Comparison of Mobile Asset Data Collection Vehicles to Manual Collection Methods

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16. Abstract

The Institute for Transportation Research and Education at North Carolina State University conducted a follow-up study to a previous North Carolina Department of Transportation (NCDOT) project, comparing mobile inventory data collection vehicles to manually-collected data techniques. The follow-up study included two additional aspects: 1) a visual component to the comparison analysis using GIS software ArcMap 10, and 2) a two-way communications loop with a thorough submission of a sample data set to be analyzed prior to the submission of a full data set. The results show that vendors can accurately *locate* the vast majority of assets, the primary exception being those that are occluded by vehicles or surrounding landscaping, such as those assets in the median. Following location of the asset, vendors showed promise collecting many of the feature descriptions such as asset type and condition. Many of the elements that vendors struggled with were only problematic for one of the vendors, showing room for further improvement through additional communication and updates to the catalog definitions and examples. Using measurement tolerances, the research team determined that measurements of height, grade, and azimuth were generally accurately obtained; however, measurements parallel to the direction of travel such as offset and width posed problems with accuracy. Last, accuracy of data elements was acceptable for finding the elements in the field; however, many specific point features such as drop inlets or attenuators were not geo-located, but instead measured from the van's location in the lane. Although mobile data collection is sufficient for most efforts, there is still room for improvement if more detailed location is necessary.

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1. INTRODUCTION

Mobile vehicle-based roadway data collection systems have existed for nearly twenty years and have been in commercial service for more than ten years. Many vendors now provide such data collection services at reasonable costs. Indeed, a quick search of the literature and on-line sources reveals a wide variety of services and a range of vehicle-based sensors. Location data can be collected via a global positioning system (GPS), inertial navigation system (INS), and distance measurement instrument (DMI); description and quality data can be collected via radar, laser, infrared, imaging, and other methods. Many systems rely on video collection in the field to be read later in the office by technicians, but the techniques and quality of these post-processing activities vary.

An efficient and accurate inventory of a state highway agency's assets, along with the means to assess the condition of those assets and model their performance, is critical to enabling an agency to make informed investment decisions in a transportation asset management environment. Currently, the North Carolina Department of Transportation (NCDOT) does not have sufficient resources to amass data on its 79,000 roadway miles on a regular interval, leaving many assets to deteriorate to an unacceptable level of performance. Today, new technologies have provided fast and improved methods for gathering, processing, and analyzing data. The key is to identify the information and assess how much of it is needed to make informed decisions that affect the assets. The data must be useful, reliable, and cost-effective to obtain; should provide a safety benefit; and need to be delivered in a timely fashion and in a user-friendly format that can tie into existing management system databases. In addition, the data must be defendable and repeatable so that users of this information have a high level of confidence in its overall effectiveness.

1.1. Research Need

The Office of Asset Management at the NCDOT has identified five asset types with potential for automated data collection. These five areas are: drainage, guardrails, signs, pavement, and pavement markings/markers. In each area, the asset management database includes four categories of data: identification, location, description, and quality. That is, for each component, the database names it, locates it, defines and describes it, and explains how well it functions. Although the general requirements for these data categories are basically the same, the nature of data collection may differ, depending on the asset.

Various issues in the asset data collection process include precision, subjectivity and variability of the process, efficiency of data collection, safety of the survey crew, cost, etc. Even with these confounding factors, our previous effort for the NCDOT-sponsored "Asset Expo" in 2008 found that communication seemed to be the leading cause for the majority of data collection mishaps, and even recommended that a small test track be utilized to compare manual and automated data prior to conducting a full blown data collection effort. Should the findings of this effort prove beneficial, the NCDOT's Office of Asset Management could provide a significant amount of data to Division staff in a much more responsive manner than is currently available. In addition, the data would be collected in a much safer manner and possibly at a reduced cost than is currently done through manual methods.

