	0.93	0.79	0.94	0.92	0.86	0.93	0.94	0.96	0.90	0.96	0.93	0.96	0.94	0.98	0.98	0.98	0.99	0.98	**0.94**
6	0.99	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	0.99	0.99	1.00	1.00	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	**0.99**
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.97	0.96	0.96	0.92	0.93	0.82	0.92	0.87	**0.97**
8	0.99	1.00	1.00	1.00	0.99	0.99	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	**1.00**
9	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.97	0.97	1.00	0.98	0.99	0.99	0.97	**0.99**
10	0.83	0.93	0.61	0.94	1.00	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.98	0.98	0.97	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.96	**0.96**
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.99	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.95	**0.99**
12	0.98	1.00	0.96	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	**0.99**
13	0.99	0.99	1.00	0.99	0.99	0.97	0.98	1.00	0.94	0.99	0.97	0.99	0.99	1.00	0.99	0.99	1.00	0.99	0.99	1.00	1.00	1.00	0.99	**0.99**
14	0.98	0.96	0.98	0.99	0.98	0.99	0.99	0.99	0.95	0.97	0.96	0.99	0.82	0.96	0.98	1.00	0.99	0.99	1.00	1.00	1.00	0.99	0.99	**0.98**
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.99	1.00	0.99	1.00	1.00	1.00	0.99	0.97	1.00	0.96	1.00	1.00	**0.99**
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
17	0.90	0.90	0.96	0.99	0.97	0.98	0.99	0.99	0.99	0.98	0.99	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.99	0.99	0.99	0.99	0.99	**0.98**
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
19	0.98	0.99	0.99	0.99	1.00	0.99	1.00	1.00	0.97		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.97	0.99	1.00	0.99	**0.99**
20	0.89	0.92	0.97	0.71	0.98	0.96	0.99	0.99	0.95	0.94	0.96	0.21	0.81	0.99	0.64	0.87	0.98	0.97	0.97	0.98	0.98	1.00	0.98	**0.90**
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
22	1.00	1.00	0.99	1.00	1.00	0.99	0.80	0.96	0.98	0.99	0.98	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	**0.98**
23	1.00	0.97	0.99	0.99	0.87	1.00	0.94	1.00	1.00	0.83	0.96	0.99	1.00	1.00	0.99	0.99	0.97	0.90	0.98	0.94	0.99	0.97	0.98	**0.97**
24	0.96	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	0.97	0.97	0.99	1.00	0.99	0.98	0.98	0.97	0.96	0.99	1.00	**0.99**
25	0.99	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	**1.00**
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.98	0.99	0.99	1.00	0.99	0.99	0.99	0.99	0.97	0.99	0.93	0.99	0.85	**0.98**

Table 4.24: Correlation between GT Profile and Dynatest Profile [16th in]

	Station																							
Section	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00		1.00		1.00		1.00		1.00		1.00	**1.00**
4	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	**1.00**
5	0.99	0.99	0.99	0.99	0.98	0.91	0.97	0.99	0.97	0.99	0.99	0.97	0.99	0.84	0.98	0.98	0.99	0.98	0.98	0.99	0.99	1.00	0.99	**0.98**
6	0.99	1.00	1.00	1.00	0.99	0.99	1.00	1.00	0.99	0.99	1.00	1.00	1.00	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.99	0.98	0.99	0.97	0.95	0.98	0.99	0.94	0.88	0.94	0.96	**0.98**
8	0.99	1.00	0.99	1.00	0.99	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
9	1.00	0.99	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.99	0.99	0.98	0.99	0.98	1.00	1.00	1.00	0.99	0.99	1.00	**0.99**
10	0.95	0.98	0.89	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.98	0.99	0.99	1.00	0.99	1.00	1.00	1.00	0.99	**0.99**
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
12	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
13	0.98	1.00	1.00	0.99	0.97	0.99	0.99	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.99	1.00	**0.99**
14	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.97	0.99	1.00	0.99	0.99	1.00	0.99	1.00	1.00	0.99	**0.99**
15	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	**1.00**
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
17	0.96	0.96	0.99	1.00	1.00	0.99	1.00	1.00																**0.99**
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
19	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.99	1.00	1.00	1.00	1.00	**1.00**
20	0.99	0.92	0.99	0.94	0.99	0.98	0.99	1.00	0.99	0.98	0.96	0.97	0.99	1.00	0.99	0.99	1.00	0.99	1.00	1.00	1.00	1.00	0.99	**0.98**
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
22	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
23	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.97	0.99	0.99	0.98	**0.99**
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.99	**1.00**
25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.99	0.99	1.00	1.00	0.96	**1.00**

Table 4.25: Correlation between GT Profile and Roadware Profile [16th in]

		Station																						
		0	**25**	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**	**375**	**400**	**425**	**450**	**475**	**500**	**525**	**550**	**Avg**
Section	**3**	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00		1.00		1.00		0.90		1.00		1.00		1.00	**0.99**
	4	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.99	1.00	1.00	0.99	0.99	1.00	1.00	1.00	0.99	**0.99**
	5	0.97	0.98	0.99	0.99	0.96	0.97	0.97	0.99	0.98	0.97	0.92	0.99	0.98	0.97	0.97	0.98	0.99	0.95	0.94	0.99	0.99	0.99	1.00	**0.98**
	6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
	7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.96	0.99	0.84	0.73	0.99	**0.98**
	8	1.00	1.00	0.99	0.99	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
	9	1.00	0.99	0.99	1.00	1.00	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.98	0.99	1.00	0.99	0.99	0.99	0.91	0.98	1.00	**0.99**
	10	0.95	0.97	0.88	0.94	0.99	1.00	1.00	0.99	0.99	0.99	0.99	0.98	0.98	1.00	0.97	0.99	1.00	1.00	1.00	1.00	0.99	1.00	1.00	**0.98**
	11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00	1.00	0.99	0.99	0.99	**1.00**
	12	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.99	**1.00**
	13	1.00	0.99	0.99	1.00	0.98	0.99	0.99	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.97	1.00	0.78	0.99	1.00	0.99	0.99	0.99	0.99	**0.98**
	14	1.00	0.99	0.99	1.00	1.00	0.99	1.00	1.00	0.98	0.97	0.99	0.99	0.84	0.78	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00	**0.98**
	15	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00	1.00	**1.00**
	16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
	17	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	0.99	1.00	1.00	0.99	0.99	**0.99**
	18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
	19	1.00	1.00	0.99	0.98	0.99	0.99	1.00	0.99	0.96	0.99	1.00	0.98	1.00	1.00	0.99	0.99	0.92	0.99	1.00	0.99	1.00	1.00	1.00	**0.99**
	20	0.95	0.90	0.98	0.75	0.99	0.97	0.98	1.00	0.97	0.97	0.98	0.96	1.00	1.00	0.99	0.94	1.00	0.84	1.00	1.00	1.00	1.00	1.00	**0.96**
	21	1.00	1.00	0.79	1.00	1.00	0.96	1.00	0.93	0.71	1.00	0.61	0.98	0.53	0.53	0.47	0.52	0.63	0.62	1.00	0.88	0.69	1.00	0.90	**0.81**
	22	1.00	1.00	1.00	1.00	0.78	0.59	-0.25	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.89	0.99	1.00	1.00	1.00	1.00	1.00	1.00	**0.91**
	23	1.00	1.00	1.00	0.99	1.00	1.00	1.00		0.96	0.99	1.00	0.99	1.00	0.99	0.99	1.00	0.99	0.97						**0.99**
	24	0.81	1.00	1.00	0.99	1.00	1.00	1.00	0.59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	1.00	1.00	0.99	0.99	1.00	1.00	1.00	**0.97**
	25	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.51	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.96	1.00	**0.98**
	26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.99	0.99	0.97	0.92	0.99	0.99	0.97	**0.99**

Table 4.26: Correlation between GT Profile and Applus Profile [16th in]

Section	Station																						
	0	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	Avg
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00		1.00		1.00		1.00		1.00		1.00	**1.00**
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	0.99	**1.00**
5	0.98	0.98	0.99	0.98	0.96	0.97	0.89	0.97	0.97	0.98	0.96	0.97	0.97	0.98	0.98	0.98	0.97	0.97	0.98	0.99	1.00	1.00	0.99	**0.97**
6	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
7	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	0.99	0.97	1.00	0.99	0.97	0.99	0.97	0.95	0.98	0.95	0.88	0.62	0.79	0.90	**0.95**
8	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
9	1.00	1.00	1.00	1.00	0.99	1.00	0.99	1.00	1.00	1.00	0.98	1.00	1.00	1.00	0.99	0.99	1.00	1.00	0.99	0.99	1.00	0.99	1.00	**0.99**
10	0.90	0.96	0.74	0.99	0.98	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.99	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.99	**0.98**
11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
12	0.98	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
13	1.00	1.00	1.00	0.99	0.99	1.00	0.99	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	**1.00**
14	0.99	1.00	0.99	0.99	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.96	0.99	0.96	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	**0.99**
15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.99	1.00	1.00	0.99	1.00	1.00	0.99	0.98	1.00	**1.00**
16	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
17	0.97	0.91	0.99	1.00	1.00	0.99		1.00	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	1.00	0.99	0.99	**0.99**
18	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
19	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99	0.96		1.00	1.00	1.00	1.00	1.00	0.99	1.00			1.00	1.00	1.00	1.00	**0.99**
20	0.97	0.91	0.97	0.96	0.98	0.97	0.99	0.99	0.97	0.98	0.99	0.97	1.00	1.00	0.99		1.00		1.00			1.00		**0.98**
21	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
22	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
23	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.99	0.96	1.00	0.98	0.99	**0.99**
24	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	**1.00**
25	1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	**1.00**
26	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	0.99	0.98	0.98	1.00	1.00	0.97	**1.00**

Table 4.27: Comparison of average Bias of each section

		Average Bias of the section [16th in]					Vendor with average Bias closest to zero
		TxDOT	Pathway	Dynatest	Roadware	Applus	
Section	3	0.00	0.00	0.00	-0.16	0.00	Dynatest
	4	0.00	0.00	0.00	0.00	0.00	Roadware
	5	-0.01	0.00	0.00	0.02	0.01	Dynatest
	6	0.00	0.00	-0.01	0.00	0.00	Pathway
	7	0.00	0.00	0.00	-0.02	0.01	TxDOT
	8	-0.01	0.00	0.00	0.06	0.01	Dynatest
	9	0.00	-0.02	0.00	0.00	0.00	Applus
	10	0.00	0.00	0.00	0.01	-0.01	TxDOT
	11	0.00	-0.07	-0.01	0.00	0.00	TxDOT
	12	0.00	0.01	0.02	-0.01	0.01	TxDOT
	13	0.00	0.01	0.00	-0.10	0.00	TxDOT
	14	-0.04	-0.01	0.00	-0.01	0.03	Dynatest
	15	0.00	0.01	0.06	0.01	0.03	TxDOT
	16	0.01	0.00	0.00	0.00	0.00	Dynatest
	17	0.00	0.00	0.00	0.00	0.00	Dynatest
	18	0.00	0.00	0.00	0.00	-0.01	Dynatest
	19	-0.02	-0.03	0.00	0.00	-0.02	Dynatest
	20	-0.01	0.04	-0.01	-0.17	0.00	Applus
	21	0.00	0.01	0.00	-1.36	0.00	Dynatest
	22	0.00	-0.01	0.01	-0.45	0.00	Applus
	23	0.00	0.00	0.00	0.00	0.00	TxDOT
	24	0.00	0.00	-0.01	-0.73	0.00	TxDOT
	25	0.00	-0.01	0.04	-1.06	0.01	TxDOT
	26	0.00	-0.05	0.00	0.00	0.00	Applus
		# of section (percentage) at which each participant presents the average Bias closest to 0					
		9 (37.5%)	1 (4.2%)	9 (37.5%)	1 (4.2%)	4 (16.7%)	

Table 4.28: Comparison of average Precision of each section

		Average Precision of the section [16th in]					Vendor with minimum average Precision
		TxDOT	Pathway	Dynatest	Roadware	Applus	
Section	3	2.13	1.71	1.10	1.87	1.06	Applus
	4	2.17	1.64	1.32	1.27	1.25	Applus
	5	1.71	1.37	0.93	1.04	1.19	Dynatest
	6	2.12	1.34	1.27	0.93	1.24	Roadware
	7	1.77	1.15	1.09	0.90	1.55	Roadware
	8	1.82	1.40	1.61	1.17	1.00	Applus
	9	1.69	1.68	1.28	1.68	1.14	Applus
	10	1.69	1.58	1.05	1.14	1.19	Dynatest
	11	2.11	2.67	1.98	2.42	1.79	Applus
	12	2.17	3.08	2.28	2.23	2.21	TxDOT
	13	2.04	2.11	1.79	2.35	1.65	Applus
	14	2.01	1.39	0.91	1.02	0.86	Applus
	15	1.90	2.78	2.00	2.36	2.46	TxDOT
	16	1.83	1.11	0.56	0.54	0.67	Roadware
	17	1.71	1.09	0.55	0.58	0.73	Dynatest
	18	1.64	1.24	0.67	0.57	0.73	Roadware
	19	3.16	2.91	1.85	2.54	2.26	Dynatest
	20	3.13	4.79	1.91	2.73	1.62	Applus
	21	1.65	1.06	0.89	6.27	0.88	Applus
	22	1.54	1.18	0.50	2.41	0.51	Dynatest
	23	3.23	3.42	1.19	2.05	1.55	Dynatest
	24	3.41	3.56	1.77	3.53	1.52	Applus
	25	2.15	3.23	1.42	4.59	1.49	Dynatest
	26	2.09	2.63	1.24	1.80	1.17	Applus
		# of section (percentage) at which each participant presents the minimum average Precision					
		2 (8.3%)	0 (0%)	7 (29.2%)	4 (16.7%)	11 (45.8%)	

Table 4.29: Comparison of average MSE of each section

		Average MSE of the section [16th in]					Vendor with minimum MSE
		TxDOT	Pathway	Dynatest	Roadware	Applus	
Section	3	2.13	1.71	1.10	1.89	1.06	Applus
	4	2.17	1.64	1.32	1.27	1.25	Applus
	5	1.71	1.37	0.93	1.04	1.19	Dynatest
	6	2.12	1.34	1.27	0.93	1.24	Roadware
	7	1.77	1.15	1.09	0.90	1.55	Roadware
	8	1.82	1.40	1.61	1.17	1.00	Applus
	9	1.69	1.68	1.28	1.68	1.14	Applus
	10	1.69	1.58	1.05	1.14	1.19	Dynatest
	11	2.11	2.68	1.98	2.42	1.79	Applus
	12	2.17	3.08	2.28	2.23	2.21	TxDOT
	13	2.04	2.11	1.79	2.36	1.65	Applus
	14	2.01	1.39	0.91	1.02	0.86	Applus
	15	1.90	2.79	2.01	2.36	2.47	TxDOT
	16	1.83	1.11	0.56	0.54	0.67	Roadware
	17	1.71	1.09	0.55	0.58	0.73	Dynatest
	18	1.64	1.24	0.67	0.57	0.73	Roadware
	19	3.16	2.92	1.85	2.54	2.26	Dynatest
	20	3.13	4.80	1.91	2.74	1.62	Applus
	21	1.65	1.06	0.89	6.42	0.88	Applus
	22	1.54	1.18	0.50	2.46	0.51	Dynatest
	23	3.23	3.42	1.19	2.05	1.55	Dynatest
	24	3.41	3.56	1.77	3.66	1.52	Applus
	25	2.15	3.23	1.42	4.80	1.49	Dynatest
	26	2.09	2.64	1.24	1.80	1.17	Applus
		number of section (percentage) at which each participant presents the minimum MSE					
		2 (8.3%)	0 (0%)	7 (29.2%)	4 (16.7%)	11 (45.8%)	

Table 4.30: Comparison of average SSEn of each section

		Average SSEn of the section [16th in]					Vendor with minimum SSEn
		TxDOT	Pathway	Dynatest	Roadware	Applus	
Section	3	2.09	1.66	1.08	1.84	1.04	Applus
	4	2.13	1.60	1.29	1.23	1.22	Applus
	5	1.67	1.34	0.90	1.01	1.17	Dynatest
	6	2.08	1.30	1.23	0.91	1.21	Roadware
	7	1.74	1.12	1.07	0.88	1.52	Roadware
	8	1.78	1.36	1.57	1.14	0.97	Applus
	9	1.65	1.64	1.25	1.63	1.11	Applus
	10	1.65	1.54	1.02	1.11	1.16	Dynatest
	11	2.06	2.61	1.93	2.36	1.75	Applus
	12	2.13	3.00	2.22	2.17	2.16	TxDOT
	13	1.99	2.06	1.75	2.30	1.61	Applus
	14	1.97	1.36	0.90	1.00	0.84	Applus
	15	1.86	2.71	1.96	2.30	2.41	TxDOT
	16	1.80	1.08	0.55	0.53	0.65	Roadware
	17	1.68	1.06	0.54	0.57	0.72	Dynatest
	18	1.60	1.21	0.66	0.55	0.71	Roadware
	19	3.10	2.84	1.81	2.47	2.21	Dynatest
	20	3.07	4.68	1.87	2.67	1.58	Applus
	21	1.62	1.03	0.87	6.26	0.86	Applus
	22	1.51	1.15	0.49	2.40	0.50	Dynatest
	23	3.16	3.33	1.16	2.00	1.51	Dynatest
	24	3.34	3.46	1.73	3.57	1.48	Applus
	25	2.10	3.14	1.39	4.68	1.46	Dynatest
	26	2.05	2.57	1.22	1.75	1.14	Applus
		number of section (percentage) at which each participant presents the minimum SSEn					
		2 (8.3%)	0 (0%)	7 (29.2%)	4 (16.7%)	11 (45.8%)	

Table 4.31: Comparison of average Correlation of each section

		Average Correlation of the section					Vendor with Correlation closest to 1
		TxDOT	Pathway	Dynatest	Roadware	Applus	
Section	3	1.00	1.00	1.00	0.99	1.00	Applus
	4	0.99	0.99	1.00	0.99	1.00	Applus
	5	0.95	0.94	0.98	0.98	0.97	Dynatest
	6	0.99	0.99	1.00	1.00	1.00	Roadware
	7	0.96	0.97	0.98	0.98	0.95	Dynatest
	8	1.00	1.00	1.00	1.00	1.00	Applus
	9	0.99	0.99	0.99	0.99	0.99	Applus
	10	0.96	0.96	0.99	0.98	0.98	Dynatest
	11	1.00	0.99	1.00	1.00	1.00	Applus
	12	1.00	0.99	1.00	1.00	1.00	TxDOT
	13	0.99	0.99	0.99	0.98	1.00	Applus
	14	0.98	0.98	0.99	0.98	0.99	Dynatest
	15	1.00	0.99	1.00	1.00	1.00	TxDOT
	16	1.00	1.00	1.00	1.00	1.00	Dynatest
	17	0.97	0.98	0.99	0.99	0.99	Roadware
	18	1.00	1.00	1.00	1.00	1.00	Dynatest
	19	0.99	0.99	1.00	0.99	0.99	Dynatest
	20	0.97	0.90	0.98	0.96	0.98	Dynatest
	21	0.99	1.00	1.00	0.81	1.00	Applus
	22	0.99	0.98	1.00	0.91	1.00	Applus
	23	0.97	0.97	0.99	0.99	0.99	Dynatest
	24	0.99	0.99	1.00	0.97	1.00	Applus
	25	1.00	1.00	1.00	0.98	1.00	Dynatest
	26	0.99	0.98	1.00	0.99	1.00	Dynatest
		# of section (percentage) at which each participant presents the Correlation closest to 1					
		2 (8.3%)	0 (0%)	11 (45.8%)	2 (8.3%)	9 (37.5%)	

4.2.2 Comparison

Each participant reported their best estimate of the 111 MRD values for each wheel path of every section. The set of values reported by each participant was compared with the GT values, which were determined by manually measuring the MRD for all the stations. This section presents a series of charts prepared to visually compare the reported values, as well as tables with the statistical parameters calculated to determine the participant that produced the best results.

The residuals of the MRD values reported by the participants were calculated as shown in Equation 4.8. Therefore, when the resulting residual had a positive sign, the measurement was underestimated, and when it had a negative sign the measurement was overestimated.

$$residual_i = MRD_i^{GT} - MRD_i \tag{4.8}$$

Where:

$residual_i$ = Residual of the MRD reported by the participant at station "i";
MRD_i^{GT} = GT value of the MRD at station "i"; and
MRD_i = MRD value reported by the participant at station "i";

As an example, the longitudinal residual distributions for each wheel path of Section 9 are presented in Figures 4.20 to 4.31. The closer the residual plot line coincides with the horizontal axis, the closer the participant's measurements are to GT. Thus, referring to Figures 4.21 and 4.27, Section 9, each wheel path, the MRD values calculated by TxDOT using the TxDOT ASTM algorithm are clearly closer to GT than those calculated using the TxDOT PMIS algorithm.

As shown in Figures 4.26 to 4.31, the residuals of the participants' measurements for the Section 9 OWP are greater for the stations between 350 ft to 500 ft. Referring to Figures 4.14 to 4.19, the MRD values for those stations are greater than for the rest of the stations in Section 9, which suggests that the residual of the measurement might increase as the MRD value increases.

Figures 4.32 to 4.43 show the Section 9 MRD values of each wheel path reported by each participant compared with GT values. Each chart contains one point per station or a total of 111 points per chart. The points are plotted as (x,y) coordinate pairs with the GT MRD values as the 'x' coordinate and the participant's MRD value as the 'y' coordinate. In this way, if the participant's measurement is equal to the GT value, the point will coincide with the 45° reference line drawn in the charts. If a point is located below the reference line, the participant underestimated the MRD value for that station; if the point is above the line, the participant overestimated the MRD value.

The yellow lines in Figures 4.20 to 4.31 indicate the boundaries of the PMIS rutting level categories defined as No Rut, Shallow, Deep, Severe, and Failure. The boundaries of the green boxes define the regions where the participant's reported MRD value either overestimated or underestimated the GT MRD values, but was still within the thresholds of the PMIS category for the GT MRD value.

The complete series of charts with the longitudinal distribution of residuals and the comparison of MRD values for both wheel path for all the sections and participants are presented in Appendix B (provided on CD).