1.2. Scope and Objectives

The specific aims for this project were to provide NCDOT with evidence on the viability of automated data collection vehicles in comparison to human collection methods to gather data efficiently, accurately, and reliably. The research team met the following objectives in completing this goal:

- Select test sites that can be evaluated using accurate ground truth data versus a data collection vehicle. Manual data will be collected by members of the research team and supplemented by data collected under the performance-based maintenance contract (PBMC) employed by NCDOT on various interstate facilities.
- Provide a forum for open communication between vendors and the research team so that no stone is overturned. The research team provided all necessary information to vendors through a detailed catalog, an interim data submission “check” where feedback was provided to vendors on small samples of data, and finally vendors completed data collection on the entire course based on feedback.
- Present NCDOT staff with a study that conclusively states whether a single chosen data collection vendor can actually replicate ground truth data gathered through human collection methods. Comparisons between ground truth and vendor data are made directly, as well as a comparison of interim and final data collection results to document any improvements that were made from the initial submission.

As noted earlier, previous studies did not allow the team or NCDOT to interact with the individual vendors directly to calibrate the data collection equipment, because the team had to treat multiple vendors in an unbiased manner. While this restriction was necessary for the intended comparison of different vendors at the 2008 Asset Expo, it also contributed to some miscommunication and confusion. For this particular effort, the approach shifted away from a performance comparison amongst multiple vendors, to a more targeted comparison of a vendor's "best effort" to manual (human) data collection. This approach focused on better calibrated automated data collection that more accurately replicated an actual deployment of vehicle-based technology.

2. LITERATURE REVIEW

A highway inventory is a detailed record of existing highway conditions. Generally, a highway inventory is taken at a network or statewide level by the corresponding highway agency. An inventory documents facts, descriptions, and measurements of elements in, along, and within the vicinity of the roadway. The type of information collected for each element depends on the purpose it serves to the agency. Inventories are key components to highway agencies' efforts in planning, design, construction, and maintenance of highways and highway assets *(1)*. Agencies require accurate and up-to-date inventory in order to make sound investment decisions in a Transportation Asset Management (TAM) program.

The traditional method to inventorying highway assets requires field personnel to drive or walk along a roadway segment and manually measure or take note of roadway infrastructure and attributes. For example, during a statewide traffic sign inventory, maintenance technicians will locate all signs in question prior to site visits and arrange a schedule to inspect them. Once an inspection plan is developed, field inspectors will drive from location to location and take note of sign conditions and classifications. For more in-depth sign inventories, personnel are required to stop at each location to take geometric or retroreflectivity measurements. The sign inventorying process, comparable to other infrastructure, is labor-intensive and tedious, may not be capable of collecting multiple attributes at once, and, more importantly, put field personnel in or along the roadway – a major concern for agencies *(1, 2)*. For these reasons, traditional manual data collection methods are inefficient, require a significant workforce, and put field personnel at a safety risk. The sheer size of a network-level inventory compounds the challenge of collecting, processing, and providing the asset data. Therefore, many agencies have sought to move from manual methods to efficient, safe, and, ideally, cost-effective automated solutions.

Asset inventory data are generally classified by identification, location, description, and quality. Precision, subjectivity, and variability as well as timeliness, safety, and public proximity are the primary issues associated with inventorying highway assets *(2)*. This literature review identifies various automated inventory practices and documents comprehensive studies that have been conducted to assess these methods. Literature pertaining to origins of asset management, specific programs in place, and automated highway asset data collection is summarized in the following sections. Collection of pavement, bridges, geotechnical features, hydraulics, roadside appurtenances, roadway geometry, and pole-like objects are discussed in detail as they are the primary asset data inventoried under this project. Where possible, newer methods of asset inventory are presented as possible tools for collecting and processing assets. Right-of-way video logging and light detection and ranging (LiDAR) technology are the two primary tools identified as having strong potential for data collection and asset inventory.

2.1. Transportation Asset Management Programs (TAMS)

Transportation asset management (TAM) was defined by the United State Department of Transportation (USDOT) Office of Asset Management as *(3):*

> *A systematic process of maintaining, upgrading, and operating physical assets cost effectively. It combines engineering principles with sound business practices and economic theory, and provides tools to facilitate a more organized, logical approach to decision making.*

The wealth of literature pointing to the benefits of TAM programs through case studies within state DOTs indicates a robust effort towards utilizing such programs, which crosses over the increasingly fuzzy line between business and transportation infrastructure management. Bittner and Rosen provided a TAM overview in the 2004 Public Works Management & Policy: Transportation Asset Management Overview, indicating that the TAM concept is reaching not only the US but also Australia, the United Kingdom, and Kuwait *(4)*. Since they are stewards of Federal tax dollars spent through state DOT projects, it is important that metropolitan planning organizations (MPOs) and state DOTs have the correct data needed to make the best possible investment decisions. By initiating this research, the NCDOT is looking to the future of TAM data collection technology within state DOTs and how to best provide the most accurate information for decision-making agencies.

This first push towards asset management included a priority for inventorying state transportation assets and the condition of those assets *(5; 6)*. An original priority was placed on pavement and bridge inventory and assessment; more recently concern for ancillary structures surfaced in National Cooperative Highway Research Program (NCHRP) reports, seeing the need to document current DOT practices, as well as supplement the 2002 USDOT FHWA Asset Management Primer, and the recently published AASHTO Transportation Asset Management Guide: A Focus on Implementation *(3, 7, 8)*.

Improved transportation data collection and organization, particularly with lower-cost, high-inventory roadside assets has been found to be a safety topic as well. Most recently, ancillary transportation assets risk assessments are being developed by the Georgia Transportation Institute University Transportation Center *(9)*. The project involves risk assessment of failures in ancillary transportation assets such as culverts, guardrails, and traffic signals. The assessment includes a probability evaluation and the consequent results, such as assessment of damages and fatalities as a result of ancillary asset failures. Although the project has not yet completed, the work thus far recommends improving the tracking and documentation of ancillary asset failures to improve accuracy of the risk management model.

Case studies of TAMs utilizing various tools for data collection have positively impacted government spending both in the US and internationally. In a study of the successful New Brunswick Department of Transportation TAM program, a challenging transportation system with limited funding was able to achieve its goals and develop long-term plans for TAM development and implementation through Operations Research. The program anticipated $1.4 billion in savings over the 20 year plan. Development of the plan included “spatial scheduling,” which implemented the use of GIS mapping to indicate timing and location of inventory treatments, as well as interactivity for experts within the regional area. A Best Practices report by GaDOT reminds TAM users of the interactivity that will ultimately be involved in system performance, thus achieving the overall strategic goals of a TAM, while still staying abreast of recent changes in mandated performance measures *(10)*.

2.2. Roadway Asset Data Collection

Many roadway assets are monitored under state TAM programs. The focus of the following sections is roadway assets of interest to NCDOT. A description of the various data collection methods employed across the US is summarized and includes applications such as manual methods, video-based algorithm's, and LiDAR to name a few.

2.2.1. Pavement

Pavement is the surface material that directly sustains the loads and stresses of vehicular traffic, making it a vital asset of highway infrastructure. Therefore, it is critical that pavement be properly managed and maintained. Many highway agencies have gradually shifted from manual inspection to automatically surveying pavement distress and performance. Many state transportation departments automatically manage the pavement infrastructure by means of an automated pavement condition survey (APCS). This annual network-level inventory consists of two processes. First, pavement condition data is automatically collected by cameras and sensors mounted on a data collection vehicle. Surface profiles, pavement surface images, forward perspective images, and right-of-way (ROW) images are collected at highway speeds during surveys *(11)*. Second, these images are processed and recorded into a pavement management system (PMS). There are various ranking methods and algorithms in assessing pavement conditions. The key factors that highway agencies must consider are the establishment of well-defined pavement distress definitions and the implementation of consistent, calibrated procedures for automated surveys *(2)*.

In addition to pavement condition monitoring, pavement grade and cross slope can be collected. In a pavement grade and cross slope study, researchers used LiDAR to extract grade and cross slope measurements on tangent highway segments *(12)*. LiDAR data were used to estimate grades and slopes; results were compared to ground-truth collected by an automatic level for 10 test segments in Iowa. Pavement grades were calculated within 0.5% for most sections and within 0.87% for all sections. Pavement shoulder grades were calculated within 1% of the surveyed value. Measurement estimates for cross slope were not as accurate as grade estimates. Cross slope estimates from LIDAR data deviated from ground truth by 0.72% to 1.65%, while estimates on shoulder sections could not be made with any confidence. Researchers determined that inaccuracy was due to the narrowness of shoulder sections coupled with the randomness of the LIDAR scan points. The study concluded that grade could be estimated within 1.0%, and whether this accuracy is adequate depends on the specific application. Although the results indicated that cross slopes could not be practically estimated using a LIDAR surface model, the technology has significantly improved in the past eight years since this study was conducted. Current LiDAR systems can calculate geometric measurements to a much higher degree of accuracy and precision.