Figures 4.44 to 4.55 present a comparison of each participant's MRD values in relation to GT MRD values by wheel path for all the sections. Each chart, therefore, contains 50% of the data points or 2,664 points. Figures 4.44 to 4.55 illustrate that, in general, all of the participants tended to underestimate the GT measurements. Additionally, the TxDOT ASTM and Dynatest MRD values appear closest to GT for the IWP, whereas TxDOT ASTM, Dynatest, and Roadware MRD values appear the closest to the GT for the OWP.

As for the transverse profile analysis and comparison, five statistical parameters were calculated to evaluate the participant's MRD results:

- Bias, defined as the mean MRD residual for the section;
- Precision, defined as the standard deviation of the MRD residuals for the section;
- MSE, which accounts for both Bias and Precision;

- Slope of the linear regression line (Slope); and
- Correlation coefficient (corr) of the participant and GT MRD values.

The calculated slope of the linear regression line refers to the line fitting the points of the MRD comparison charts (dashed blue line in Figures 4.32 to 4.55). These parameters were calculated using Equations 4.9 to 4.13.

$$Bias = \sum_{i=1}^{111} \frac{error_i}{111} \tag{4.9}$$

$$Precision = \sqrt{\sum_{i=1}^{111} \frac{(error_i - Bias)^2}{111-1}} \tag{4.10}$$

$$MSE = \sqrt{Bias^2 + Precision^2} \tag{4.11}$$

$$Slope = \frac{\sum_{i=1}^{111}(MRD_i^{GT} - \overline{MRD^{GT}})(MRD_i - \overline{MRD})}{\sum_{i=1}^{111}(MRD_i^{GT} - \overline{MRD^{GT}})^2} \tag{4.12}$$

$$corr = \frac{\sum_{i=1}^{111}(MRD_i^{GT} - \overline{MRD^{GT}})(MRD_i - \overline{MRD})}{\sqrt{\sum_{i=1}^{111}(MRD_i^{GT} - \overline{MRD^{GT}})}\sqrt{\sum_{i=1}^{111}(MRD_i - \overline{MRD})}} \tag{4.13}$$

Where:

$\overline{MRD^{GT}}$ = Mean GT MRD of the section;
$\overline{MRD}$ = Mean Participant's MRD of the section;

Tables 4.32 to 4.41 report the values for each section and wheel path for all the participants for the respective parameters. The last column of each table indicates which participant presented the best value at each section for the respective parameter. The last row of each table indicates the number (also expressed in percentage) of sections for which each participant presented the best value for the respective parameter. These numbers are used in the next section to determine the participant that reported the best measurements.

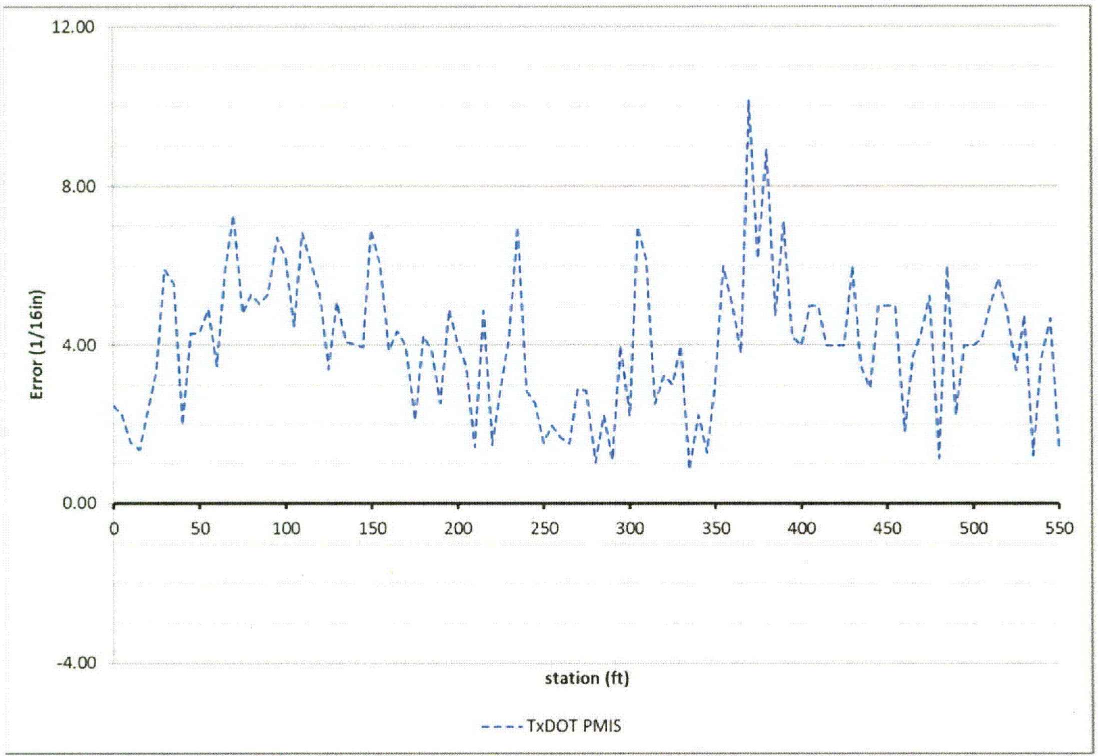


Figure 4.20: TxDOT PMIS (dashed blue line) IWP MRD Residual longitudinal distribution (Section 9)

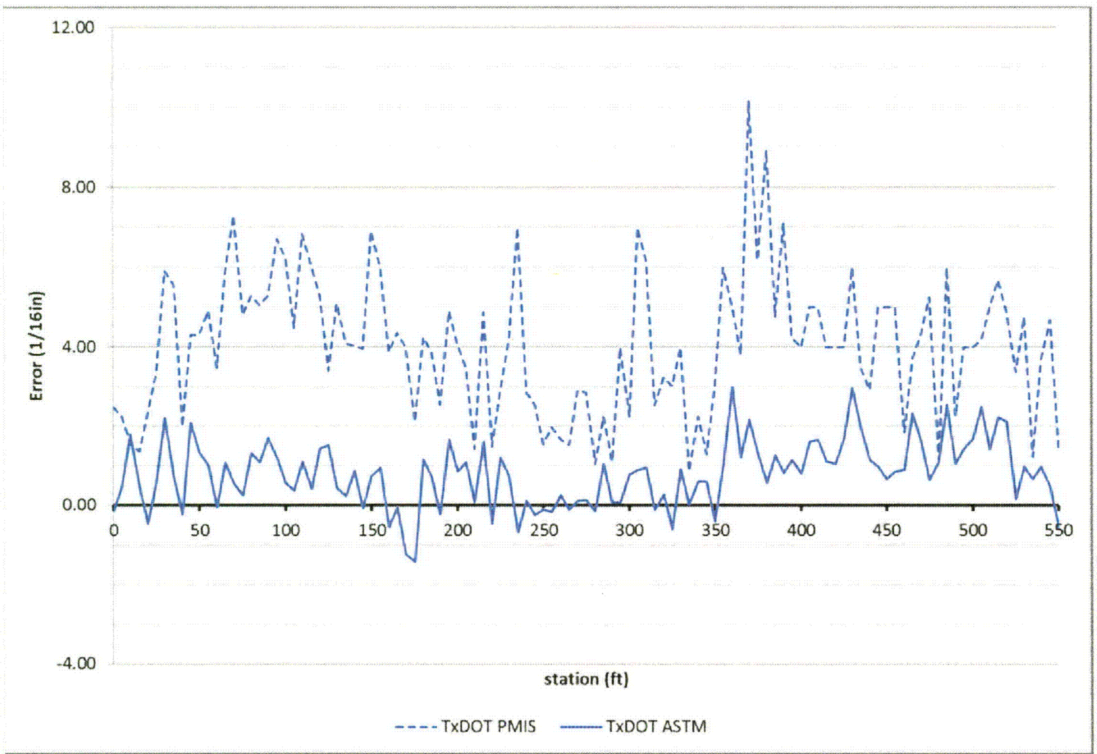


Figure 4.21: TxDOT PMIS (dashed blue line) and TxDOT ASTM (solid blue line) IWP MRD Residual longitudinal distribution (Section 9)

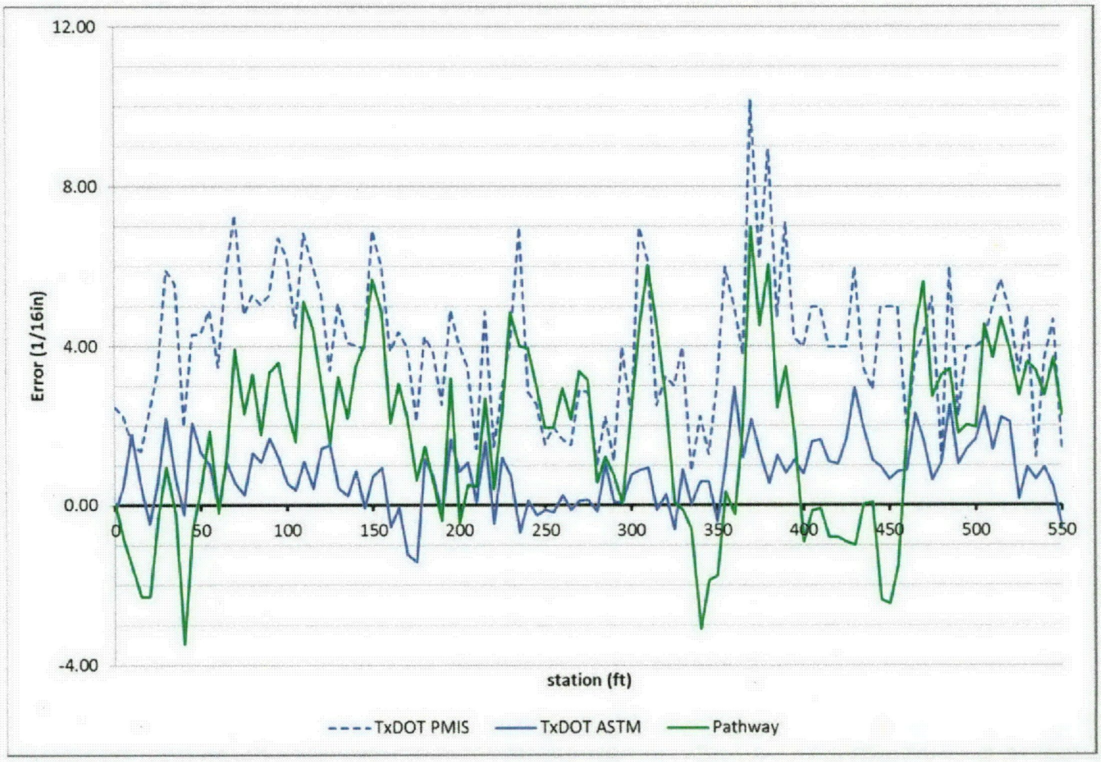


Figure 4.22: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Pathway (green line) IWP MRD Residual longitudinal distribution (Section 9)

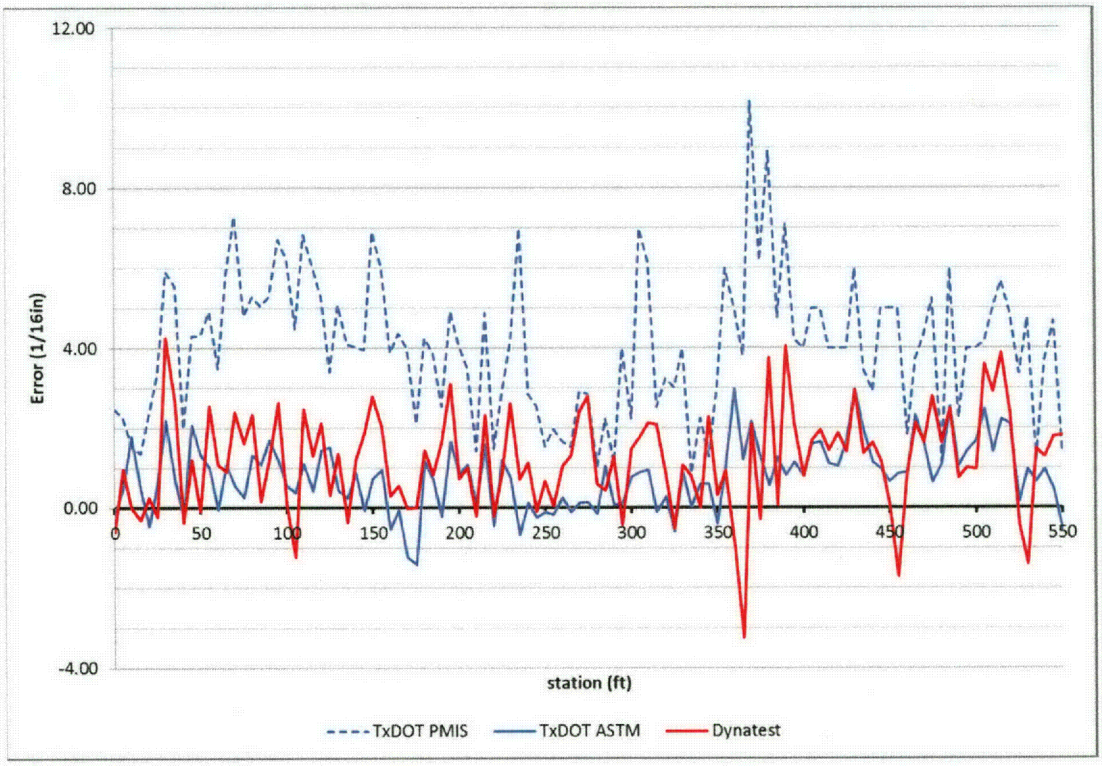


Figure 4.23: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Dynatest (red line) IWP MRD Residual longitudinal distribution (Section 9)

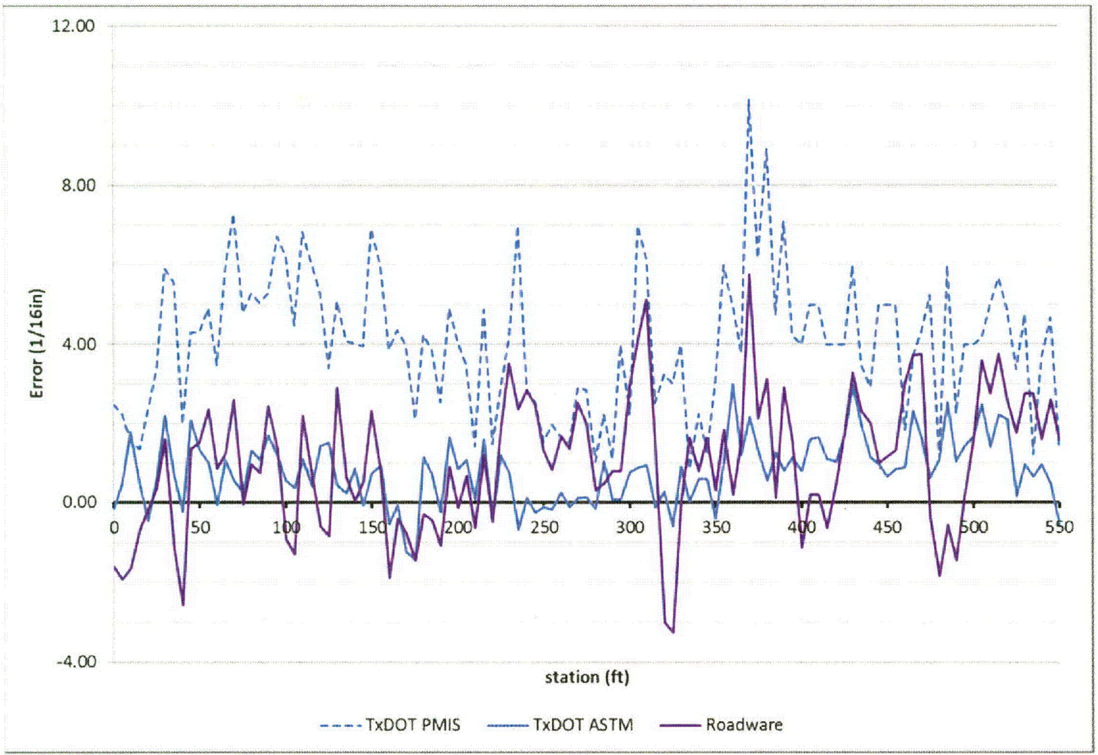


Figure 4.24: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Roadware (purple line) IWP MRD Residual longitudinal distribution (Section 9)

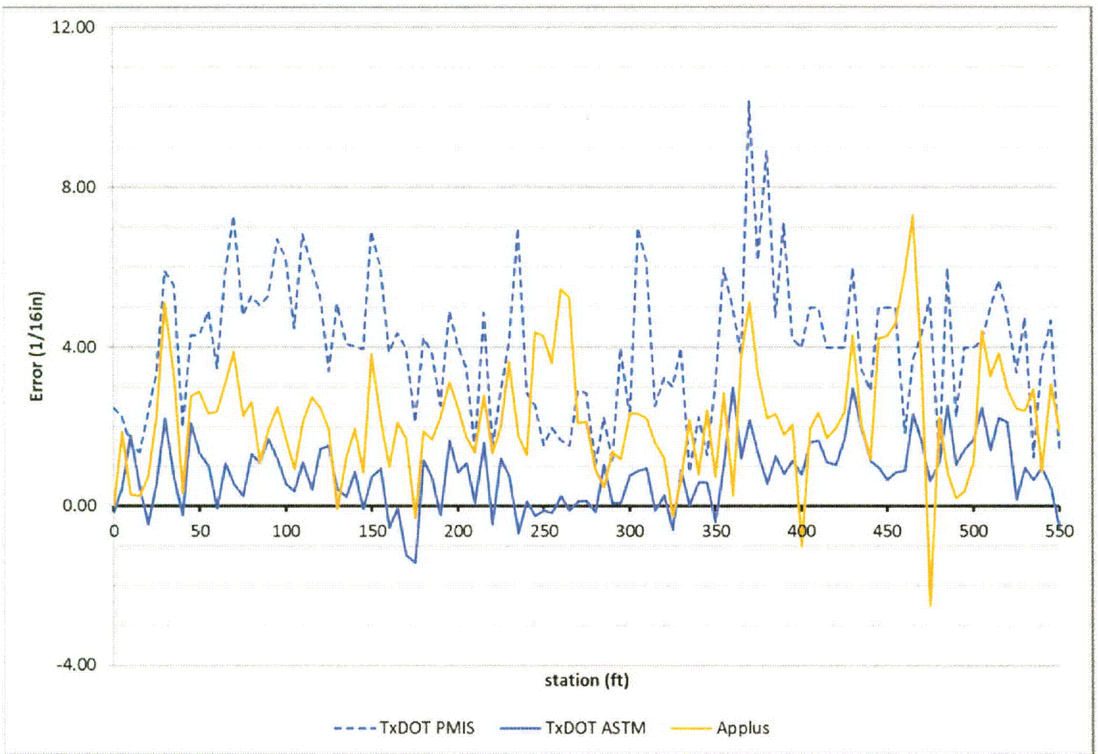


Figure 4.25: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Applus (yellow line) IWP MRD Residual longitudinal distribution (Section 9)

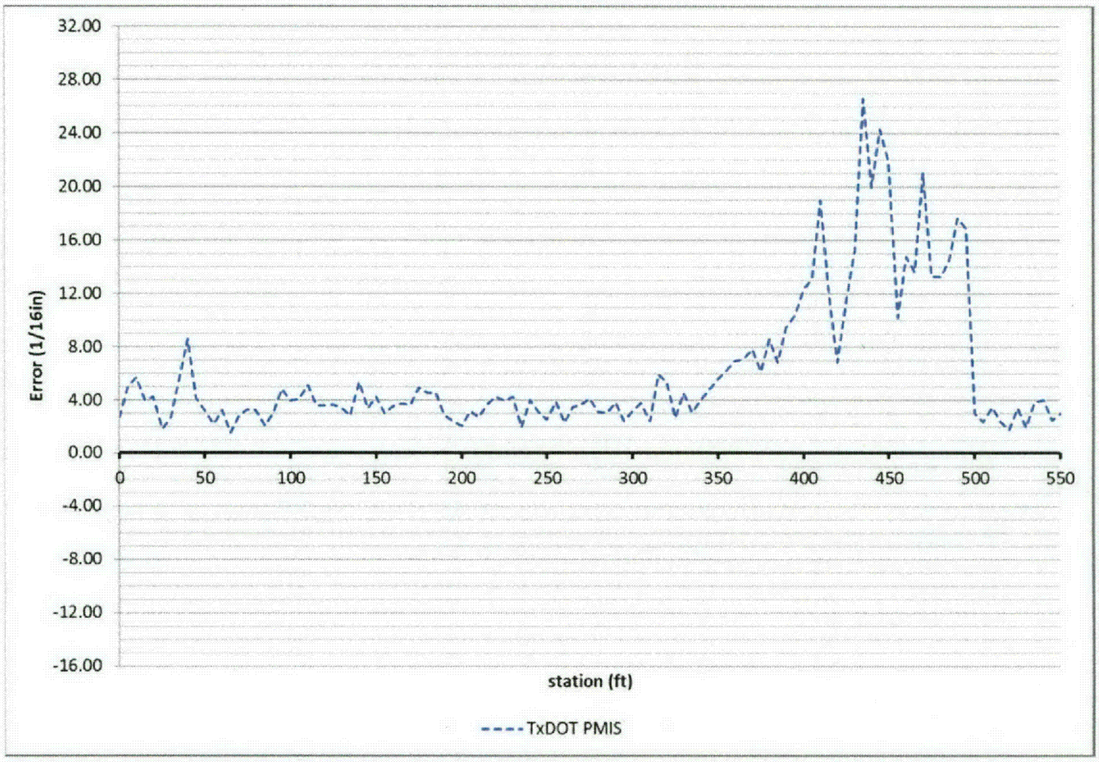


Figure 4.26: TxDOT PMIS (dashed blue line) OWP MRD Residual longitudinal distribution (Section 9)