2.2.2. Bridges

In the "2009 Report Card for America's Infrastructure," the nation's bridges are said to be an average of 43 years old. Many bridges are long past their intended design lives, and have been deemed structurally deficient or functionally obsolete *(13)*. Bridges are vital components of the highway network and serve both personal and commerce-related travel. The bridge construction process is very expensive and time consuming. Therefore, comprehensive and cost-effective bridge evaluation that considers the safety of the driving public is essential when considering structural maintenance, repair, and replacement decisions. The current bridge inspection method for publicly owned highway bridges is a standard visual inspection process established by the federal government *(14)*. When bridges are subjected to chemical exposure, deck delamination, steel corrosion, fatigue cracking, scour, etc., visual inspections may not always be sufficient in diagnosing deficiencies or providing comprehensive assessments.

Nondestructive Evaluation (NDE) methods have been developed to provide Quality Assurance (QA) for new structures and condition assessment of older structures. Three automated technologies include a vehicle-mounted Bridge Deck Scanner (BDS), the Digital Highway Data Vehicle (DHDV), and Light Detection and Ranging (LiDAR). Alternative remote sensing instruments are also discussed.

Olson Engineering Inc. developed a system, the Bridge Deck Scanner, which assesses the internal conditions of concrete bridge decks *(15)*. The Bridge Deck Scanner employs a rolling wheel transducer with multiple sensors to test bridge deck delamination and corrosion damage to steel reinforcement due to freeze-thaw cracking and chloride exposure. Additional NDE testing methods can be implemented to evaluate the deck integrity of structures subjected to alkali-silica reaction cracking and fire damage. Ground Penetrating Radar (GPR) technology may also be used to determine overall bridge health, rebar spacing, depth, steel reinforcement arrangement, and concrete cover attributes of bridge decks. In Tinkey et al.'s study to evaluate the basic capability of BDS, researchers worked with the Wyoming Department of Transportation (WYDOT) to detect concrete delamination of bridge decks. The results concluded that the scanner could identify top and bottom deck delamination more precisely (i.e. 0.5 square foot resolution) than the traditional chain dragging surveys.

A prototype device developed by the Federal Highway Administration (FHWA) was tested to measure vertical clearances of bridge decks *(16)*. The vehicle-mounted device uses a laser and sensor to measure vertical clearances from a moving vehicle. The research concluded that the device's accuracy did not depend on the reflectivity of the paint covering the bottom of the bridge deck, but rather was dependent on the sensor sampling rate and vehicular speed. A minimum sensor rate of 500 Hz was needed for a vehicle traveling at 50 mph. The equipment used by this prototype device is similar to the technology found in LiDAR systems. Figure 1 displays the device used to measure vertical clearances of bridge decks.

Figure 1 Device for automated vertical clearance measurement *(16)*.

LiDAR is an emerging technology that may have applications for bridge evaluation *(14, 17, 18)*. LiDAR utilizes lasers and sensors to capture accurate, high-density 3D surveys. Researchers have used LiDAR to automatically detect and quantify bridge damage, measure bridge geometry (i.e. vertical clearances), and detect structural change. Chen and Liu found that a 3D LiDAR scan was able to quantify visible damage volumes and provide realistic mass loss estimates of concrete members. Liu et al. concluded that terrestrial scans were highly accurate out to 70 meter distances and that a single scan would be sufficient to measure small and medium sized bridges. In addition to bridge evaluation, Chen et al. demonstrated the remote sensing capabilities for quality assurance of new bridge construction. In the study by Chen et al., LiDAR was implemented to evaluate a load test conducted on a newly constructed bridge. Researchers established a baseline Finite Element (FE) model to ensure construction quality. Static and dynamic load tests were done for model validation. The LiDAR scans confirmed the displacement estimates of the Finite Element model. Figure 2 shows a 3D LiDAR scan of a bridge.

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Figure 2 LiDAR scan of a bridge *(19)*.

The Digital Highway Data Vehicle (DHDV) is a real-time multi-functional system developed for acquiring and analyzing roadway data. The system combines laser based digital imaging, inertial profiling, and GPS mapping for highway surveying and management purposes. It has been effectively utilized to capture pavement surface images, right-of-way images, and roughness and rutting data at highway speeds *(20)*. The DHDV was used to locate, analyze, and record pavement distress of bridge decks *(21)*. Bridges in Arkansas were mapped and analyzed. The results were compared to traditional manual surveys. The DHDV yielded results that were inconsistent with ground-truth and found no reduction in testing time. Figure 3 illustrates the concept of the DHDV.

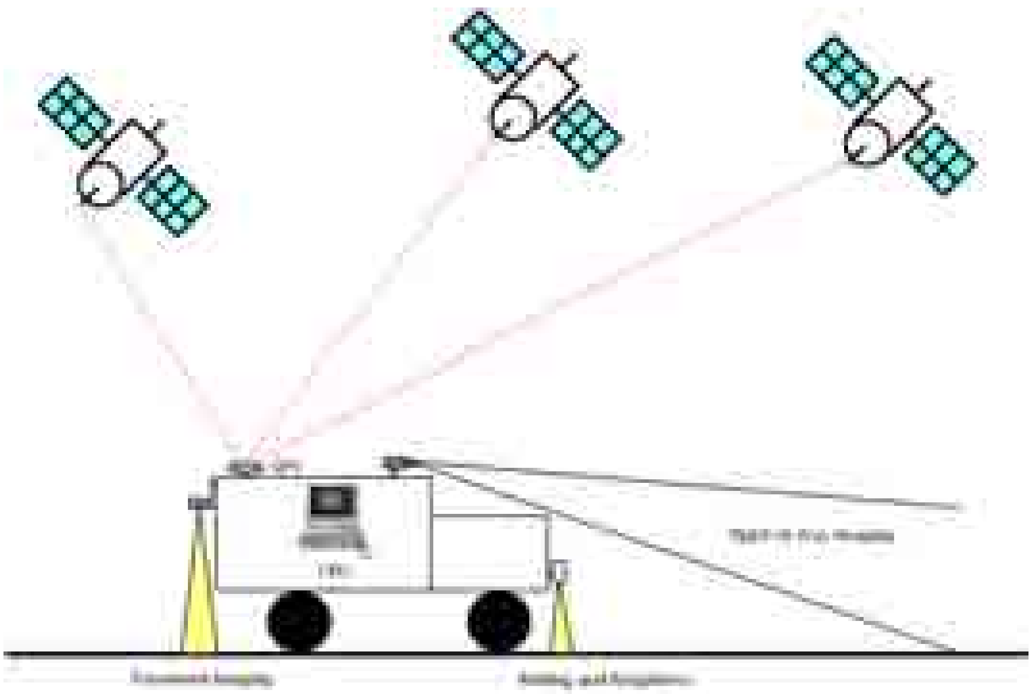

Figure 3 Concept of the digital highway data vehicle.

2.2.3. Roadside Appurtenances

Roadside appurtenances refer to roadside and roadway geometric assets installed in transportation networks. There are two types of roadside appurtenances: linear elements and point elements. Linear elements are the items that run alongside or within the travel way. Point elements are items that are defined geospatially by a single installment point *(22)*. Typical linear elements could include paved and unpaved shoulders, lateral ditches, curb and gutters, brush and tree, turf, landscape areas, concrete barriers, guardrail, median, raised pavement markers, roadway lanes, or rumble strips. Typical point elements could include access points, drop inlets, attenuators and end treatments, median openings, traffic signs, centerlines, or geometric curves. It is critical that many, if not all, of these linear and point elements are inventoried for maintenance and operation purposes. For example, highway safety engineers could be interested in unpaved shoulders in order to justify the installment of new countermeasures. Or, traffic engineers would be concerned with driveways and access points to assess the operational conditions of roadway segments and intersections.