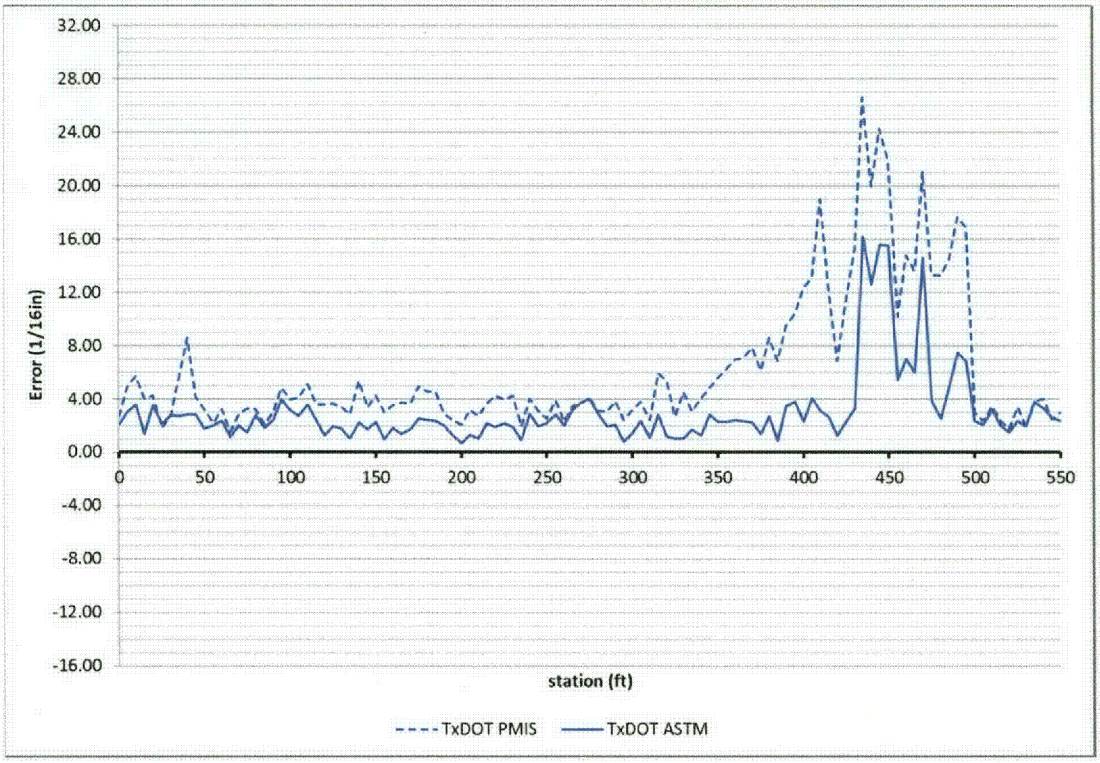


Figure 4.27: TxDOT PMIS (dashed blue line) and TxDOT ASTM (solid blue line) OWP MRD Residual longitudinal distribution (Section 9)

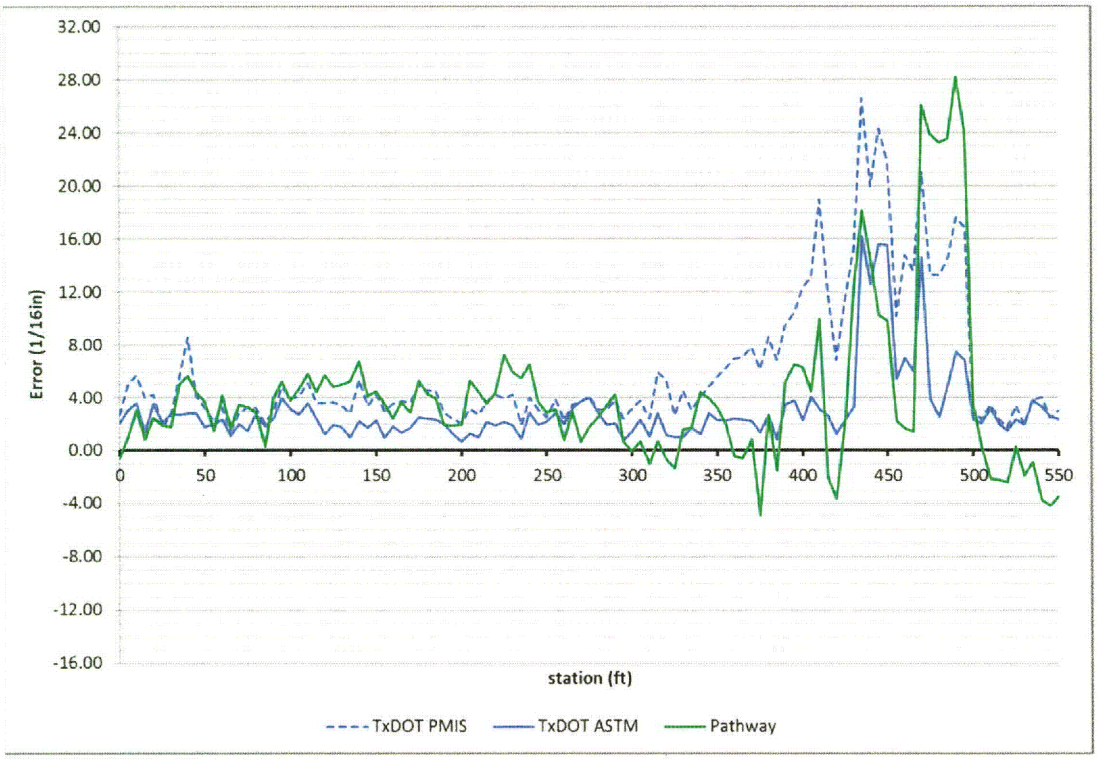


Figure 4.28: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Pathway (green line) OWP MRD Residual longitudinal distribution (Section 9)

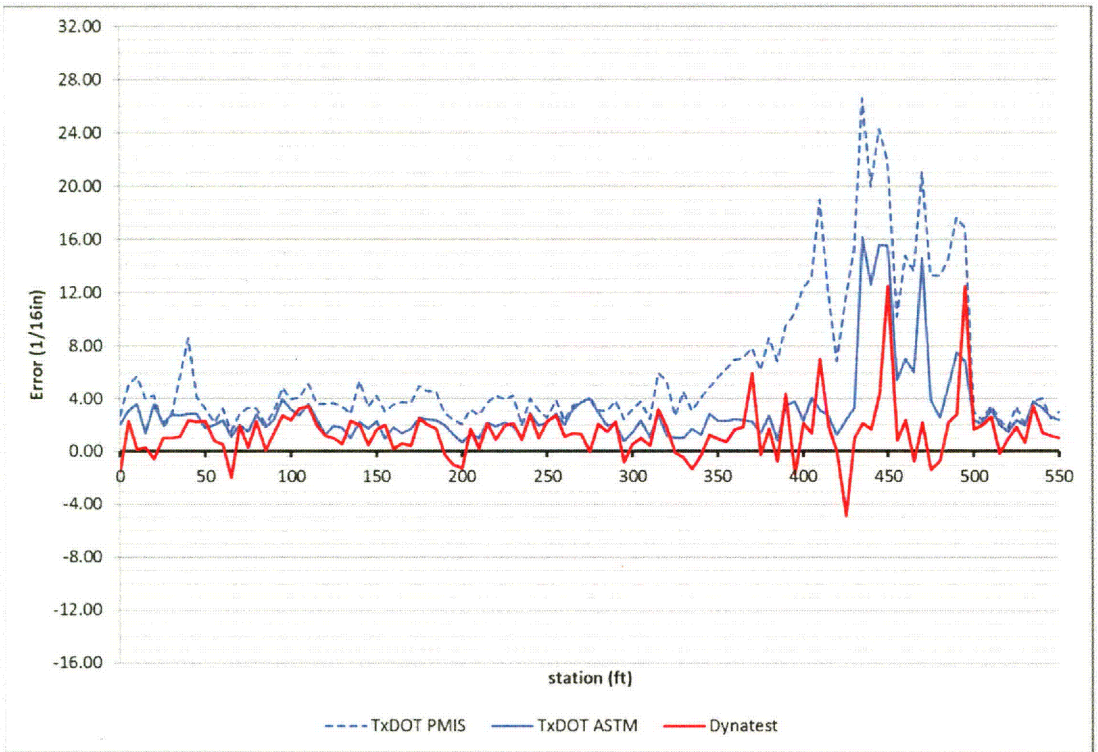


Figure 4.29: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Dynatest (red line) OWP MRD Residual longitudinal distribution (Section 9)

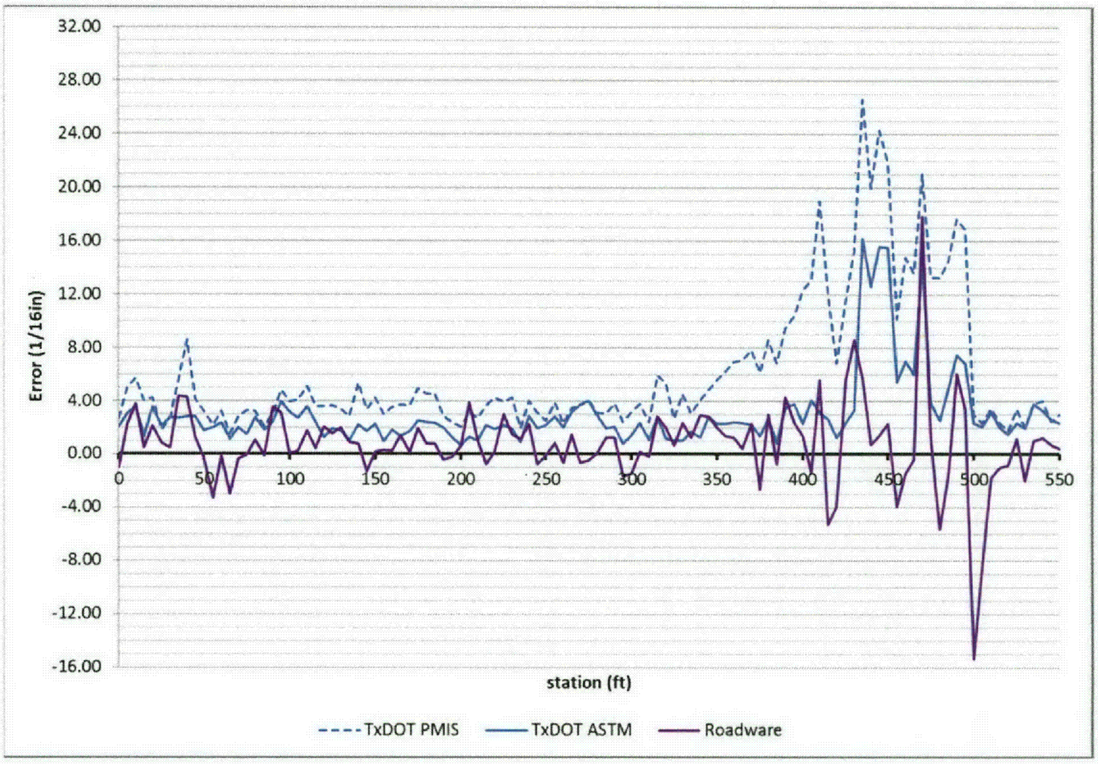


Figure 4.30: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Roadware (purple line) OWP MRD Residual longitudinal distribution (Section 9)

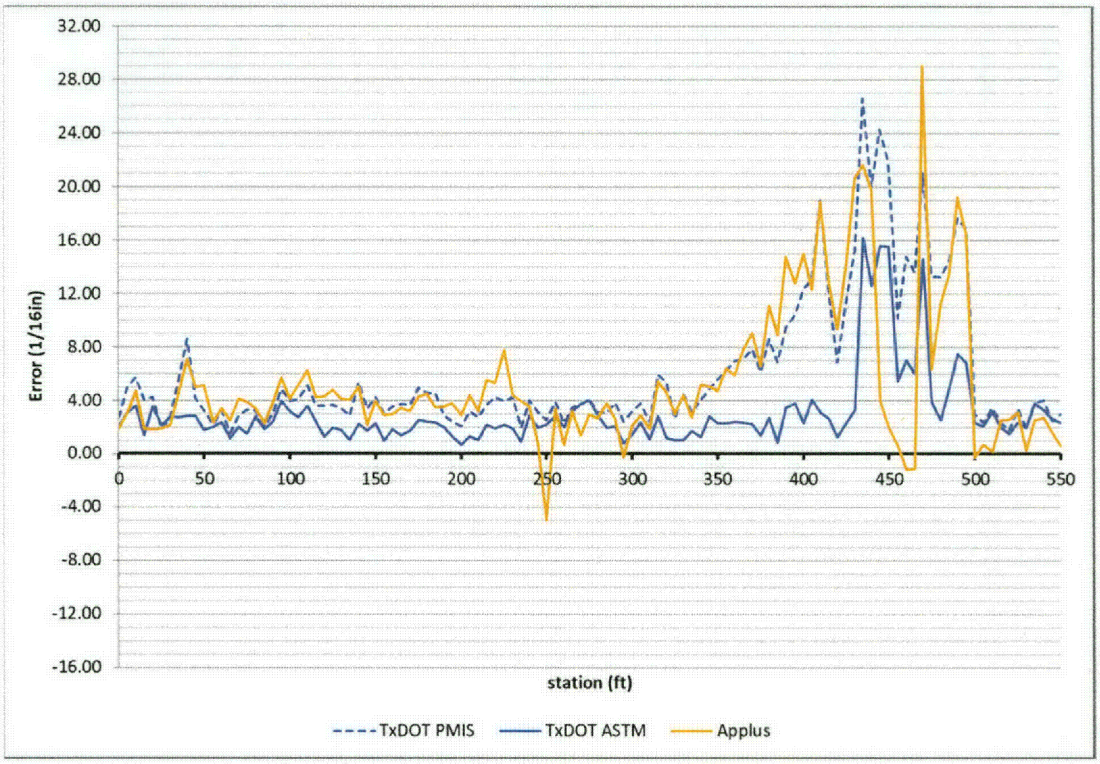


Figure 4.31: TxDOT PMIS (dashed blue line), TxDOT ASTM (solid blue line), and Applus (yellow line) OWP MRD Residual longitudinal distribution (Section 9)