During the NCDOT-sponsored Asset Expo in 2008, Kim et al. conducted the latest assessment of pavement and roadway appurtenances in 2008 using a 90-mile test course located in central NC over a variety of highways *(2)*. Six vendors supplied data along the course; no vendors supplied sign retroreflectivity data, one submitted pavement marking retroreflectivity, three submitted roadway geometry data, and five submitted data on roadside elements. The results showed that mobile data compared reasonably well to manual data for most of the desired variables. Mobile data on elements in or close to the road generally matched manual data better than elements further from the road. Item counts were generally a better fit between mobile and manual data than elements that needed qualitative judgments. Among the lessons learned is the need for crystal clear specifications before embarking on a mobile data collection program and the desirability of having vendors submit data for a small sample of roadway before embarking on the bulk of a data collection effort.

2.2.4. Retroreflectivity

Retroreflectivity is used to describe how light is reflected back to its original source. In terms of roadway assets, the two most prominently studied retroreflective treatments include signs and pavement markings. Both assets are considered very important safety devices to motorist; however, current methods for analyzing the retroreflectivity of these assets is time consuming and, in some cases, unsafe.

Five study methods are proposed to evaluate and maintain retroreflectivity *(23)*: 1) routine visual nighttime inspections, 2) retroreflectivity measurements, 3) expected life method, 4) the blanket replacement method, and 5) the control method. These five are categorized as assessment methods (1 and 2) and management methods (3, 4, and 5). Assessment methods evaluate individual signs by means of routine inspections and measurements. Method 1, routine nighttime inspection, is the typical method used because it is simple and safe. Method 2, field measurement, is the most accurate method but is time consuming and can be unsafe (see Figure 4). Management methods are used to sustain sign retroreflectivity over time without having to assess individual signs.

Figure 4 Manual collection of pavement marking and sign retroreflectivity *(24)*.

With respect to new management methods, there has been extensive research on automated pavement marking and sign retroreflectivity. Regarding pavement marking retroreflectivity, highway agencies have recognized the mobile retroreflectometer unit (MRU) as a safer and more efficient alternative to handheld retroreflectometers. Many times pavement marking retroreflectivity is done in conjunction with automated pavement monitoring efforts. An example is provided in Figure 5.

Figure 5 Mobile pavement retroreflectometer *(24)*.

The Florida Department of Transportation (FDOT) conducted a study to evaluate the MRU's precision in measuring retroreflectivity. For six randomly selected sites and 480 retroreflectivity measurements taken, the research concluded that two properly conducted MRU inspections of the same pavement markings should not yield more than a 6.7% difference for retroreflectivity measurements at a 95% confidence level *(25)*. The Texas Department of Transportation (TxDOT) has detailed systematic guidelines to sampling, verifying, storing, and calibrating a MRU in "Mobile Retroreflectivity Best Practices Handbook" *(26)*. Figure 4 depicts the use of a manual pavement retroreflectometer. Figure 5 shows a vehicle-mounted pavement retroreflectometer.

Regarding road signs, asset inventory of road signs consists of detecting, identifying, classifying, locating, and monitoring signs and sign conditions. Generally, automatically generated inventories of road signs have been created by means of processing photo logs, video logs, or right-of-way (ROW) images. The process is as follows: 1) images are taken from a traveling vehicle for a given highway segment or corridor and 2) images are post-processed using software in the lab which calibrates video to known distances in the field. Researchers have developed algorithms that extract road sign inventories by means of geometric recognition, color identification, and region of interest (ROI) detection *(27, 28, 29, 30, 31)*. In addition to video logging and photo logging cameras, Global Position System (GPS) devices, distance measurement instruments (DMI), and inertial measurement units (IMU) have been implemented into data collection vehicles to track and locate road signs *(28, 32)*.

Moreover, sign inventories often take the condition of signs into account. Due to new requirements issued by the Federal Highway Administration, retroreflectivity standards have become increasingly important in recent years *(33)*. According to FHWA's 2009 edition of the Manual on Uniform Traffic Control Devices (MUTCD), all highway agencies must establish and implement traffic sign assessment or management methods of maintaining minimum retroreflectivity levels by May 2014. Furthermore, regulatory, warning, and ground-mounted guide signs were originally scheduled to be in compliance with minimum levels by January 2015 and overhead guide signs and street name signs by January 2018. However, as of the printing of this report, dates for compliance were removed from the MUTCD.

In trying to meet sign condition requirements, FHWA along with private vendors have been working to develop vehicle-based retroreflectometers. FHWA was first to introduce this technology in 2001, called the Sign Management and Retroreflectivity Tracking System (SMARTS) which is equipped with a high intensity flash source, cameras, a range-sensing device, and a GPS unit *(34)*. The system requires a driver and retroreflectometer operator. While the driver maneuvers through the inspection route, the operator aims the instrument towards oncoming traffic signs. At approximately 200 feet from each sign, the range finder triggers a xenon flash and cameras capture sign images. A computer produces a histogram of each sign's legend and background, which is used to calculate retroreflectivity. A record of sign locations, images, and retroreflectivity measurements are stored into a database for future processing.

More recently, vendors have implemented sensors and data collection devices to increase the accuracy of retroreflectivity measurements and make the process more automated. Private vendors have been slow to pick up on this idea, likely due to the very challenging aspects of collecting this element on the move. In addition, with the onset of LIDAR, there may be methods developed in the future that calibrate LIDAR to retroreflectivity measurements. Private vendor's methods that have been produced are mobile but manually operated and results on their accuracy have yet to be formally tested as of this report. An example of Facet's new automated sign inventory, classification, and mobile retroreflectivity software are provided in Figure 6.

Figure 6 Facet's new sign inventory software utilizing LiDAR and mobile retroreflectometer *(24)*.

2.2.5. Road Geometry

Road geometry directly effects vehicle dynamics and is associated with the safety of road segments; therefore, detailed measurements of geometric properties are used by highway agencies to assess hazardous roads to assist in implementing safety countermeasures. A proper road geometry inventory includes lengths, curvatures, gradients, cross-falls, and slopes. The Pennsylvania Department of Transportation (PennDOT) contracted Fugro Roadware to collect longitudinal and transverse profiles of PennDOT's road network. Additionally, Fugro Roadware's data collection system was able to collect longitudinal grade, horizontal cross slopes and super elevation of curves, degree of curvature, radius of curvature, and curve start and end coordinates.

In a 2009 Western Michigan University study, elevation data from LiDAR and the National Elevation Dataset (NED) was used to estimate length of road centerlines *(36)*. The distances estimated from LiDAR and NED data was compared to ground-truth taken by a distance measurement instrument. Researchers determined the accuracy of distance estimates produce from LiDAR and NED datasets. The results concluded that the LiDAR approach was efficient in estimating lengths along road centerlines. Distance estimates from LiDAR points were 28.0% more accurate than estimates using NED data. Additionally, the geometric properties (distances, average and weighted slope, and slope change) were examined for relationships to the accuracy of estimated distances. Analysis found positive correlation between geometric properties and error but negative correlation from the aspect of proportional error. Therefore, road geometric properties could be used as accuracy indicators in estimating centerline distances.

2.2.6. Geotechnical Features

The geotechnical arena of roadway asset inventories is a relatively new concept. A geotechnical inventory deals with two asset classifications; the first being subsurface soil properties taken by field and laboratory testing and the second regarding performance and mechanical behavior obtained by infrastructure condition surveys *(2)*. The highway components that are considered geotechnical assets include embankments, slopes, tunnels, earth retaining structures, culverts, drainage, channels, and foundations *(37)*.

In demonstrations by vendors, terrestrial, mobile, and aerial LiDAR applications were discussed *(38)*. Since LiDAR effectively takes 3D snapshots using laser scanning, the technology can be implemented to detect differential change or provide quality assessment for existing or newly built geotechnical infrastructure. For example, LiDAR may be used to monitor dam and slope deformation as well as structural settlement. In western North Carolina, a vendor took digital scans of a mountainous highway segment multiple times over a year long period using mobile LIDAR *(39)*. Between scans, NCDOT staff rolled rocks to test if the digital scans could accurately capture any notable change. Although no statistical evidence exists, NCDOT staff noted that the scans were able to effectively detect change in the areas where rock was manually displaced, and supplemental software was used to color-code the depth change within inches. The primary concern that the vendor expressed was the potential for error in displacement from the build-up of foliage during certain times of the year. The LiDAR scanners are so accurate that the buildup of fallen leaves would register in digital scans. Therefore, the vendor recommended that scans be taken in times of little to no leaf fall. Figure 7 depicts a LiDAR scan showing differential change on a mountain slope.