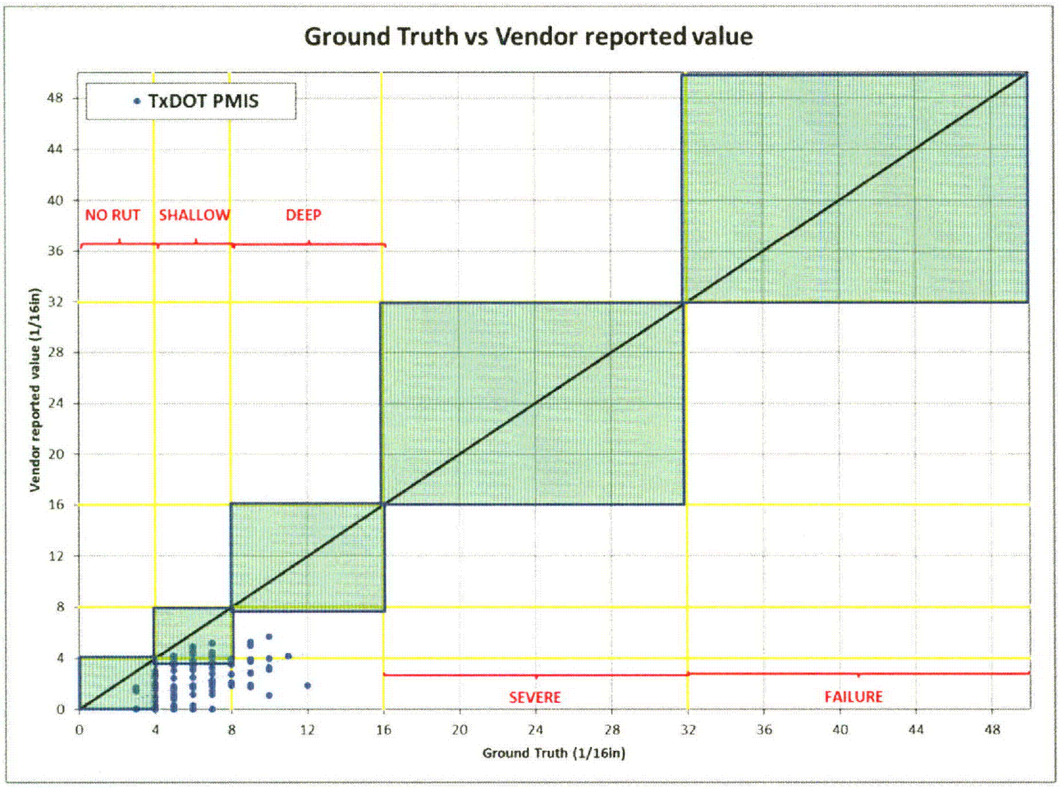


Figure 4.32: TxDOT PMIS vs. GT IWP MRD values for section 9

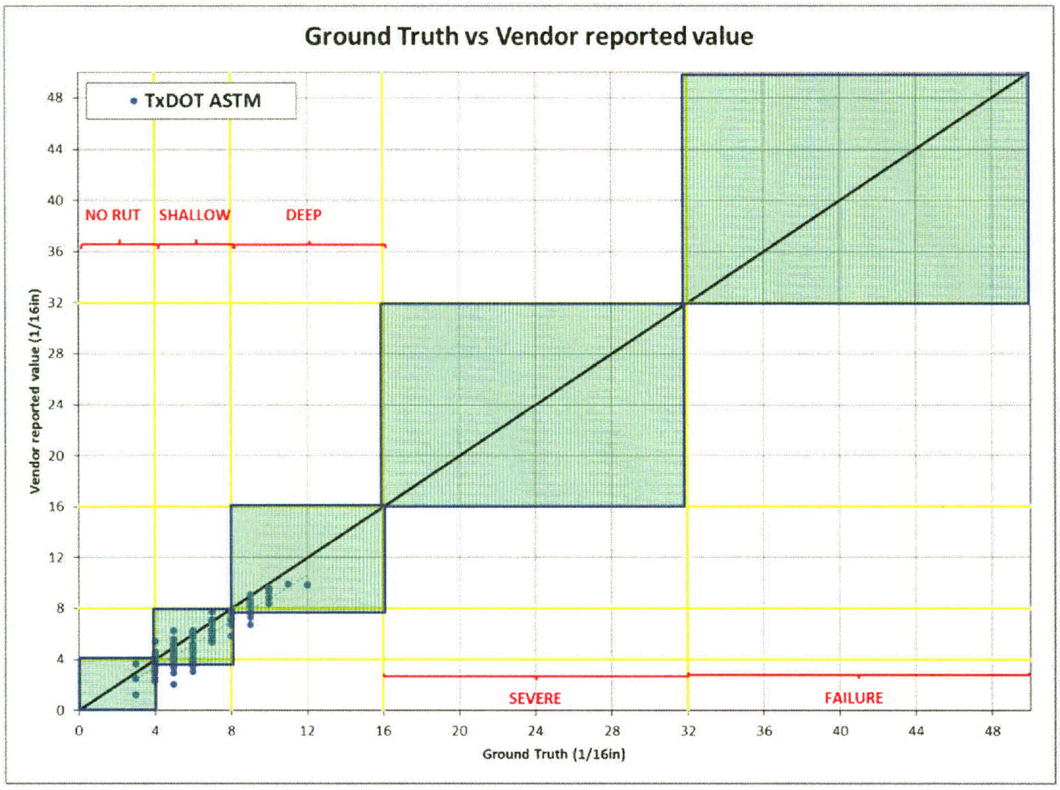


Figure 4.33: TxDOT ASTM vs. GT IWP MRD values for section 9

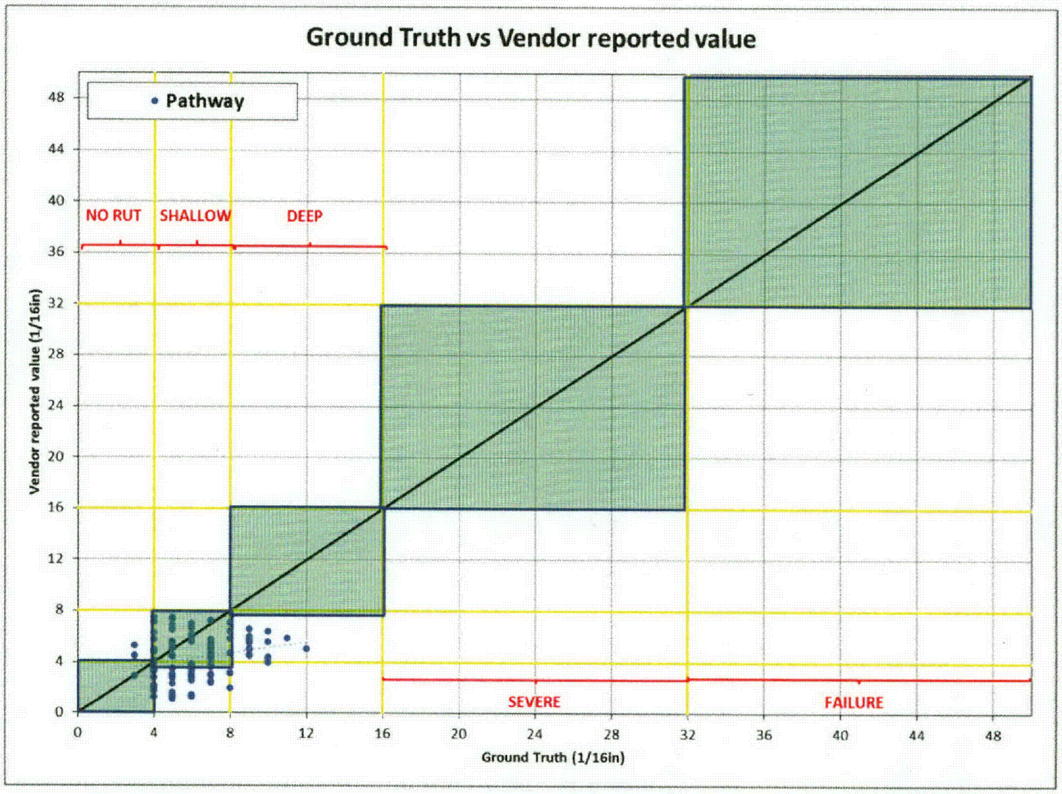


Figure 4.34: Pathway vs. GT IWP MRD values for section 9

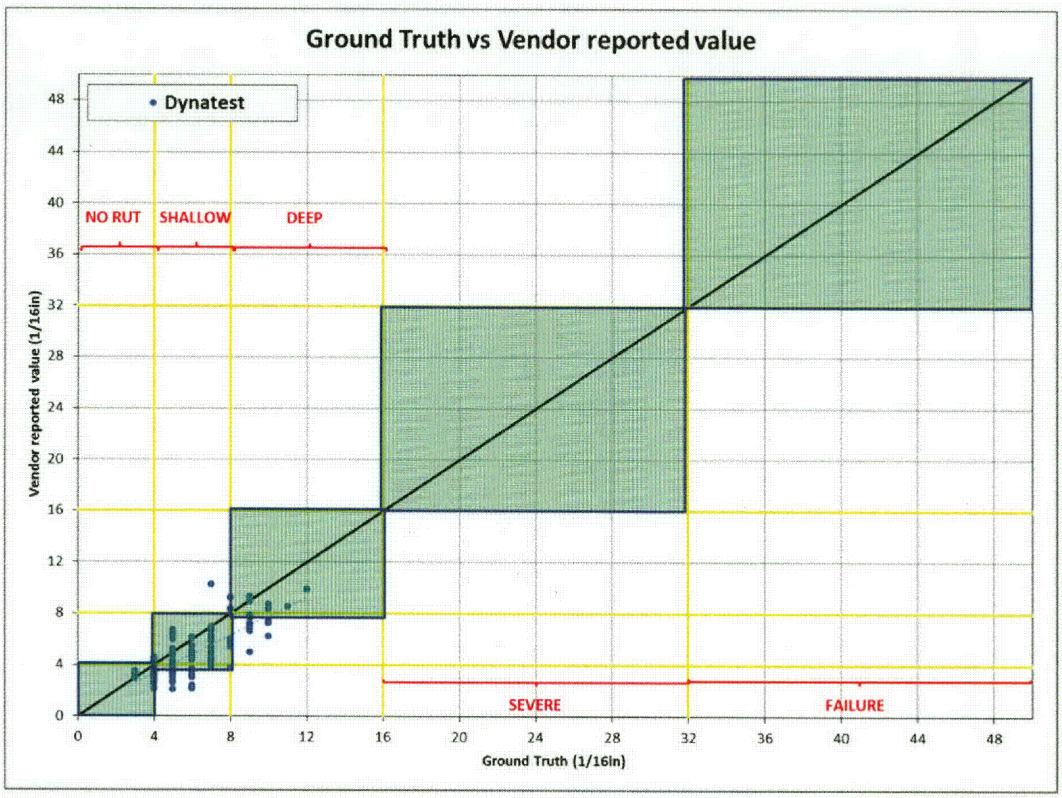


Figure 4.35: Dynatest vs. GT IWP MRD values for section 9

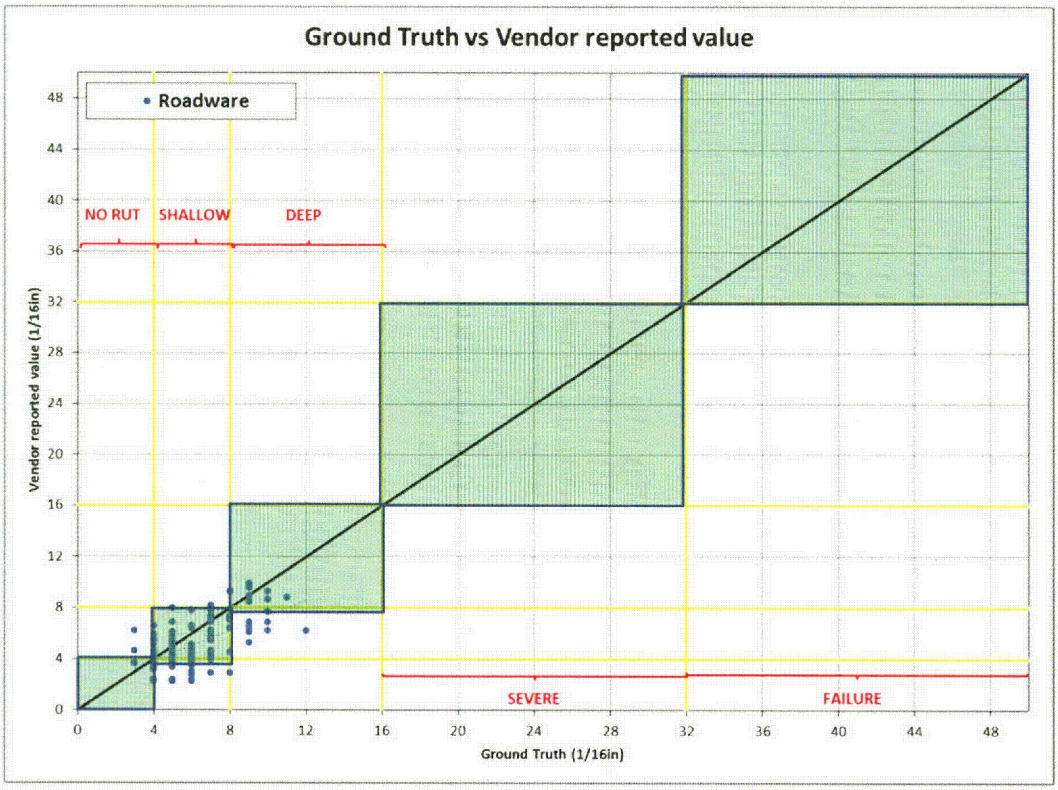


Figure 4.36: Roadware vs. GT IWP MRD values for section 9

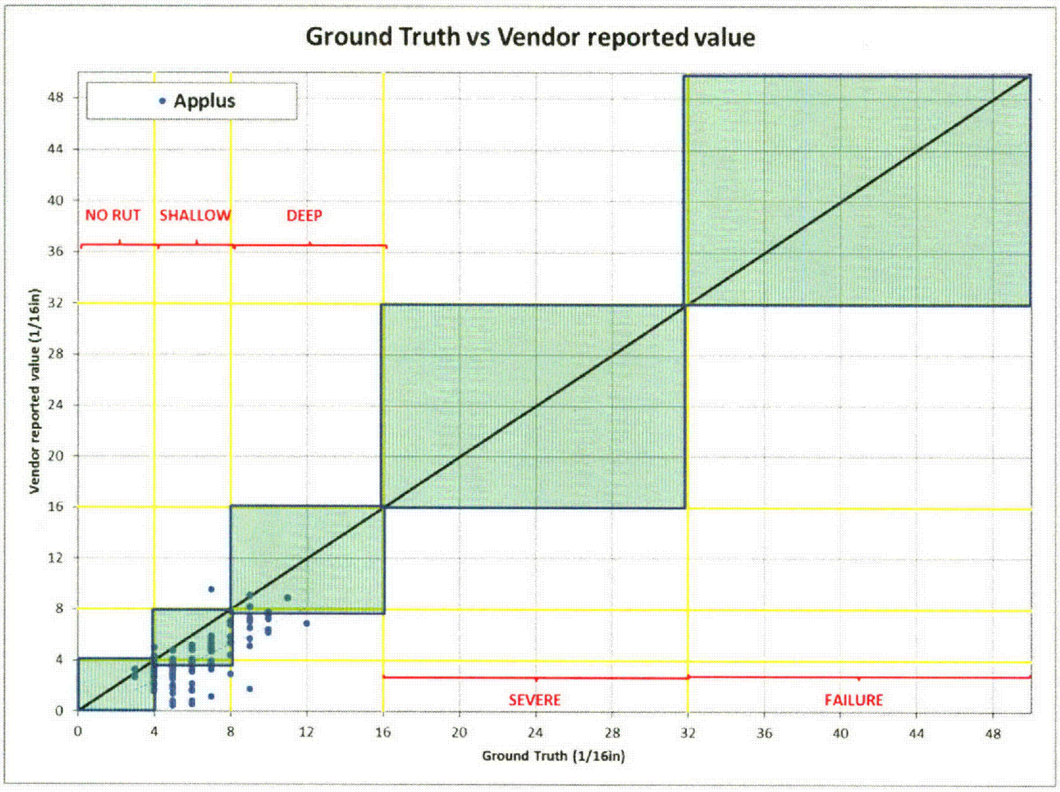


Figure 4.37: Applus vs. GT IWP MRD values for section 9

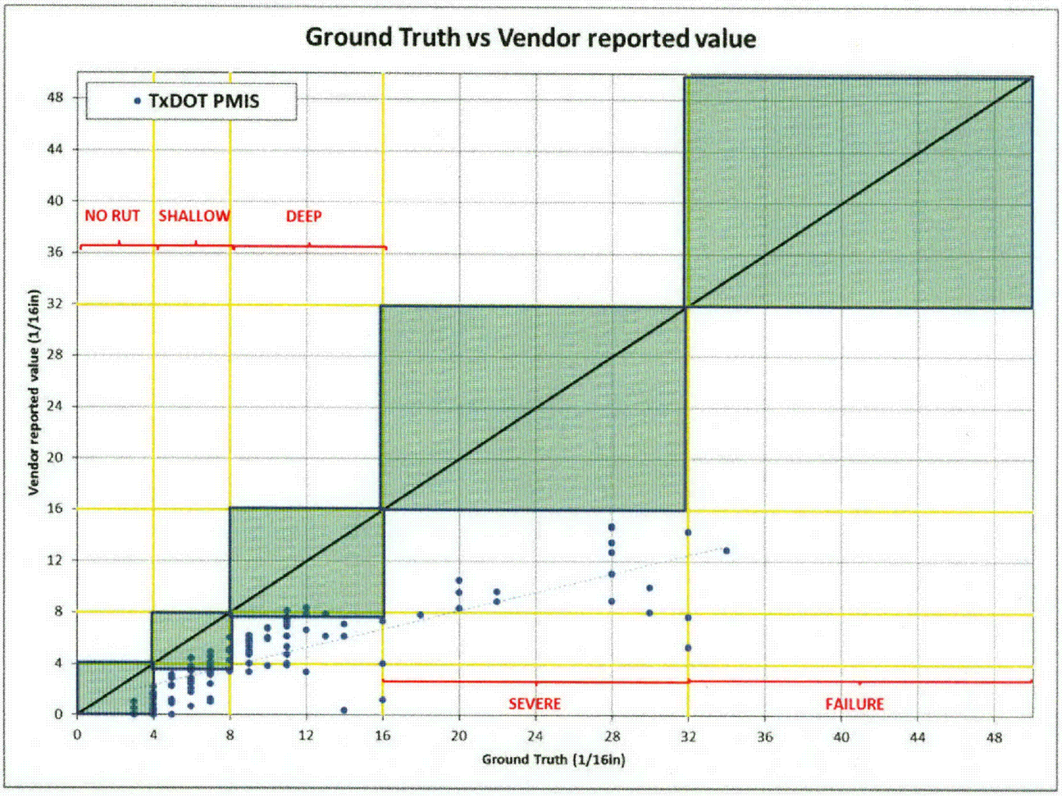


Figure 4.38: TxDOT PMIS vs. GT OWP MRD values for section 9

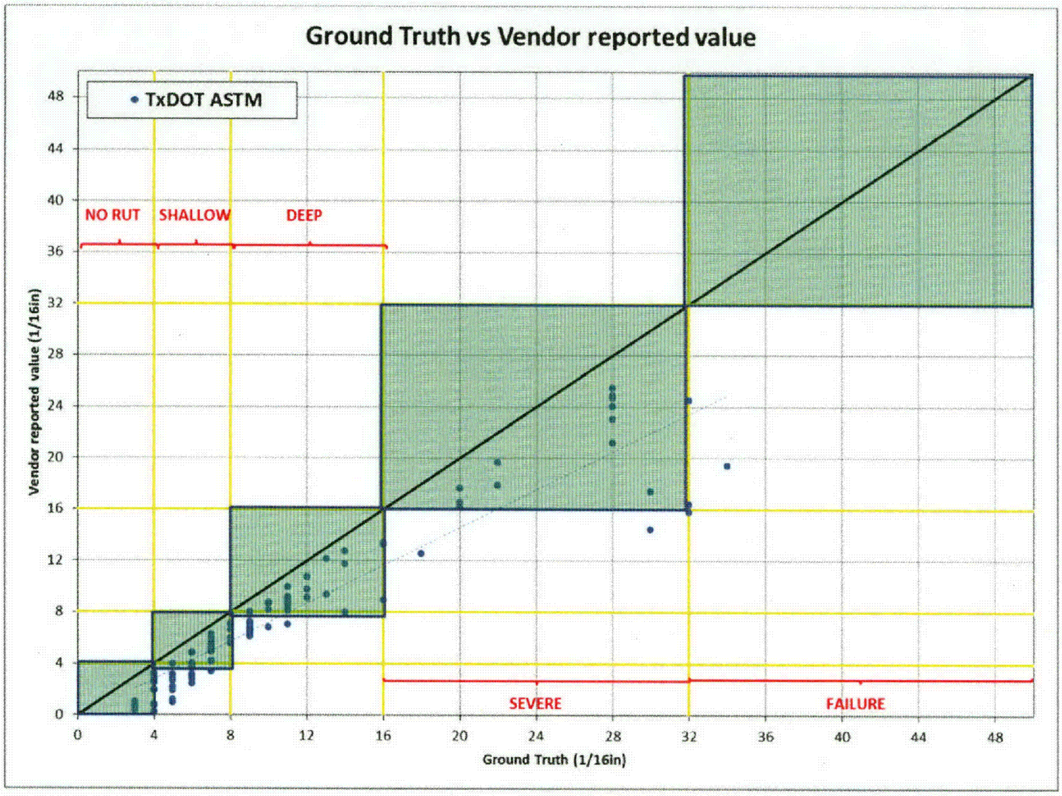


Figure 4.39: TxDOT ASTM vs. GT OWP MRD values for section 9

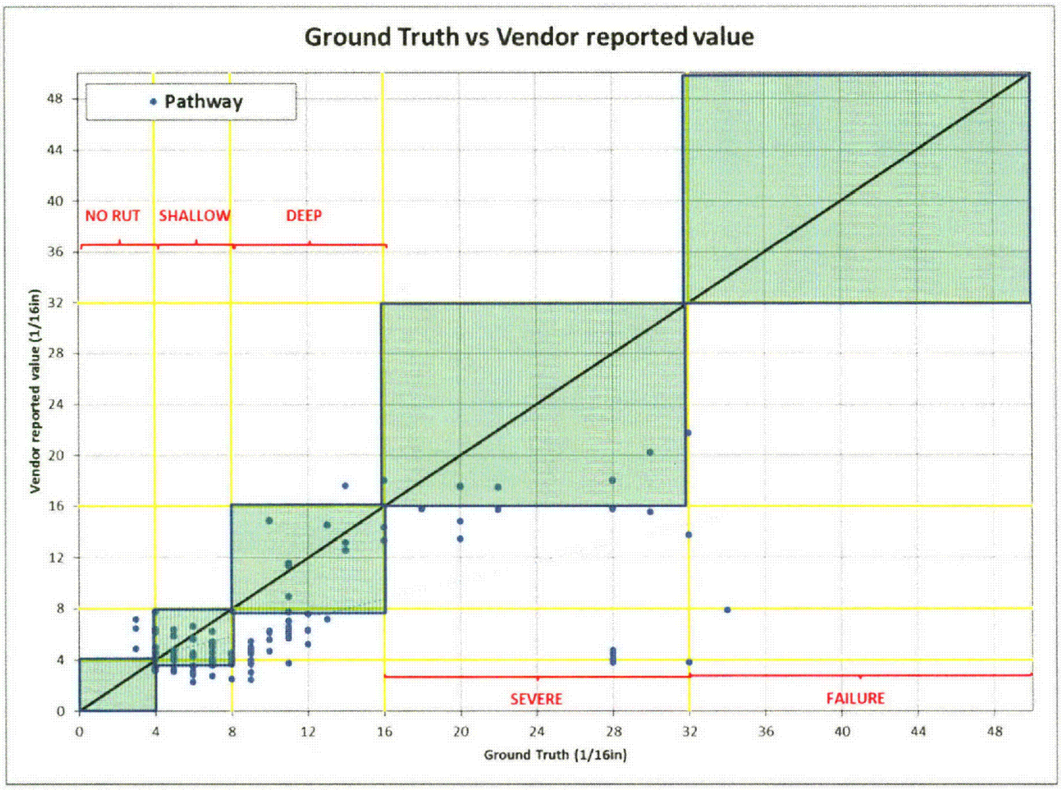


Figure 4.40: Pathway vs. GT OWP MRD values for section 9

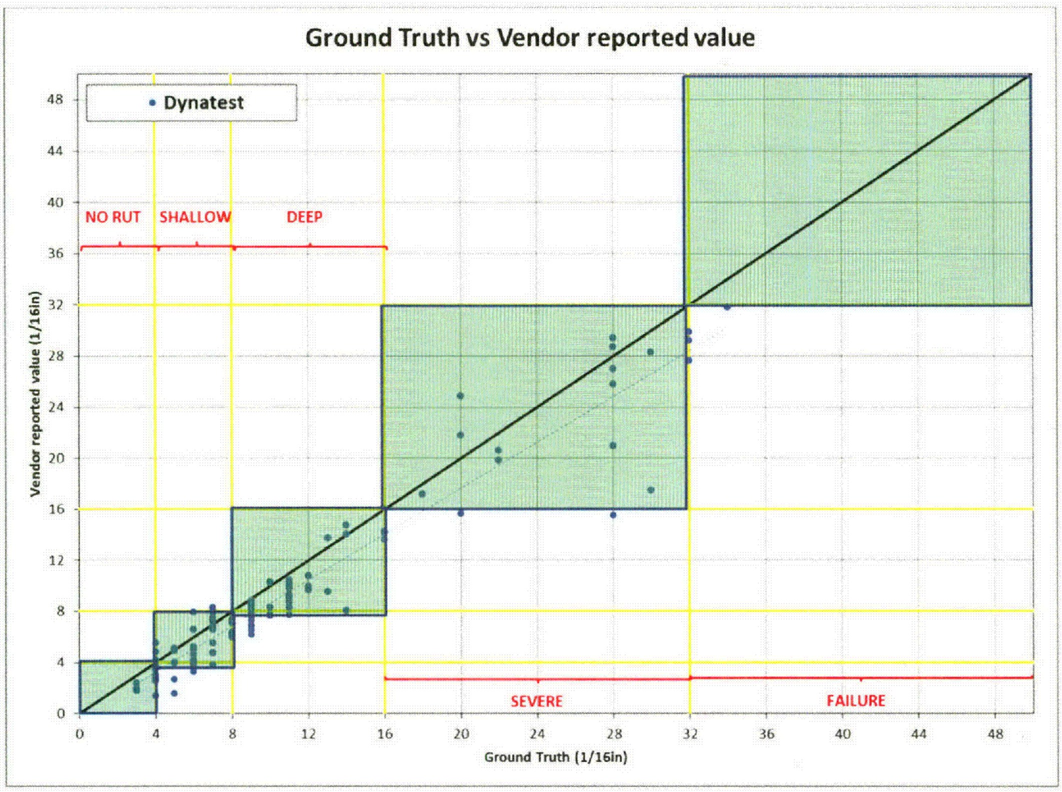


Figure 4.41: Dynatest vs. GT OWP MRD values for section 9

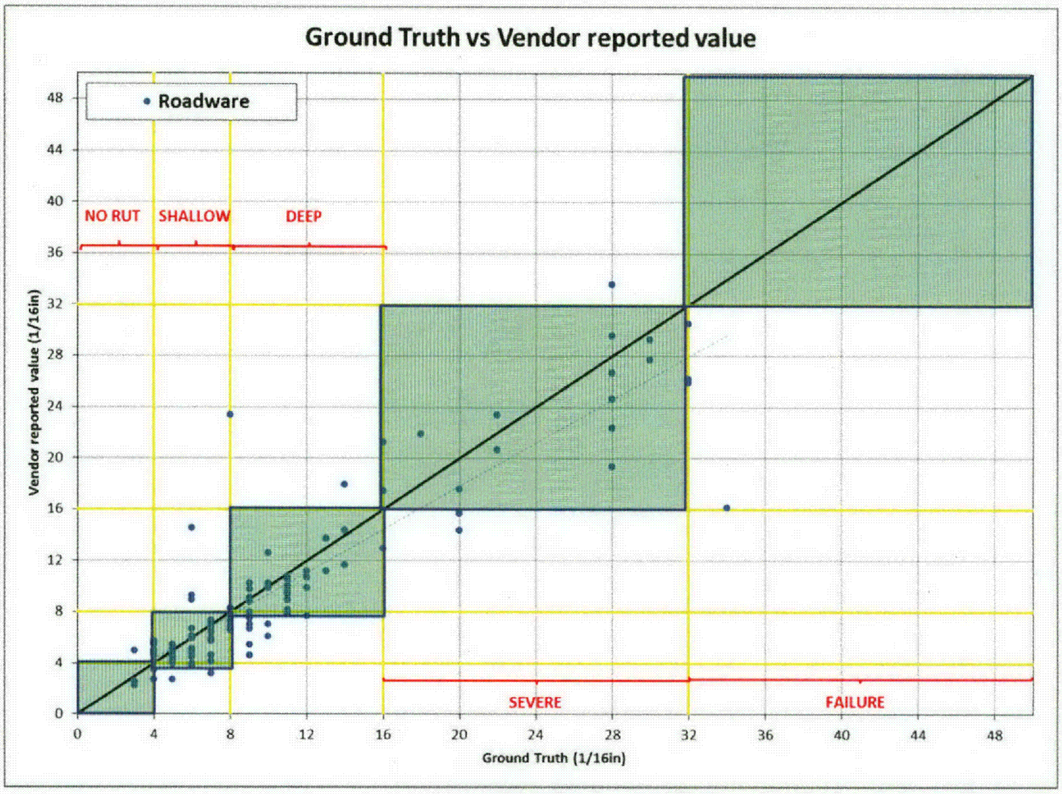


Figure 4.42: Roadware vs. GT OWP MRD values for section 9

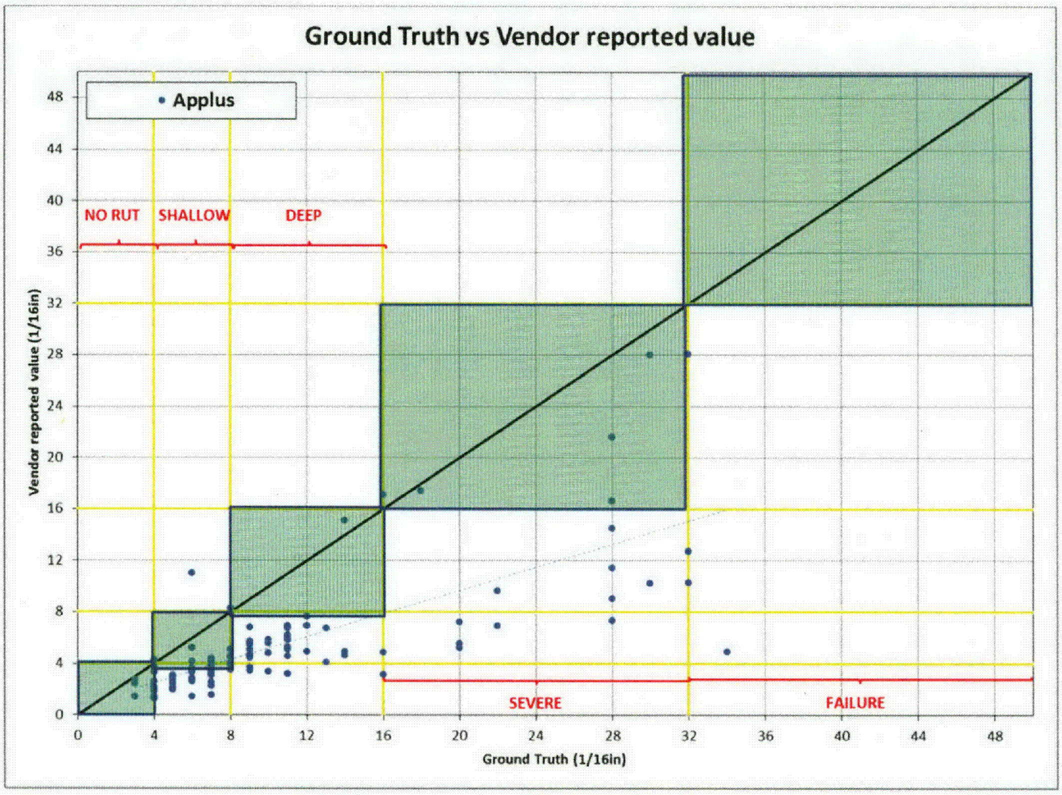


Figure 4.43: Applus vs. GT OWP MRD values for section 9

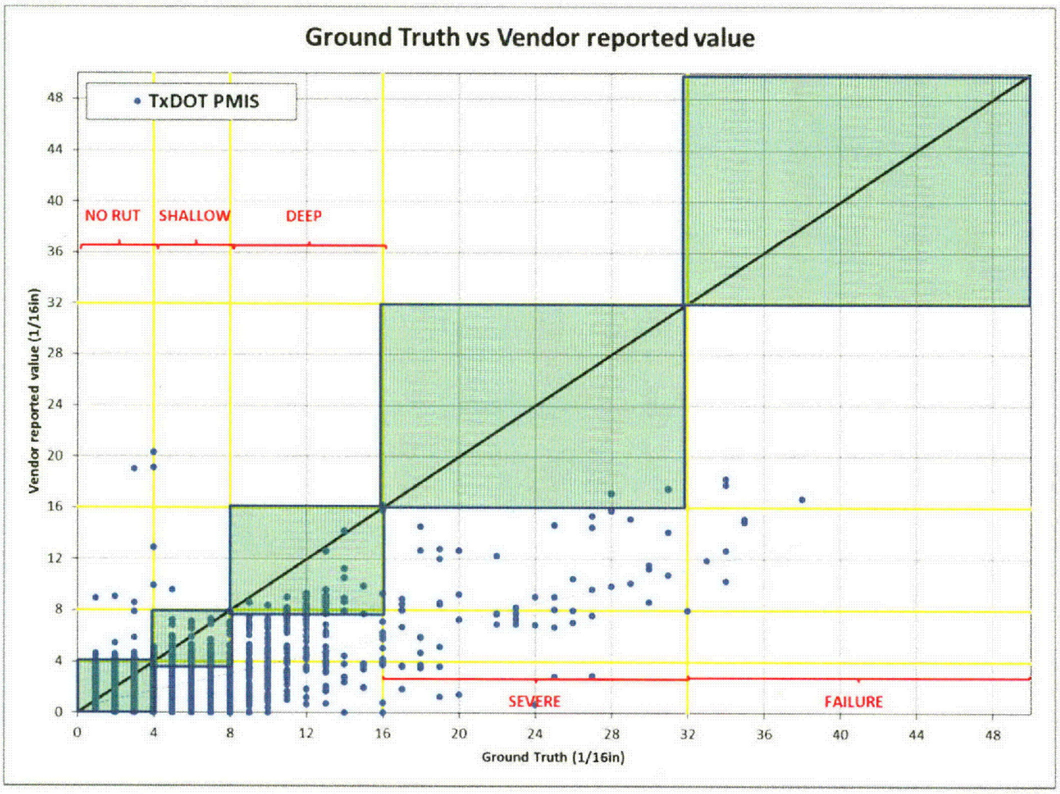


Figure 4.44: TxDOT PMIS vs. GT IWP MRD values for all the sections

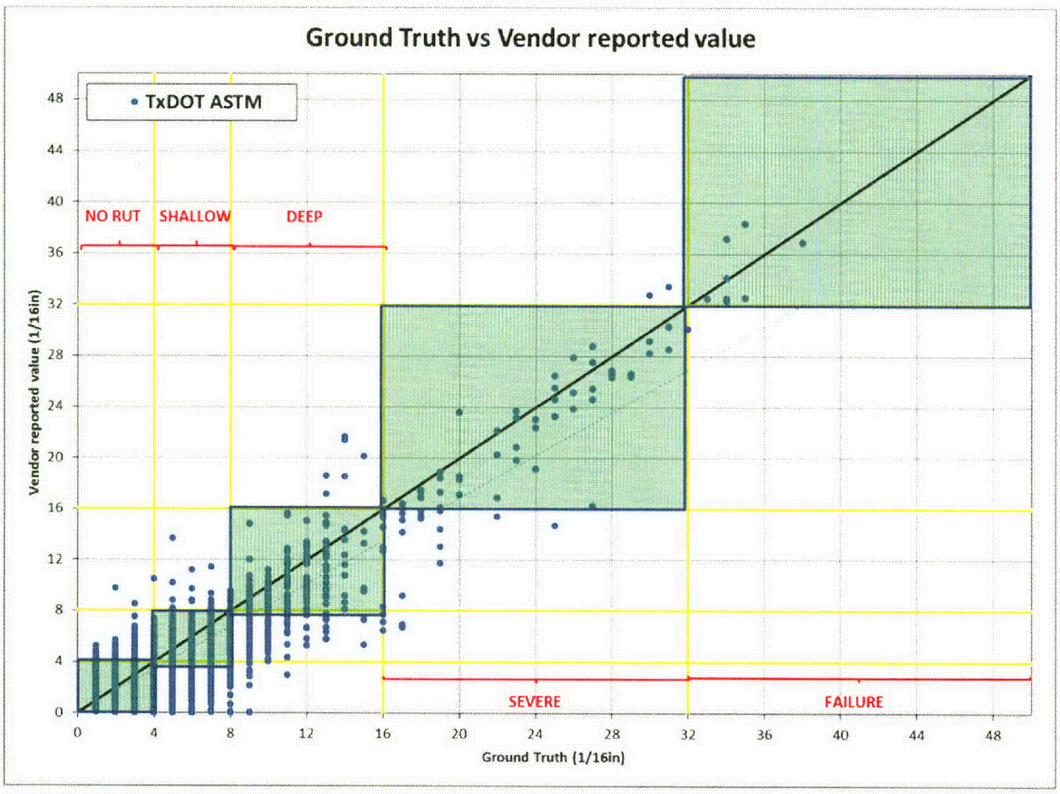


Figure 4.45: TxDOT ASTM vs. GT IWP MRD values for all the sections

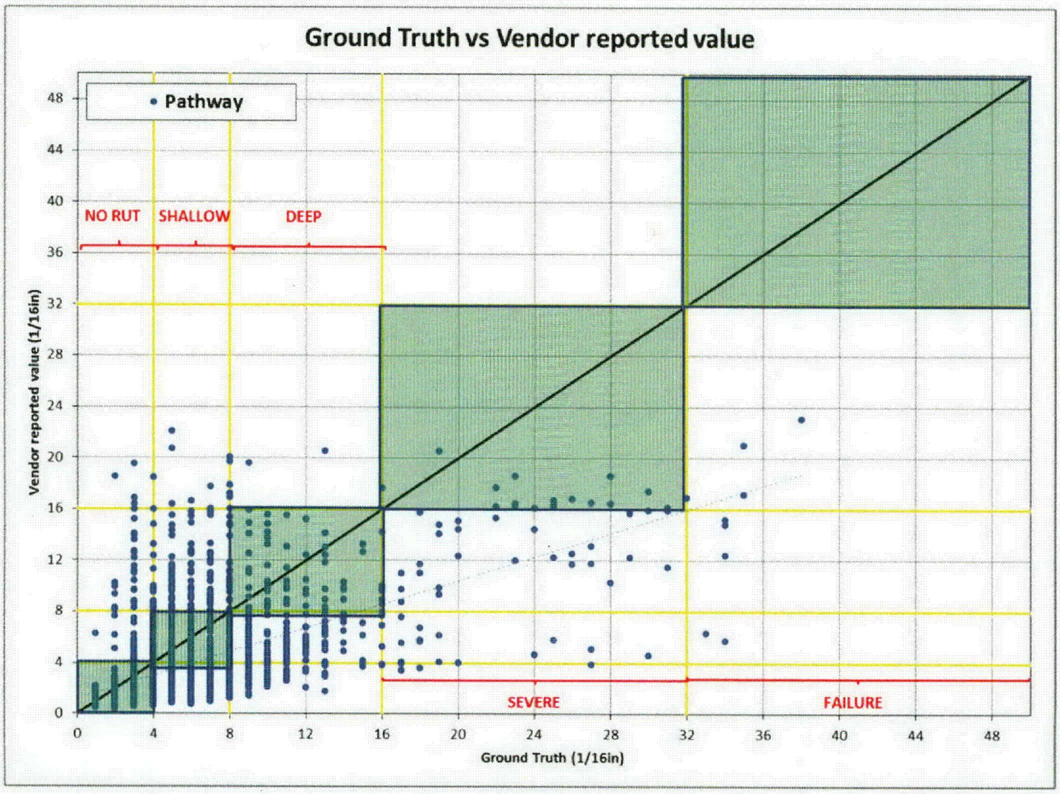


Figure 4.46: Pathway vs. GT IWP MRD values for all the sections

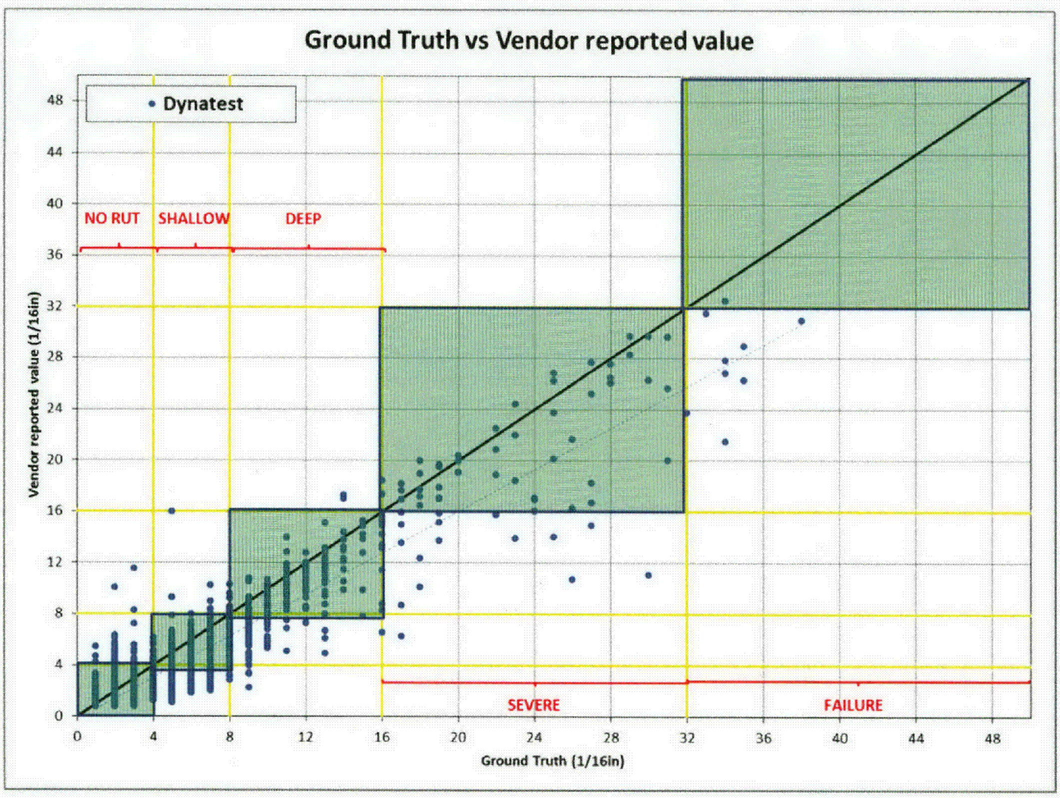


Figure 4.47: Dynatest vs. GT IWP MRD values for all the sections

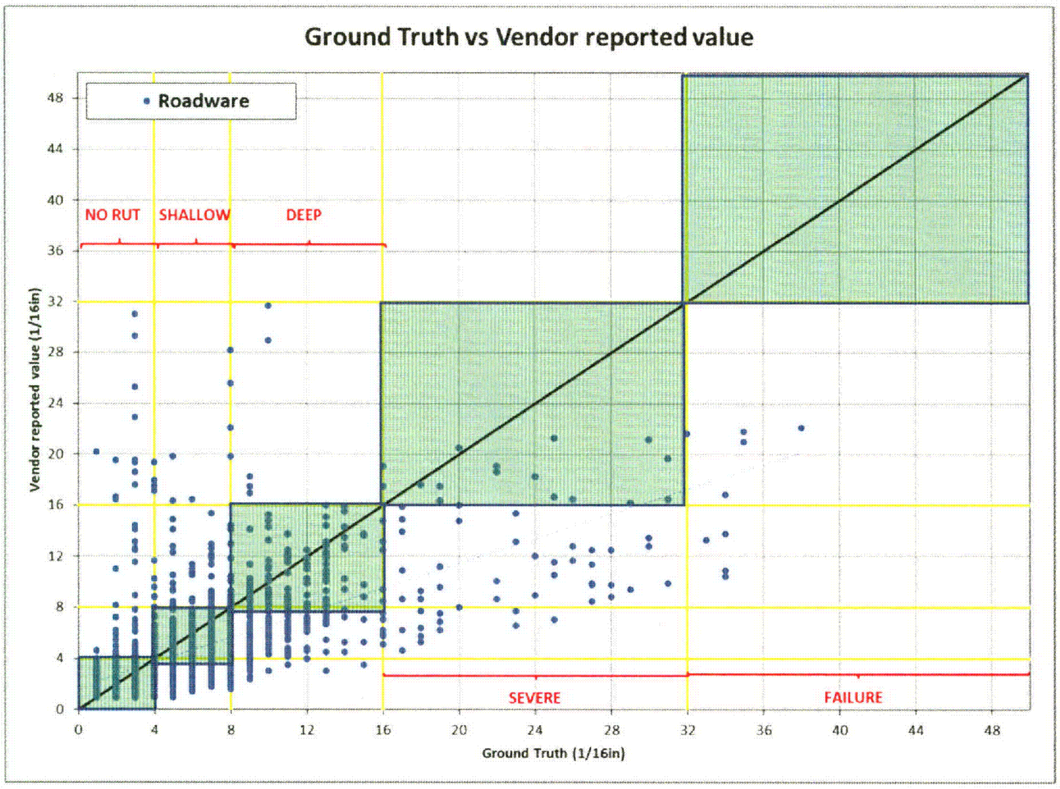


Figure 4.48: Roadware vs. GT IWP MRD values for all the sections

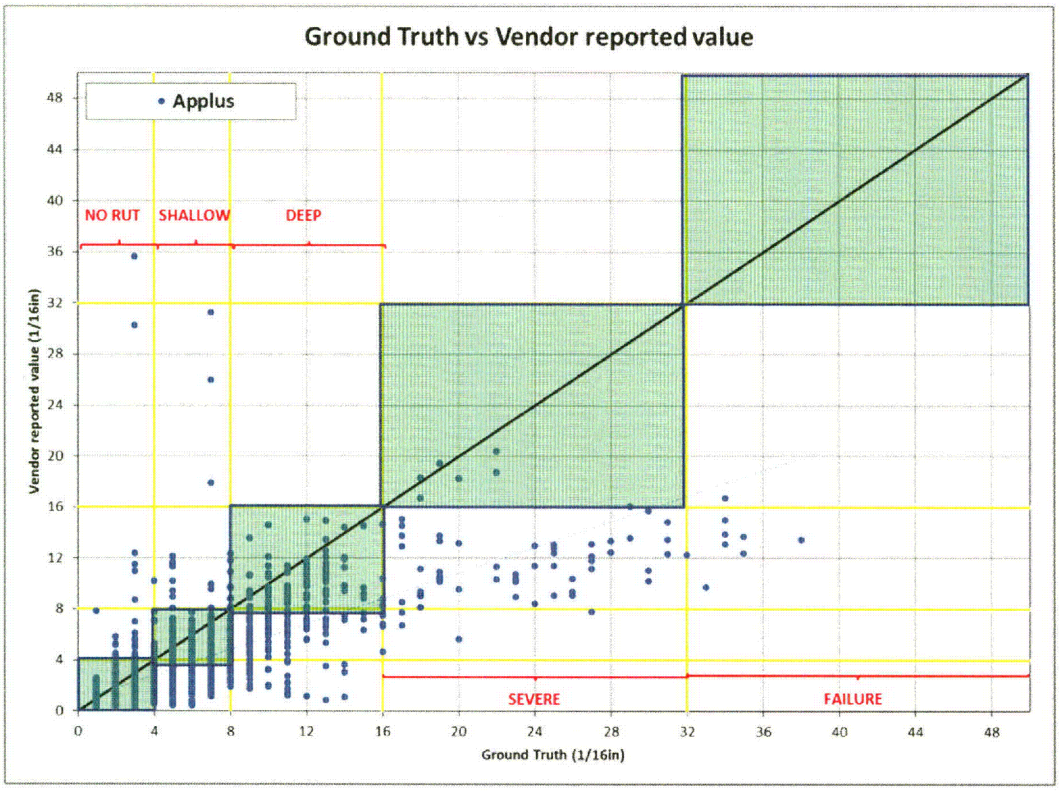


Figure 4.49: Applus vs. GT IWP MRD values for all the sections

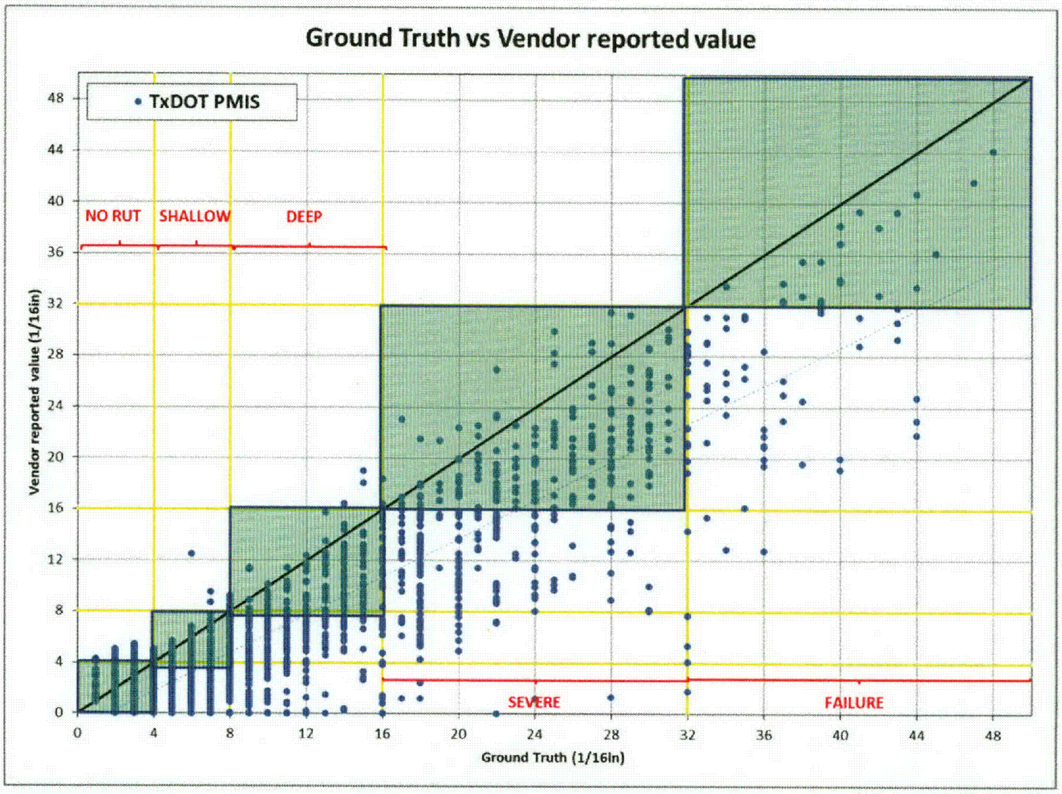


Figure 4.50: TxDOT PMIS vs. GT OWP MRD values for all the sections

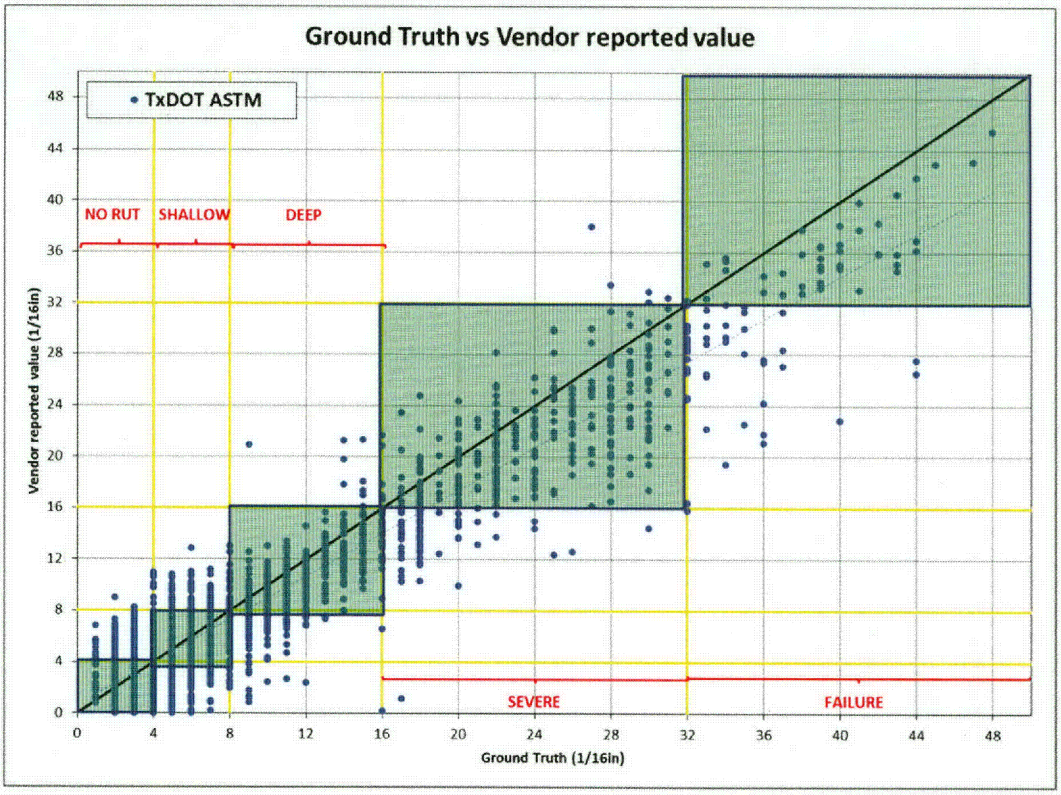


Figure 4.51: TxDOT ASTM vs. GT OWP MRD values for all the sections

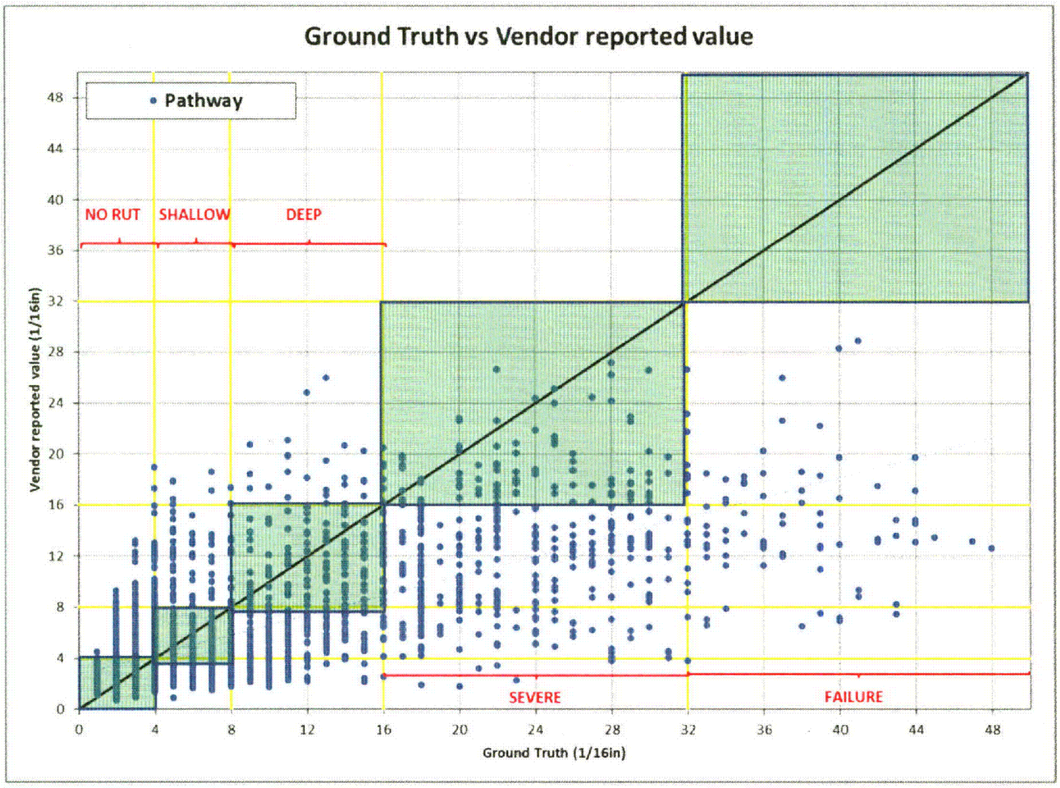


Figure 4.52: Pathway vs. GT OWP MRD values for all the sections

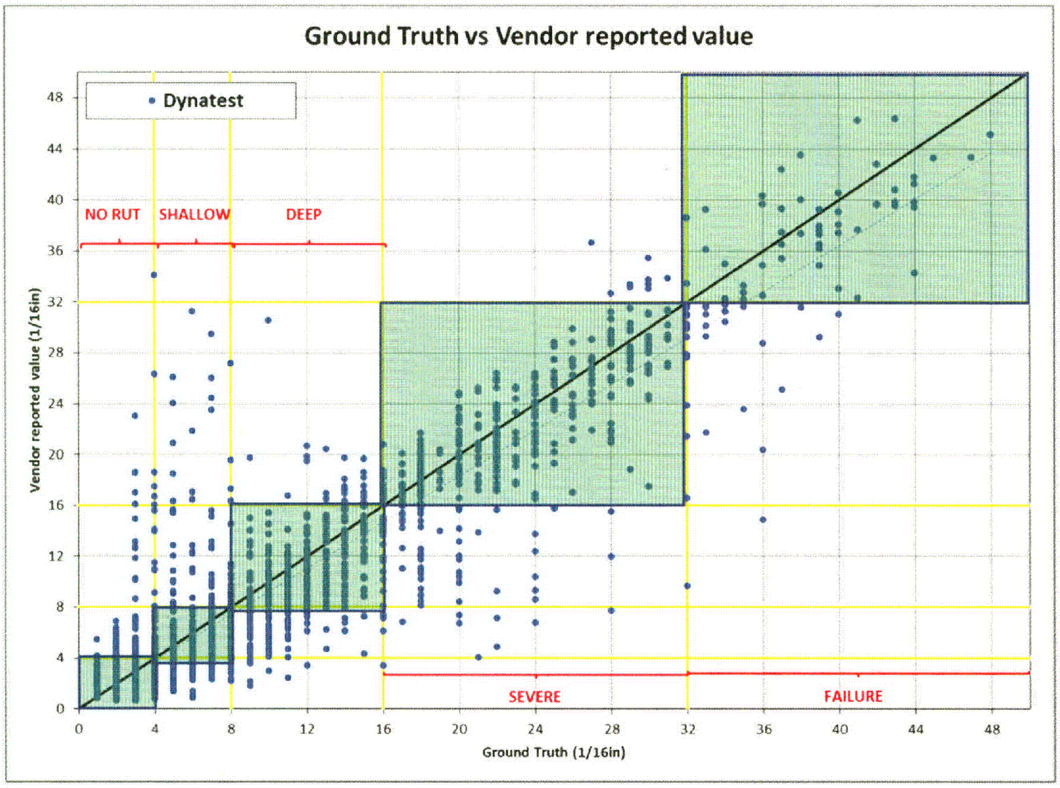


Figure 4.53: Dynatest vs. GT OWP MRD values for all the sections

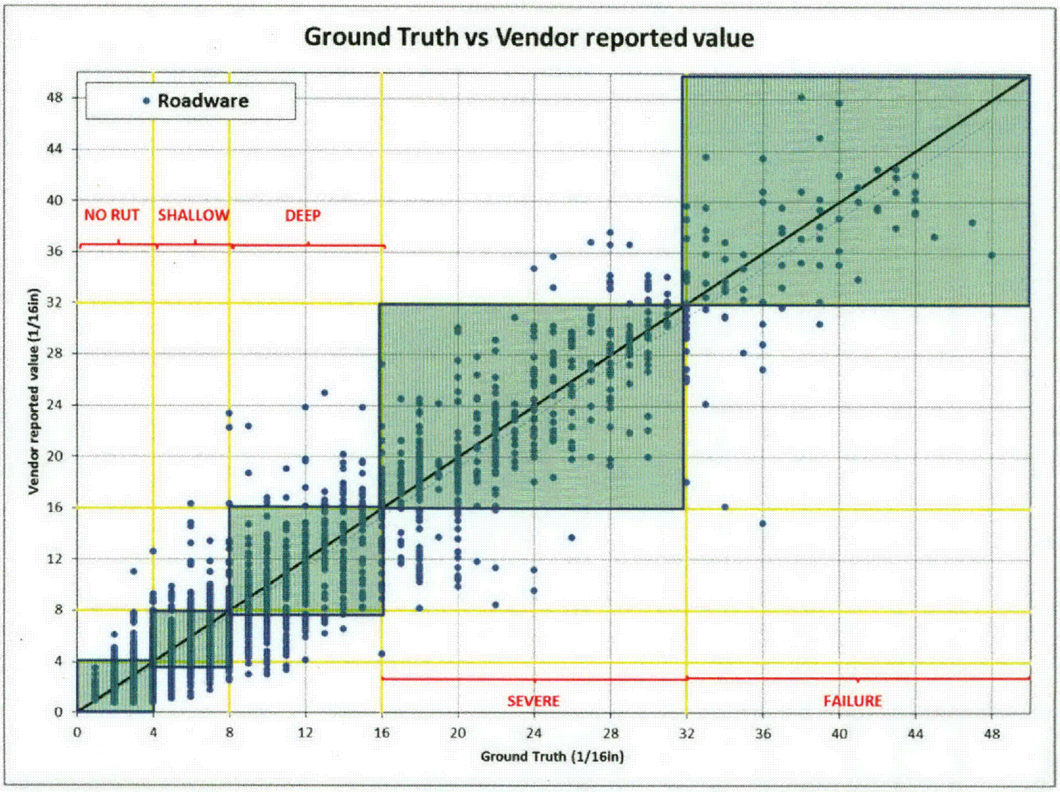


Figure 4.54: Roadware vs. GT OWP MRD values for all the sections

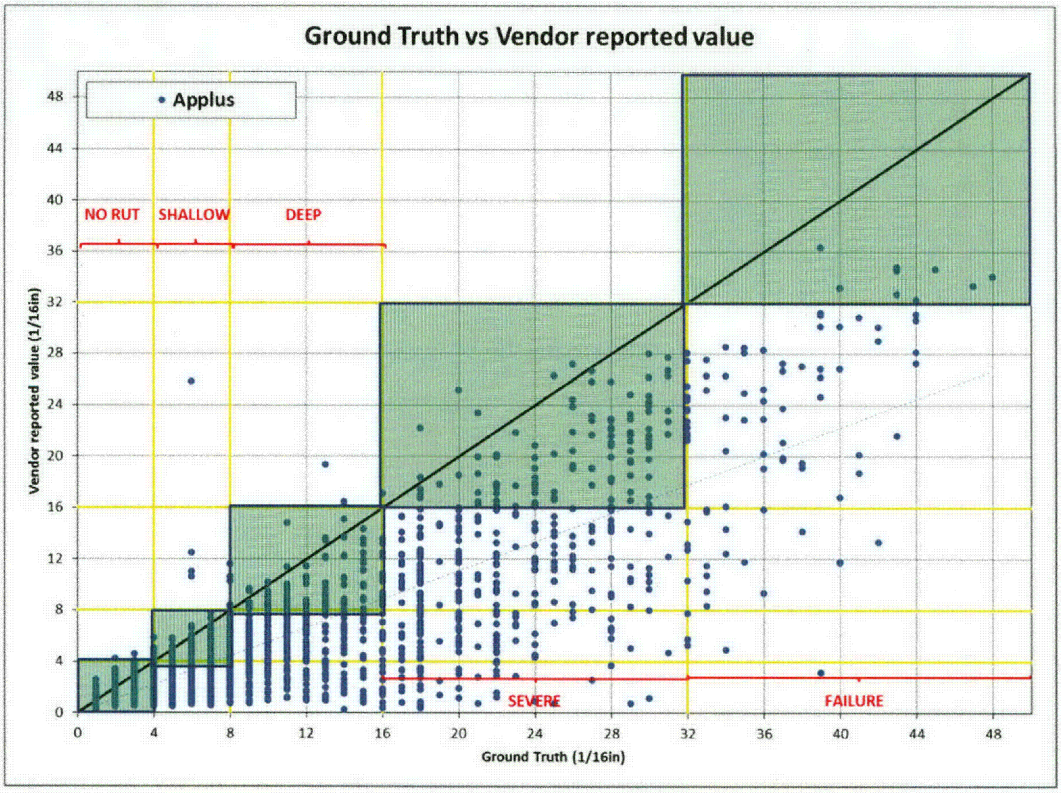


Figure 4.55: Applus vs. GT OWP MRD values for all the sections

Table 4.32: IWP Bias Comparison

Section	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	Vendor with Bias closest to zero
	IWP - Bias [16th in]						
3	1.60	0.17	2.81	1.37	0.78	1.64	TxDOT ASTM
4	-1.49	-2.44	0.07	-0.56	-1.27	-0.55	Pathway
5	5.59	1.26	4.59	2.09	4.10	2.80	TxDOT ASTM
6	4.08	2.87	2.72	1.97	1.79	1.91	Roadware
7	3.77	1.02	5.50	1.04	2.88	1.79	TxDOT ASTM
8	4.42	0.79	1.51	1.79	2.01	2.61	TxDOT ASTM
9	4.04	0.79	1.78	1.18	1.01	2.20	TxDOT ASTM
10	4.22	1.40	1.77	2.40	0.97	3.79	Roadware
11	3.30	-0.33	1.64	1.82	-0.22	2.05	Roadware
12	1.86	0.75	-1.22	0.91	-3.27	0.10	Applus
13	4.96	1.53	2.11	2.51	1.61	2.73	TxDOT ASTM
14	2.65	-0.59	2.32	1.24	2.07	2.22	TxDOT ASTM
15	3.82	0.73	2.79	2.14	2.15	3.03	TxDOT ASTM
16	2.28	-0.37	1.30	0.93	0.61	1.11	TxDOT ASTM
17	0.41	-0.39	0.18	0.32	0.35	0.58	Pathway
18	1.08	0.90	1.02	0.58	0.05	1.07	Roadware
19	6.44	4.07	0.18	2.00	0.42	3.02	Pathway
20	4.31	4.04	-0.21	0.90	0.41	-0.18	Applus
21	0.10	-0.37	1.24	-1.41	-0.15	0.32	TxDOT PMIS
22	0.35	-0.19	1.09	0.66	0.63	1.06	TxDOT ASTM
23	9.67	0.93	7.63	2.79	6.96	8.03	TxDOT ASTM
24	4.16	2.65	1.26	1.66	1.09	1.71	Roadware
25	5.36	0.88	0.98	1.53	2.11	3.11	TxDOT ASTM
26	5.10	0.76	1.98	1.03	1.33	2.70	TxDOT ASTM
	number of section (percentage) at which each participant presents the Bias closest to zero						
	1 (4.2%)	13 (54.2%)	3 (12.5%)	0 (0%)	5 (20.8%)	2 (8.3%)	

Table 4.33: IWP Precision Comparison

Section		IWP - Precision [16th in]						Vendor with Precision closest to zero
		TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	
Section	3	1.56	2.06	1.60	1.49	1.97	1.38	Applus
	4	0.95	0.79	0.59	0.57	0.69	0.61	Dynatest
	5	1.38	0.79	1.43	0.99	1.45	1.21	TxDOT ASTM
	6	1.23	1.35	0.96	0.91	1.42	1.05	Dynatest
	7	1.14	2.02	1.78	0.75	2.03	1.55	Dynatest
	8	1.52	0.99	1.85	1.11	1.60	1.32	TxDOT ASTM
	9	1.78	0.84	2.22	1.27	1.70	1.49	TxDOT ASTM
	10	1.35	1.03	2.30	1.01	1.40	1.01	Applus
	11	1.42	1.16	1.41	0.96	1.05	0.98	Dynatest
	12	3.98	2.35	5.93	1.84	6.69	4.69	Dynatest
	13	1.17	0.99	2.74	0.98	1.13	1.03	Dynatest
	14	1.96	1.47	1.70	1.06	1.48	1.37	Dynatest
	15	1.40	1.21	1.58	0.92	1.07	0.97	Dynatest
	16	0.78	1.47	0.86	0.64	0.69	0.70	Dynatest
	17	1.53	1.29	1.30	0.80	0.82	0.88	Dynatest
	18	0.93	0.74	0.40	0.36	0.43	0.49	Dynatest
	19	3.25	2.18	5.54	2.34	6.59	3.84	TxDOT ASTM
	20	2.47	1.43	4.45	1.22	2.06	9.22	Dynatest
	21	0.82	0.73	0.58	1.17	0.82	0.91	Pathway
	22	0.90	0.82	0.53	0.63	0.61	0.63	Pathway
	23	6.50	1.29	6.13	3.54	6.84	6.96	TxDOT ASTM
	24	1.98	1.90	3.08	1.24	2.23	1.69	Dynatest
	25	4.36	2.57	6.26	2.59	5.56	3.13	TxDOT ASTM
	26	2.99	1.52	4.19	1.14	2.01	3.41	Dynatest
		number of section (percentage) at which each participant presents the Precision closest to zero						
		0 (0%)	6 (25%)	2 (8.3%)	14 (58.3%)	0 (0%)	2 (8.3%)	

Table 4.34: IWP MSE Comparison

Section	IWP - MSE [16th in] TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	Vendor with MSE closest to zero
3	2.24	2.07	3.23	2.02	2.11	2.14	Dynatest
4	1.77	2.56	0.60	0.80	1.44	0.82	Pathway
5	5.76	1.49	4.81	2.31	4.35	3.05	TxDOT ASTM
6	4.26	3.17	2.89	2.17	2.29	2.18	Dynatest
7	3.94	2.27	5.78	1.28	3.52	2.36	Dynatest
8	4.67	1.27	2.39	2.10	2.57	2.92	TxDOT ASTM
9	4.41	1.16	2.85	1.73	1.97	2.66	TxDOT ASTM
10	4.43	1.74	2.91	2.60	1.70	3.92	Roadware
11	3.59	1.20	2.16	2.06	1.07	2.27	Roadware
12	4.40	2.47	6.05	2.06	7.44	4.69	Dynatest
13	5.09	1.83	3.46	2.70	1.97	2.92	TxDOT ASTM
14	3.29	1.59	2.88	1.63	2.55	2.61	TxDOT ASTM
15	4.07	1.41	3.21	2.33	2.40	3.18	TxDOT ASTM
16	2.40	1.52	1.56	1.12	0.92	1.31	Roadware
17	1.58	1.35	1.31	0.86	0.89	1.06	Dynatest
18	1.43	1.16	1.10	0.69	0.43	1.17	Roadware
19	7.21	4.62	5.54	3.08	6.61	4.89	Dynatest
20	4.96	4.29	4.46	1.52	2.10	9.22	Dynatest
21	0.83	0.81	1.37	1.83	0.83	0.96	TxDOT ASTM
22	0.96	0.84	1.21	0.92	0.87	1.23	TxDOT ASTM
23	11.65	1.59	9.78	4.51	9.76	10.63	TxDOT ASTM
24	4.61	3.26	3.32	2.07	2.48	2.41	Dynatest
25	6.91	2.71	6.33	3.00	5.95	4.41	TxDOT ASTM
26	5.91	1.70	4.64	1.54	2.41	4.35	Dynatest
number of section (percentage) at which each participant presents the MSE closest to zero	0 (0%)	10 (41.7%)	1 (4.2%)	9 (37.5%)	4 (16.7%)	0 (0%)	

Table 4.35: IWP Slope Comparison

		IWP - Slope						Vendor with Slope closest to 1
		TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	
Section	3	0.47	0.50	0.22	0.67	0.47	0.69	Applus
	4	0.21	0.41	-0.02	0.08	0.41	0.24	Roadware
	5	0.17	0.74	0.20	0.81	0.37	0.58	Dynatest
	6	-0.05	0.22	0.13	0.40	-0.04	0.36	Dynatest
	7	0.89	0.69	0.45	1.03	1.03	0.93	Dynatest
	8	0.10	0.80	0.01	0.47	0.04	0.25	TxDOT ASTM
	9	0.40	0.90	0.21	0.74	0.59	0.72	TxDOT ASTM
	10	0.03	0.68	-0.85	0.30	0.44	0.20	TxDOT ASTM
	11	0.38	0.66	0.33	0.75	0.72	0.68	Dynatest
	12	0.41	1.40	-0.43	0.67	-0.01	0.34	Dynatest
	13	0.70	0.74	1.13	0.80	0.90	0.69	Roadware
	14	0.23	0.86	0.47	0.97	0.48	0.71	Dynatest
	15	-0.05	0.39	-0.17	0.34	0.13	0.30	TxDOT ASTM
	16	-0.02	0.85	-0.06	0.39	0.29	0.47	TxDOT ASTM
	17	0.08	0.54	0.68	0.74	0.53	0.67	Dynatest
	18	-0.20	0.03	0.17	0.39	0.35	0.19	Dynatest
	19	0.18	0.56	-0.08	0.73	0.07	0.42	Dynatest
	20	0.37	0.80	0.57	0.92	0.72	0.72	Dynatest
	21	0.08	0.03	0.01	-0.32	-0.14	0.18	Applus
	22	0.02	-0.15	0.13	0.06	0.00	-0.01	Pathway
	23	0.42	1.01	0.51	0.83	0.42	0.35	TxDOT ASTM
	24	0.27	0.67	0.34	0.57	0.05	0.36	TxDOT ASTM
	25	0.19	0.80	-0.12	0.82	0.12	0.58	Dynatest
	26	0.58	0.80	0.41	0.96	0.79	0.56	Dynatest
		number of section (percentage) at which each participant presents the slope closest to 1						
		0 (0%)	7 (29.2%)	1 (4.2%)	12 (50%)	2 (8.3%)	2 (8.3%)	

Table 4.36: IWP Correlation Comparison

Section	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	Vendor with Correlation closest to 1
3	0.49	0.38	0.33	0.60	0.39	0.65	Applus
4	0.13	0.29	-0.05	0.15	0.34	0.27	Roadware
5	0.37	0.84	0.35	0.79	0.44	0.64	TxDOT ASTM
6	-0.05	0.17	0.21	0.45	-0.03	0.36	Dynatest
7	0.91	0.71	0.77	0.97	0.81	0.85	Dynatest
8	0.15	0.75	0.01	0.60	0.06	0.37	TxDOT ASTM
9	0.50	0.91	0.25	0.78	0.61	0.71	TxDOT ASTM
10	0.04	0.60	-0.61	0.43	0.34	0.37	TxDOT ASTM
11	0.47	0.69	0.44	0.79	0.74	0.77	Dynatest
12	0.26	0.85	-0.21	0.70	0.00	0.18	TxDOT ASTM
13	0.59	0.68	0.43	0.70	0.68	0.64	Dynatest
14	0.40	0.78	0.61	0.89	0.71	0.77	Dynatest
15	-0.05	0.33	-0.14	0.43	0.18	0.38	Dynatest
16	-0.04	0.36	-0.08	0.47	0.36	0.46	Dynatest
17	0.08	0.43	0.50	0.73	0.66	0.66	Dynatest
18	-0.10	0.02	0.30	0.52	0.40	0.22	Dynatest
19	0.38	0.78	-0.07	0.76	0.04	0.41	TxDOT ASTM
20	0.66	0.90	0.40	0.93	0.79	0.25	Dynatest
21	0.07	0.04	0.06	-0.21	-0.17	0.14	Applus
22	0.02	-0.17	0.39	0.10	-0.01	-0.03	Pathway
23	0.89	0.99	0.85	0.94	0.81	0.94	TxDOT ASTM
24	0.42	0.63	0.26	0.83	0.11	0.61	Dynatest
25	0.45	0.85	-0.19	0.85	0.16	0.77	Dynatest
26	0.73	0.94	0.47	0.97	0.89	0.65	Dynatest
number of section (percentage) at which each participant presents the correlation closest to 1							
	0 (0%)	7 (29.2%)	1 (4.2%)	13 (54.2%)	1 (4.2%)	2 (8.3%)	

Header "IWP - Correlation" spans the six participant columns.

Table 4.37: OWP Bias Comparison

Section	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	Vendor with Bias closest to zero
	OWP - Bias [16th in]						
3	4.50	1.49	3.16	2.24	2.00	3.27	TxDOT ASTM
4	1.71	-0.78	-0.35	-0.97	0.14	0.38	Roadware
5	3.70	0.65	3.25	1.04	1.28	1.99	TxDOT ASTM
6	4.19	-2.66	2.25	1.53	-0.78	1.74	Roadware
7	6.68	0.61	7.18	5.06	4.93	5.97	TxDOT ASTM
8	1.62	1.06	-2.07	0.11	-0.10	0.80	Roadware
9	6.15	3.06	4.12	1.45	0.78	5.38	Roadware
10	3.98	2.30	1.07	1.46	0.17	3.29	Roadware
11	2.13	1.39	0.31	0.39	0.00	2.04	Roadware
12	6.77	2.91	-1.40	3.52	0.82	6.44	Roadware
13	6.52	3.87	8.21	0.05	0.12	4.90	Dynatest
14	0.68	-0.19	2.42	0.00	0.44	5.74	Dynatest
15	9.97	2.11	6.09	-1.17	-0.56	10.53	Roadware
16	0.46	-0.91	0.90	0.58	0.36	1.28	Roadware
17	1.64	-1.21	1.30	0.81	1.22	1.60	Dynatest
18	-0.46	-2.55	-0.34	1.02	1.24	1.64	Pathway
19	2.31	1.36	6.41	2.82	-1.71	8.36	TxDOT ASTM
20	3.08	2.23	5.97	1.11	1.26	4.68	Dynatest
21	1.29	-1.78	-1.24	-1.81	-0.42	0.25	Applus
22	1.32	-1.98	-0.62	0.11	1.18	1.47	Dynatest
23	4.79	3.41	13.01	1.37	-0.05	5.50	Roadware
24	5.00	1.79	4.62	0.10	0.14	7.92	Dynatest
25	3.68	1.92	2.49	-3.25	-0.50	6.46	Roadware
26	4.45	2.94	5.95	-1.04	-0.58	8.33	Roadware
	number of section (percentage) at which each participant presents the Bias closest to zero						
	0 (0%)	4 (16.7%)	1 (4.2%)	6 (25%)	12 (50%)	1 (4.2%)	

Table 4.38: OWP Precision Comparison

Section	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	Vendor with Precision closest to zero
	OWP - Precision [16th in]						
3	1.30	2.07	1.75	0.91	1.64	1.21	Dynatest
4	0.88	1.29	0.74	0.88	0.90	0.72	Applus
5	1.28	1.08	2.13	1.12	1.66	1.53	TxDOT ASTM
6	2.21	1.68	1.77	1.26	1.78	1.36	Dynatest
7	3.27	1.34	2.81	2.61	2.48	2.98	TxDOT ASTM
8	1.11	0.95	1.79	2.40	0.95	0.91	Applus
9	5.28	2.88	6.11	2.16	3.27	5.34	Dynatest
10	1.62	1.54	3.91	1.65	1.90	1.79	TxDOT ASTM
11	1.55	1.36	4.11	2.27	1.66	1.70	TxDOT ASTM
12	5.10	3.15	7.82	5.82	4.35	7.01	TxDOT ASTM
13	4.10	3.73	6.46	3.05	2.90	3.54	Roadware
14	2.15	1.98	4.17	1.78	2.52	6.42	Dynatest
15	4.36	2.73	6.96	2.64	3.51	5.04	Dynatest
16	0.77	2.30	0.88	0.83	1.09	0.66	Applus
17	1.30	1.50	1.73	1.06	0.92	0.88	Applus
18	1.66	1.87	1.44	1.24	1.22	1.13	Applus
19	3.48	3.24	9.19	3.72	4.47	7.16	TxDOT ASTM
20	2.64	2.44	7.06	2.62	3.19	4.31	TxDOT ASTM
21	0.81	1.06	0.69	1.05	0.93	0.70	Pathway
22	0.98	1.35	0.98	0.89	0.83	0.79	Applus
23	2.58	2.15	10.56	1.33	3.37	4.24	Dynatest
24	3.29	2.42	7.44	2.85	1.94	6.20	Roadware
25	3.20	3.25	6.89	7.57	2.96	5.87	Roadware
26	2.78	2.48	8.15	5.04	2.10	6.71	Roadware
number of section (percentage) at which each participant presents the Precision closest to zero							
	0 (0%)	7 (29.2%)	1 (4.2%)	6 (25%)	4 (16.7%)	6 (25%)	

Table 4.39: OWP MSE Comparison

		OWP - MSE [16th in]						Vendor with MSE closest to zero
		TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	
Section	3	4.68	2.55	3.61	2.42	2.59	3.49	Dynatest
	4	1.93	1.51	0.82	1.31	0.91	0.81	Applus
	5	3.91	1.26	3.88	1.53	2.10	2.51	TxDOT ASTM
	6	4.74	3.14	2.86	1.99	1.94	2.21	Roadware
	7	7.44	1.47	7.71	5.69	5.52	6.67	TxDOT ASTM
	8	1.96	1.42	2.73	2.40	0.95	1.21	Roadware
	9	8.11	4.20	7.37	2.60	3.36	7.58	Dynatest
	10	4.30	2.77	4.05	2.20	1.91	3.74	Roadware
	11	2.64	1.95	4.12	2.30	1.66	2.66	Roadware
	12	8.48	4.29	7.94	6.80	4.43	9.52	TxDOT ASTM
	13	7.70	5.37	10.45	3.05	2.90	6.04	Roadware
	14	2.25	1.99	4.82	1.78	2.56	8.61	Dynatest
	15	10.88	3.45	9.25	2.89	3.56	11.67	Dynatest
	16	0.90	2.48	1.26	1.01	1.15	1.44	TxDOT PMIS
	17	2.09	1.93	2.16	1.34	1.53	1.82	Dynatest
	18	1.72	3.16	1.48	1.60	1.74	1.99	Pathway
	19	4.18	3.52	11.21	4.67	4.78	11.01	TxDOT ASTM
	20	4.05	3.30	9.24	2.84	3.42	6.36	Dynatest
	21	1.52	2.07	1.42	2.09	1.02	0.75	Applus
	22	1.64	2.40	1.16	0.90	1.45	1.67	Dynatest
	23	5.44	4.03	16.76	1.91	3.37	6.94	Dynatest
	24	5.99	3.01	8.76	2.85	1.95	10.06	Roadware
	25	4.88	3.78	7.33	8.24	3.00	8.73	Roadware
	26	5.25	3.84	10.09	5.15	2.18	10.69	Roadware
		number of section (percentage) at which each participant presents the MSE closest to zero						
		1 (4.2%)	4 (16.7%)	1 (4.2%)	8 (33.3%)	8 (33.3%)	2 (8.3%)	

Table 4.40: OWP Slope Comparison

	OWP - Slope						Vendor with Slope closest to 1
Section	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	
3	0.48	1.09	0.03	0.65	0.40	0.47	TxDOT ASTM
4	-0.31	0.16	0.48	0.18	-0.08	0.40	Pathway
5	0.69	0.86	0.35	0.87	0.81	0.81	Dynatest
6	-0.08	0.86	0.18	0.63	0.60	0.51	TxDOT ASTM
7	0.30	0.76	0.39	0.49	0.50	0.37	TxDOT ASTM
8	0.23	0.31	0.21	1.11	0.46	0.25	Dynatest
9	0.36	0.74	0.36	0.90	0.84	0.45	Dynatest
10	0.60	0.66	-0.50	0.45	0.53	0.22	TxDOT ASTM
11	0.94	0.94	0.12	0.90	0.96	0.71	Roadware
12	0.58	1.02	0.15	0.43	0.99	0.20	Roadware
13	0.64	0.70	0.36	0.88	0.94	0.72	Roadware
14	0.81	1.00	0.49	0.83	0.79	0.01	TxDOT ASTM
15	0.66	0.95	0.45	1.03	0.96	0.61	Dynatest
16	0.41	0.37	0.31	0.50	0.80	0.66	Roadware
17	0.73	0.88	0.36	0.70	0.62	0.82	TxDOT ASTM
18	0.04	0.05	0.03	0.15	0.03	0.11	Dynatest
19	1.09	1.04	0.06	0.86	1.09	0.36	TxDOT ASTM
20	0.89	0.91	0.29	0.91	0.86	0.61	Dynatest
21	-0.13	0.79	-0.12	0.26	0.03	0.05	TxDOT ASTM
22	-0.14	0.68	0.07	0.28	0.00	0.03	TxDOT ASTM
23	0.91	0.93	0.33	0.96	0.91	0.76	Dynatest
24	0.80	1.01	0.32	0.90	0.95	0.40	TxDOT ASTM
25	0.82	0.76	0.15	0.52	0.84	0.24	Roadware
26	0.80	0.83	0.34	0.85	0.99	0.49	Roadware
	number of section (percentage) at which each participant presents the slope closest to 1						
	0 (0%)	10 (41.7%)	1 (4.2%)	7 (29.2%)	6 (25%)	0 (0%)	

Table 4.41: OWP Correlation Comparison

Section	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus	Vendor with Correlation closest to 1
	OWP - Correlation						
3	0.59	0.63	0.06	0.81	0.42	0.63	Dynatest
4	-0.27	0.07	0.34	0.12	-0.06	0.31	Pathway
5	0.88	0.91	0.58	0.91	0.80	0.83	TxDOT ASTM
6	-0.18	0.70	0.36	0.75	0.57	0.69	Dynatest
7	0.65	0.96	0.81	0.80	0.84	0.74	TxDOT ASTM
8	0.17	0.26	0.09	0.31	0.35	0.23	Roadware
9	0.83	0.94	0.61	0.96	0.91	0.73	Dynatest
10	0.66	0.70	-0.40	0.62	0.55	0.51	TxDOT ASTM
11	0.92	0.94	0.19	0.84	0.91	0.91	TxDOT ASTM
12	0.77	0.93	0.31	0.69	0.88	0.50	TxDOT ASTM
13	0.94	0.94	0.86	0.95	0.95	0.95	Roadware
14	0.95	0.96	0.77	0.97	0.92	0.05	Dynatest
15	0.83	0.94	0.54	0.95	0.91	0.76	Dynatest
16	0.55	0.15	0.40	0.54	0.55	0.71	Applus
17	0.70	0.70	0.40	0.78	0.84	0.85	Applus
18	0.04	0.04	0.04	0.21	0.05	0.22	Applus
19	0.94	0.94	0.12	0.91	0.91	0.58	TxDOT ASTM
20	0.95	0.96	0.56	0.95	0.93	0.88	TxDOT ASTM
21	-0.12	0.36	-0.17	0.14	0.02	0.05	TxDOT ASTM
22	-0.21	0.36	0.08	0.29	-0.01	0.09	TxDOT ASTM
23	0.99	0.99	0.78	1.00	0.97	0.98	Dynatest
24	0.93	0.97	0.54	0.95	0.98	0.74	Roadware
25	0.89	0.88	0.28	0.47	0.91	0.55	Roadware
26	0.97	0.98	0.58	0.87	0.98	0.75	Roadware
	number of section (percentage) at which each participant presents the correlation closest to 1						
	0 (0%)	9 (37.5%)	1 (4.2%)	6 (25%)	5 (20.8%)	3 (12.5%)	

4.2.3 Summary Tables of Comparison

This section presents the Summary Tables for both the transverse profiles and the MRD comparison. Table 4.42 contains the number of sections for which each participant presented the best transverse profile statistics for each of the five calculated parameters: Bias, Precision, MSE, SSEn, and corr. These values were compiled from the last rows of Tables 4.27 to 4.31. The values in bold indicate the largest number for each calculated parameter.

These summary tables indicate that Applus presented the best Precision (e.g., smallest Random Error) and MSE, whereas both TxDOT and Dynatest presented the best Bias (e.g., smallest Systematic Error). Additionally, Applus evidently presented the best SSEn values and Dynatest presented the best Correlation Coefficients. However, the magnitudes of the calculated parameters for each of the participants (reported in Tables 4.27 to 4.31) are generally very similar with respect to each other and very close to the ideal value for each case. This observation indicates that regardless of the number of sections at which each participant reported the best measurements, all the systems were able to provide high quality transverse profile measurements.

Table 4.42: Summary Table of Transverse Profile Comparison

	TxDOT	Pathway	Dynatest	Roadware	Applus
Bias [1]	**9 (37.5%)**	1 (4.2%)	**9 (37.5%)**	1 (4.2%)	4 (16.7%)
Precision [2]	2 (8.3%)	0 (0%)	7 (29.2%)	4 (16.7%)	**11 (45.8%)**
MSE [3]	2 (8.3%)	0 (0%)	7 (29.2%)	4 (16.7%)	**11 (45.8%)**
SSEn [4]	2 (8.3%)	0 (0%)	7 (29.2%)	4 (16.7%)	**11 (45.8%)**
Correlation [5]	2 (8.3%)	0 (0%)	**11 (45.8%)**	2 (8.3%)	9 (37.5%)

NOTES
1. Number of section (percentage) at which each participant presents the Bias closest to 0.
2. Number of section (percentage) at which each participant presents the minimum Precision.
3. Number of section (percentage) at which each participant presents the minimum MSE.
4. Number of section (percentage) at which each participant presents the minimum SSEn.
5. Number of section (percentage) at which each participant presents the correlation coefficient closest to 1.

Tables 4.43 and 4.44 contain the number of sections at which each participant presented the best MRD statistics for the IWP and OWP respectively, for each of the five calculated parameters: Bias, Precision, MSE, Slope of the Linear Regression (Slope), and Correlation Coefficient (corr). Each participant's number of sections was obtained from the last row of Tables 4.32 to 4.41. The values in bold indicate the largest number for each calculated parameter.

Table 4.43: Summary Table of IWP MRD Comparison

	IWP MRD					
	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadwar e	Applus
Bias [1]	1 (4.2%)	**13 (54.2%)**	3 (12.5%)	0 (0%)	5 (20.8%)	2 (8.3%)
Precision [2]	0 (0%)	6 (25%)	2 (8.3%)	**14 (58.3%)**	0 (0%)	2 (8.3%)
MSE [3]	0 (0%)	**10 (41.7%)**	1 (4.2%)	9 (37.5%)	4 (16.7%)	0 (0%)
Slope [4]	0 (0%)	7 (29.2%)	1 (4.2%)	**12 (50%)**	2 (8.3%)	2 (8.3%)
Correlation [5]	0 (0%)	7 (29.2%)	1 (4.2%)	**13 (54.2%)**	1 (4.2%)	2 (8.3%)

NOTES
1. Number of section (percentage) at which each participant presents the Bias closest to 0.
2. Number of section (percentage) at which each participant presents the minimum Precision.
3. Number of section (percentage) at which each participant presents the minimum MSE.
4. Number of section (percentage) at which each participant presents the Slope value closest to 1.
5. Number of section (percentage) at which each participant presents the correlation coefficient closest to 1.

Table 4.44: Summary Table of OWP MRD Comparison

	OWP MRD					
	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus
Bias [1]	0 (0%)	4 (16.7%)	1 (4.2%)	6 (25%)	**12 (50%)**	1 (4.2%)
Precision [2]	0 (0%)	**7 (29.2%)**	1 (4.2%)	6 (25%)	4 (16.7%)	6 (25%)
MSE [3]	1 (4.2%)	4 (16.7%)	1 (4.2%)	**8 (33.3%)**	**8 (33.3%)**	2 (8.3%)
Slope [4]	0 (0%)	**10 (41.7%)**	1 (4.2%)	7 (29.2%)	6 (25%)	0 (0%)
Correlation [5]	0 (0%)	**9 (37.5%)**	1 (4.2%)	6 (25%)	5 (20.8%)	3 (12.5%)

NOTES
1. Number of section (percentage) at which each participant presents the Bias closest to 0.
2. Number of section (percentage) at which each participant presents the minimum Precision.
3. Number of section (percentage) at which each participant presents the minimum MSE.
4. Number of section (percentage) at which each participant presents the Slope value closest to 1.
5. Number of section (percentage) at which each participant presents the correlation coefficient closest to 1.

These summary tables indicate that, for the IWP, the TxDOT ASTM set of values presented the smallest Systematic Error and MSE, and Dynatest presented the smallest Random Error. For the OWP, the TxDOT ASTM presented the smallest Random Error, Roadware presented the smallest Systematic Error, and both Roadware and Dynatest presented the best

MSE, which accounts for both properties. Additionally, Dynatest presented the best Slope and Correlation values for the IWP whereas the TXDOT ASTM did it for the OWP.

When comparing both sets of TxDOT results, one possible conclusion is that the MRD values produced by the ASTM algorithm are closer to the manually measured ones than the values obtained by the PMIS algorithm.

Lastly, analysis of not only Tables 4.42 to 4.44 but also the statistics presented in Tables 4.27 to 4.41 lead to this conclusion: while all the systems produced good transverse profiles, not all of the systems produce rut depth values close to the reference ones. The participants that presented the MRD values closest to the reference ones were TxDOT (when using ASTM algorithm), Dynatest, and Roadware.

4.3 Reported MRD Values and PMIS Rut Categories

Figures 4.32 to 4.55 showed the relationship between the reported MRD rut data scatter and the PMIS rut categories. Although these graphs are useful for observing the general trend of the overall results for each vendor, some trends are obscured because some data points lay on top of each other. Thus, observing when several correct or incorrect reported MRD values occur is not possible, nor is it possible to get a true assessment of how far from the correct value an incorrect value was categorized. For example, if a GT rut depth was measured as 3/16 of an inch, the correct PMIS rut category is "No Rut." However, the participant's system may have measured the MRD at this location such that it is incorrectly categorized by one, two, three, or even four categories. Note that it is possible to overestimate only the depth of MRD values that should have been categorized as "No Rut" whereas all other categories can be either overestimated or underestimated. Further, for the "Failure" rut category, the size of the error is inconsequential as long as the MRD value was measured at or above 2 inches. Thus, for example, an MRD measurement of 6 inches when the correct measurement was 2 inches would still be correctly categorized as a "Failure" rut.

Tables 4.45 and 4.46, in the left-most set of five columns, show the number of participant measurements collected for the entire experiment according to the PMIS categories for each wheel path. In addition, the percentage of the MRD readings that were correctly categorized are shown in the right-most set of five columns.

An example is presented based on the TxDOT ASTM and Pathway MRD values for the "No Rut" category to illustrate how these tables were used to better understand the results. As shown in Table 4.45, the TxDOT ASTM algorithm correctly categorized 79% of the 765 MRD values that were categorized as "No Rut" based on GT measurements.

Table 4.45: Distribution of GT and participant MRD values according to PMIS rut categories (IWP)

			IWP									
			GT (# of stations)					GT (%)				
			NO RUT	SHALLOW	DEEP	SEVERE	FAILURE	NO RUT	SHALLOW	DEEP	SEVERE	FAILURE
			765	**1404**	**411**	**75**	**9**	**100%**	**100%**	**100%**	**100%**	**100%**
TxDOT PMIS	**FAILURE**	**0**	0	0	0	0	0	0%	0%	0%	0%	0%
	SEVERE	**9**	1	2	0	3	3	0%	0%	0%	4%	33%
	DEEP	**82**	3	3	35	35	6	0%	0%	9%	47%	67%
	SHALLOW	**253**	23	99	109	22	0	3%	7%	27%	29%	0%
	NO RUT	**2320**	738	1300	267	15	0	96%	93%	65%	20%	0%
TxDOT ASTM	**FAILURE**	**10**	0	0	0	2	8	0%	0%	0%	3%	89%
	SEVERE	**53**	0	0	6	46	1	0%	0%	1%	61%	11%
	DEEP	**208**	2	21	163	22	0	0%	1%	40%	29%	0%
	SHALLOW	**1179**	157	805	212	5	0	21%	57%	52%	7%	0%
	NO RUT	**1214**	606	578	30	0	0	79%	41%	7%	0%	0%
Pathway	**FAILURE**	**0**	0	0	0	0	0	0%	0%	0%	0%	0%
	SEVERE	**43**	5	8	8	18	4	1%	1%	2%	24%	44%
	DEEP	**242**	22	110	73	34	3	3%	8%	18%	45%	33%
	SHALLOW	**539**	26	302	192	17	2	3%	22%	47%	23%	22%
	NO RUT	**1840**	712	984	138	6	0	93%	70%	34%	8%	0%
Dynatest	**FAILURE**	**1**	0	0	0	0	1	0%	0%	0%	0%	11%
	SEVERE	**59**	0	1	2	48	8	0%	0%	0%	64%	89%
	DEEP	**221**	3	7	186	25	0	0%	0%	45%	33%	0%
	SHALLOW	**807**	43	553	209	2	0	6%	39%	51%	3%	0%
	NO RUT	**1576**	719	843	14	0	0	94%	60%	3%	0%	0%
Roadware	**FAILURE**	**0**	0	0	0	0	0	0%	0%	0%	0%	0%
	SEVERE	**53**	14	7	10	17	5	2%	0%	2%	23%	56%
	DEEP	**218**	9	44	121	40	4	1%	3%	29%	53%	44%
	SHALLOW	**909**	61	615	215	18	0	8%	44%	52%	24%	0%
	NO RUT	**1484**	681	738	65	0	0	89%	53%	16%	0%	0%
Applus	**FAILURE**	**3**	1	2	0	0	0	0%	0%	0%	0%	0%
	SEVERE	**12**	1	3	0	7	1	0%	0%	0%	9%	11%
	DEEP	**195**	4	15	111	57	8	1%	1%	27%	76%	89%
	SHALLOW	**604**	19	344	230	11	0	2%	25%	56%	15%	0%
	NO RUT	**1850**	740	1040	70	0	0	97%	74%	17%	0%	0%

Table 4.46: Distribution of GT and participant MRD values according to PMIS rut categories (IWP)

			OWP									
			GT (# of stations)					GT (%)				
			NO RUT	SHALLOW	DEEP	SEVERE	FAILURE	NO RUT	SHALLOW	DEEP	SEVERE	FAILURE
			751	833	562	427	91	100%	100%	100%	100%	100%
TxDOT PMIS	FAILURE	26	0	0	0	0	26	0%	0%	0%	0%	29%
	SEVERE	258	0	0	3	198	57	0%	0%	1%	46%	63%
	DEEP	317	0	3	130	180	4	0%	0%	23%	42%	4%
	SHALLOW	480	42	113	286	36	3	6%	14%	51%	8%	3%
	NO RUT	1583	709	717	143	13	1	94%	86%	25%	3%	1%
TxDOT ASTM	FAILURE	51	0	0	0	6	45	0%	0%	0%	1%	49%
	SEVERE	371	0	0	10	316	45	0%	0%	2%	74%	49%
	DEEP	544	3	77	361	102	1	0%	9%	64%	24%	1%
	SHALLOW	837	297	372	167	1	0	40%	45%	30%	0%	0%
	NO RUT	861	451	384	24	2	0	60%	46%	4%	0%	0%
Pathway	FAILURE	0	0	0	0	0	0	0%	0%	0%	0%	0%
	SEVERE	170	0	8	26	103	33	0%	1%	5%	24%	36%
	DEEP	545	24	92	142	239	48	3%	11%	25%	56%	53%
	SHALLOW	746	155	259	245	78	9	21%	31%	44%	18%	10%
	NO RUT	1203	572	474	149	7	1	76%	57%	27%	2%	1%
Dynatest	FAILURE	63	0	1	0	9	53	0%	0%	0%	2%	58%
	SEVERE	421	5	18	30	332	36	1%	2%	5%	78%	40%
	DEEP	420	8	45	291	74	2	1%	5%	52%	17%	2%
	SHALLOW	705	117	355	222	11	0	16%	43%	40%	3%	0%
	NO RUT	1055	621	414	19	1	0	83%	50%	3%	0%	0%
Roadware	FAILURE	93	0	0	0	26	67	0%	0%	0%	6%	74%
	SEVERE	401	0	1	47	330	23	0%	0%	8%	77%	25%
	DEEP	422	1	62	288	70	1	0%	7%	51%	16%	1%
	SHALLOW	754	72	476	205	1	0	10%	57%	36%	0%	0%
	NO RUT	994	678	294	22	0	0	90%	35%	4%	0%	0%
Applus	FAILURE	9	0	0	0	0	9	0%	0%	0%	0%	10%
	SEVERE	167	0	1	2	106	58	0%	0%	0%	25%	64%
	DEEP	316	0	3	108	186	19	0%	0%	19%	44%	21%
	SHALLOW	540	3	159	286	88	4	0%	19%	51%	21%	4%
	NO RUT	1632	748	670	166	47	1	100%	80%	30%	11%	1%

Of the remaining 29% of incorrectly categorized MRD values, all were rated one PMIS category higher as "Shallow Rut." Referring to the results for the Pathway algorithm, 93% of "No Rut" MRD values were correctly categorized while 3% were categorized as a "Shallow Rut," 3% as a "Deep Rut," and 1% as a "Severe Rut."

The researchers feel that these tables provide additional insight regarding the degree to which MRD values were correctly and incorrectly measured. This insight arises both from the number of MRD values that were incorrectly measured and the number of categories away from the true PMIS Category.

Ideally, all MRD values would be correctly categorized even if bias in the measurements is present. Larger errors in the PMIS Distress Scores will accrue as greater numbers of MRD values are incorrectly categorized in PMIS Rut Categories further away from the correct category. Thus, large underestimations of "Severe" and "Failure" rutting will result in distress scores lower than the true values. Large overestimations of "No Rut" and "Shallow Rut" will result in distress scores higher than the true values. Because the PMIS distress scores are included as a factor in the TxDOT pavement funding allocation formulae, correct measurement of MRD values is critical. However, variations occur in all types of distress measurements due to systematic or random errors. The goal is to minimize the number of errors and, when errors do occur, minimize the size of the error.

Tables 4.47 and 4.48 summarize the number of MRD measurements by participant and PMIS Category for the IWP and OWP respectively.

Table 4.47: Total number of MRD values by PMIS Category and participant (IWP)

PMIS Rut Category	IWP						
	GT	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus
NO RUT	765	2320	1214	1840	1576	1484	1849
SHALLOW	1404	253	1179	539	807	909	605
DEEP	411	82	208	242	221	218	195
SEVERE	75	9	53	43	59	53	12
FAILURE	9	0	10	0	1	0	3

Table 4.48: Total number of MRD values by PMIS Category and participant (OWP)

PMIS Rut Category	OWP						
	GT	TxDOT PMIS	TxDOT ASTM	Pathway	Dynatest	Roadware	Applus
NO RUT	751	1583	861	1203	1055	994	1631
SHALLOW	833	480	837	746	705	754	540
DEEP	562	317	544	545	420	422	317
SEVERE	427	258	371	170	421	401	167
FAILURE	91	26	51	0	63	93	9

The yellow cells denote the participant with the number of MRD values closest to the GT value for each PMIS rut category for either the IWP or OWP (5 PMIS Categories x 2 wheel paths = 10 cases in all). In descending order, the TxDOT ASTM algorithm was closest in five cases or 50% of the categories; Pathway and Dynatest were closest in two cases or 20% of the categories each; and Roadware was closest in one case or 10% of the categories.

4.4 Summary

In Chapter 4, the researchers detailed the processing of participant transverse profiles and MRD values so that a comparison could be made to the GT values. In addition, a statistical analysis was performed using five methods each for transverse profiles and MRD values, with the results summarized in tables. Finally, the researchers evaluated each participant's MRD values with regard to the PMIS Rut Categories and discussed how over- or under-representation might impact PMIS Distress scores.

Chapter 5 will summarize the results of this study and recommend the best rut measurement systems in consideration of the different methods used in the comparisons discussed in Chapter 4.

Chapter 5. Recommendations for Selection of Rutting Measuring Equipment

5.1 Introduction

TxDOT has developed a state-of-the-art 3D system for rut measurements. The development of a system to more accurately measure and quantify roadway visual distress—including cracking—is also currently underway. Systems of this type will allow the assessment of road condition at both the network and project levels and potentially eliminate the need for manual visual assessments to rate pavement distress. Furthermore, the improved accuracy, repeatability, and reproducibility of these systems, which can measure distress while traveling at highway speeds, will eliminate any subjective elements in visual rating and will lead to more consistent and reliable data. In addition, automated rating can improve safety by eliminating the need for manual visual rating in a vehicle operating within the lane or along the shoulder at lower speeds. Consistent and reliable data on the Texas road network enhances pavement and maintenance management and, ultimately, will result in better utilization of ever decreasing funding levels and overall better utilization of state resources.

To ensure the rational adoption of the new systems, TxDOT has initiated this project to obtain an independent assessment of the accuracy and repeatability of new TxDOT and vendor systems, which represent the state of the practice in automated rut depth and distress data measurement. As part of this process, The University of Texas at Austin's Center for Transportation Research was awarded TxDOT Research Project 0-6663, "Evaluation of Pavement Rutting and Distress Measurements." The project comprises two phases. Phase I evaluated automated rut measurements and Phase II will evaluate automated visual distress data measurements, including the range of distresses currently evaluated for PMIS applications on asphalt concrete, surface treated, and portland cement concrete pavements.

During Phase I, a factorial experiment was developed to test different pavements, including those with HMA surfaces and surface treatments representing the vast majority of pavement textures on the Texas road network. The accuracy and repeatability of rut measurements using a 6-ft straightedge and rut wedge was compared to measurements from the TxDOT system and four vendor systems. In addition, the surface profiles obtained by the various technologies were evaluated to provide two independent assessments. One assessment was of the rut measurement hardware systems and it was based on the ability of each system to produce accurate transverse profiles in relation to GT measurements. The second assessment accounts for both hardware and software (i.e., filters and data processing algorithms) and was based on the calculated MRDs measured on the pavement surface. The recommendations for the selections of rutting measuring equipment are based on these two assessments.

For Phase II of the project, a survey was conducted to determine the current state of practice for automated distress measurements by different highway agencies in the U.S. and abroad. The system developed by TxDOT will be compared to other viable systems towards recommendations for implementation of the best system to improve the accuracy and repeatability of condition data measurements. Likewise, the impact on PMIS scores will be investigated and recommendations made regarding changes to utility factors, if necessary, to reflect the condition measurements with the new system. This Phase is currently underway.

5.2 Summary Findings

The researchers selected 26 550-ft. test sections on in-service pavements and manually measured the surface transverse profiles every 25 feet with a Leica laser system (23 profiles per section). In addition MRDs were manually measured in the inside wheel path (IWP) and outside wheel path (OWP) with a 6-ft. straightedge and rut wedge every 5 ft. (111 rutting reading per wheel path per section). These manual measurements constitute the reference measurements or benchmark against which the automated rutting measurements were compared. (In this report the manual measurements are referred to as the *ground truth* or GT). Two of the sections where later rehabilitated before automated data could be collected; therefore, the final experiment included 24 sections comprising 449 manually measured transverse profiles and 5,638 MRD readings.

After the GT was established, the sections were open to the participants to collect automatic rutting at highway speed. The following five systems participated in the experiment: Applus (with an INO LCMS), Dynatest (with an INO LRMS), Pathways (in-house developed 3D system), Roadware (with INO LRMS), and TxDOT (in-house developed 3D system). Every participant was requested to collect surface profiles with a minimum spacing of 3 ft and to provide their best estimate of the transverse profiles, reported in inches to 3 decimal places with a minimum of 30 sets of data point coordinates at each 25-ft station. No maximum limits were placed on the spacing between points, maximum number of data points, minimum spacing between profiles, or analytical methods used to analyze the profiles to provide the best estimate. The profile information was later provided to the research team in a predetermined format.

In addition, every participant was requested process the profile information and to provide MRD measurements in each wheel path on a longitudinal spacing of 5 ft. Each participant provided one set of MRD measurements, except for TxDOT, which used two different data processing procedures (filtering and algorithms) to produce values of rutting according to TxDOT PMIS protocols and ASTM protocols. For the sake of completeness, both sets of data were analyzed by the research team.

Thus, the first step in the selection process was establishing the experiment and selecting and agreeing upon the benchmark. This benchmark (or GT) has to be predefined and agreed by all participants before the field experiment begins.

5.2.1 Transverse Profiles

The comparison of the transverse profiles sought to assess the systems' hardware capabilities in capturing the road surface profile at a level of accuracy consistent with the needs of the Department and the objectives of the research project. The benchmark for MRD was established with an aluminum wedge (as described in the report) whose precision was 1/16 of an inch.

The participants' best estimates of the transverse profile at each 25-ft station was compared to the GT profile for that station. Five statistical parameters were calculated for the comparison and used to rank the participants. In these definitions, the term "residual" means the difference in elevation between the GT (established by the research team) and the elevation of the same point as measured by the various participants. Following are the five parameters:

- Bias, defined as the mean of the residuals;
- Precision, defined as the standard deviation of the residuals;
- Mean Squared Error (MSE), which accounts for both bias and precision;

- Average Sum of the Square Residuals (SSEn); and
- Correlation Coefficient (corr).

The ideal piece of equipment is one that produces the lowest mean and standard deviation of the residuals—that is, the closest to the benchmark and with the lowest variability. This, in turn, will optimize all the other statistics mentioned above. The bias accounts for systematic measurement errors and, in principle, could be corrected by modifying the hardware or the software by means of calibration. The standard deviation of the residuals, on the other hand, captures the inherent variability of the hardware and cannot be changed unless the hardware is replaced. Thus, a sound decision could be based on selecting equipment that produces the lowest standard deviation of the residuals. A compromise decision could also be based on the selection of the equipment that produces the lowest MSE, as this statistic accounts for both bias and precision. From a purely theoretical point of view, it is therefore recommended that the selection should be based the criterion of minimum MSE, followed by the criterion of minimum standard deviation of the residuals, and then by the minimum bias criterion.

From a practical point of view, however, based on the analysis of the results presented in Chapter 4, all five participants demonstrated that they could produce profiles with the desired accuracy. Although some participants show lower bias, or lower MSE, or higher correlation (in terms of r-squared) for some specific sections, none are overwhelmingly better or overwhelmingly worse than the rest. While Pathways Systems did not show the best statistics for any section, their profiles are still within reasonable accuracy for practical purposes.

5.2.2 Maximum Rut Depth

For the determination of the maximum rut depth (MRD), the participants collected and then processed the data with their own filters and algorithms to produce rutting values. Thus, this comparison accounts for both the hardware and software components of the systems. Please note that for this report, the term Maximum Rut Depth (MRD) is the same as the ASTM term rut-depth (ASTM E1703).

As for the transverse profile measurements comparison in the previous section, five statistical parameters were also calculated in order to evaluate MRD values reported by the participants:

- Bias, defined as the mean MRD error for the section;
- Precision, defined as the standard deviation of the MRD errors for the section;
- MSE, which accounts for both Bias and Precision;
- Slope of the linear regression (Slope); and,
- Correlation coefficient (corr) between the MRD values reported by the participant and GT.

In terms of MRD, the recommendation of the research team is that the selection of equipment be based on the same criteria as before: minimum MSE, minimum standard deviation of the residuals, and minimum bias.

Once again, no one piece of equipment overwhelmingly outperformed the rest consistently for all sections. However, overall Dynatest, Roadware, and TxDOT (with the ASTM protocol) did outperform Pathways and Applus. Again, all five participants produced transverse profiles within acceptable accuracy according to the criteria established for this study. The researchers also note that producing good transverse profiles at highway speeds, and for a wide range of pavement conditions, is technically more challenging than developing a rut depth algorithm to evaluate accurate profiles. This is not to minimize or suggest that rut algorithm development is technically trivial by any means. However, improving the accuracy of a rut algorithm, given good transverse profiles, is less complex than if both the profiles and the rut algorithm are a concern. This observation is meant to highlight that with additional analysis and field testing—including evaluation of the filters, decision criteria, boundary conditions, constraints, and other factors incorporated in rut algorithm development— all five participants could potentially improve their systems' MRD measurement accuracy and precision for roadways in Texas.

Note, for example, that all participants tended to underestimate rut depths on narrow FM roads when the IWP was on or crossed the center line stripe, which represents one area in which all five participants have an opportunity to improve.

5.3 Final Recommendations

The University of Texas at Austin has completed Phase I of TxDOT Research Project 0-6663, "Evaluation of Pavement Rutting and Distress Measurements." During this phase

- a field experiment consisting of 24 sections was developed,
- static manual transverse profiles and surface rut measurements were collected,
- five participants collected automated rut data at highway speeds, and
- the results were analyzed and compared based on well-established and accepted statistical parameters.

As a result of this phase of the study, the research team has reached the following preliminary conclusions.

- Although some pieces of equipment did marginally better than others during the collection of surface profiles, all five systems are clearly capable of capturing surface profiles with the necessary accuracy. However, the researchers strongly recommend that all the equipment systems be enhanced to capture the true profile—the profile of the road relative to a horizontal datum.
- In terms of MRD measurement, no single piece of equipment performed better overall. However, under the conditions evaluated, Dynatest, Roadware, and TxDOT (with the ASTM algorithm) systems outperformed the Applus and Pathway systems.

Note that these conclusions are based on a specific set of criteria developed by the research team. These criteria are described in detail in the previous sections but can be summarized as follows. For rut depth measurements, the researchers determined that a sixteenth of an inch is sufficiently accurate for network- and project-level pavement management applications and for the purposes of this experiment. The recommendations are based on minimum MSE, minimum standard deviation of the residuals, and minimum bias.

References

ARAN Rutbar Data Sheet. *ARAN Smart Rutbar*. Data Sheet. (http://www.fugroroadware.com/related/down-loads/Smart-Rutbar-Brochure).

AASHTO R48-10 (2010). *Determining Rut Depth in Pavements*. AASHTO Standards.

ASTM E867-06. *Standard Terminology Relating to Vehicle-Pavement Systems*. ASTM Standards.

ASTM E1703/E1703M-10. *Standard Test Method for Measuring Rut-Depth of Pavement Surfaces Using a Straightedge*. ASTM Standards.

Bennett, C. R. and Wang, H. (2002). *Harmonizing Automated Rut Depth Measurements*. Transfund New Zealand Research Report.

Li Q., Yao M., Yao X. and Xu B. (2009). *A real-time 3D scanning system for pavement distortion inspection*. Center for Transportation Research, University of Texas, Austin, TX 78712, USA.

Henning, T.F.P., Costello, S.B., Watson, T.G., MWH NZ Ltd (2006). 'A review of the HDM/dTIMS pavement models based on calibration site data'; Land Transport New Zealand Research Report 303; Land Transport New Zealand, PO Box 2840, Waterloo Quay, Wellington, New Zealand.

Herr, B. (2001). *Calibration and Operation of Pavement Profile Scanners*. RPUG 2001 Lake Tahoe. Phoenix Scientific Inc. (http://www.phnx-sci.com/PPS/Downloads.html).

Herr, W. J. (2009). *Mobile Survey Validation – I15 HOV Lanes*. Phoenix Scientific Inc. (http://www.phnx-sci.com/PPS/Downloads.html).

Huang, Y., Hempel, P. and Copenhaver, T. (2009). *A Rut Measurement System Based on Continuous Transverse Profiles from a 3D*. Research and Development Project Report. Texas Department of Transportation.

Pavemetrics INO LRMS. *Pavemetrics's laser rut measurement system*. Specifications (http://www.pavemetrics.com/pdf/laser_rut.pdf).

Pavemetrics INO LCMS. *Pavemetrics's laser crack measurement system*. Specifications (http://www.pavemetrics.com/pdf/laser_crack.pdf).

PSI PPS-2005 Specifications. *PPS-2005 Pavement Profile Scanner*. Phoenix Scientific Inc. (http://www.phnx-sci.com/PPS/Downloads.html).

PSI PPS White Paper (2004). *Pavement Profile Scanner White Paper*. Phoenix Scientific Inc. (http://www.phnx-sci.com/PPS/Downloads.html).

Roberts, F. L., Kandhal, P. S., Brown, E. R., Lee, D. Y. and Kennedy, T. W. (1996). *Hot Mix Asphalt Materials, Mixture Design and Construction*. Second Edition. National Asphalt Pavement Association Research and Education Foundation, Lanham, Maryland.

ROMDAS TPB-Reference Profiler Spec. *The ROMDAS Transverse Profile Beam (TPB) Reference Profiler*. Specifications (http://www.romdas.com/hard/specs/sp-tpb.pdf).

ROMDAS TPL-URB Spec. *Transverse Profile Logger - Ultrasonic Rut Bar (TPL-URB)*. Specifications (http://www.romdas.com/hard/specs/sp-tpl.pdf).

Simpson, A. L. (4-2001). *Characterization of Transverse Profiles*. Publication FHWARD-01-024. Federal Highways Administration, McLean, VA.

Simpson, A. L. (12-2001). *Measuring of Rutting in Asphalt Pavements*. Ph.D. Thesis. Department of Civil, Architectural, and Environmental Engineering. The University of Texas at Austin.

Vedula, K., Reigle, J. and Miller, R. (2002). *Comparison of 3-point and 5-point Rut Depth Data Analysis*. Presentation in Pavement Evaluation 2002 Conference, Roanoke, Virginia, October 21-25, 2002.

Wang, H. (2005). *Development of Laser System to Measure Pavement*. M.S. Thesis. Department of Civil and Environmental Engineering College of Engineering. University of South Florida.

Center for Transportation Research
The University of Texas at Austin
1616 Guadalupe Street
Austin, TX 78701

Phone: (512) 232-3100
To order reports: (512) 232-3126 (CTR Library)
E-mail: ctrlib@austin.utexas.edu
Web site: www.utexas.edu/research/ctr
CTR Library Web site: http://library.ctr.utexas.edu