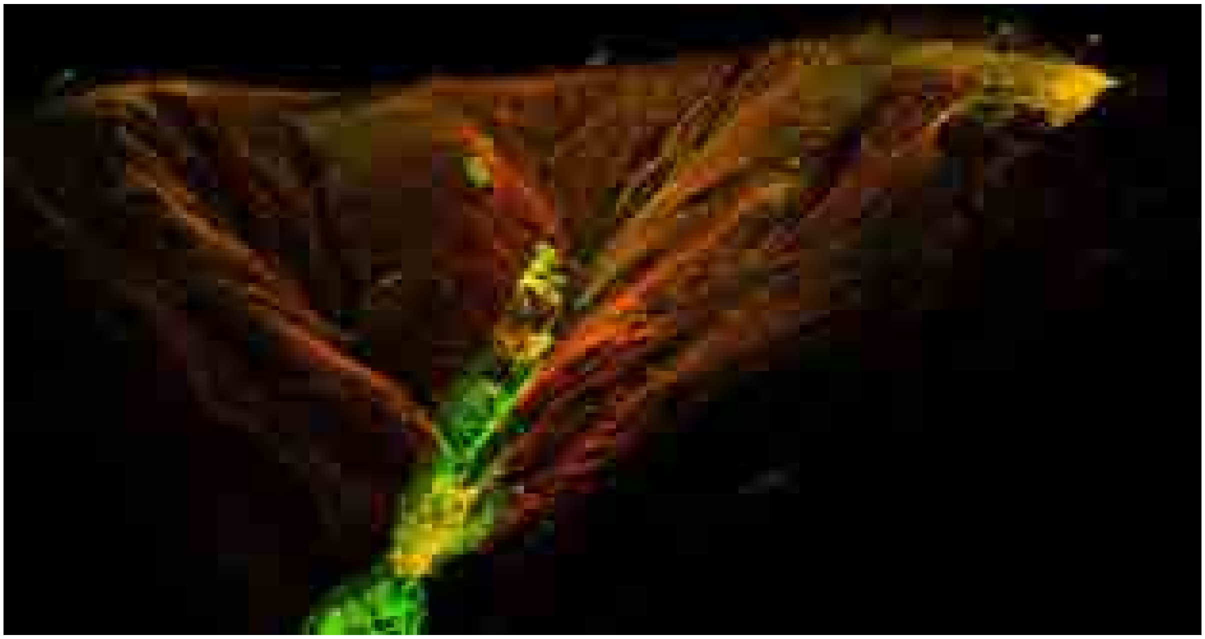

Figure 7 Mountain slope with color-coded change differences *(40)*.

2.2.7. Hydraulics

Studies have indicated that climate change may threaten the transportation system and highway infrastructure *(41)*. LiDAR elevation data has become a major source for hydraulic modeling and flood plain mapping applications. Researchers conducted a study in Pensacola, Florida to compare the inundation possibilities estimated by Digital Elevation Model (DEM) and LiDAR data. The results determined that LiDAR data was more accurate in identifying critical road segments vulnerable to inundation. This was due to LiDAR's superior vertical accuracy.

Curb and gutter systems are installed alongside the roadway to guide and drain water away from the travel lanes. However, curb and gutters will degrade over time from elemental exposure and/or vehicle impact. Blocked or damaged curb and gutter systems may fail to drain water from the travel way, which would allow water to pool in the path of traveling vehicles. Un-drained pools of water on the roadway can cause hydroplaning and loss of vehicle control which in turn put drivers at risk of running off the road or crashing into other vehicles or objects. Therefore, curb and gutter assets must be routinely inventoried or examined for service conditions.

In a curb and gutter inventory and assessment for Denver, Colorado, the University of Colorado Denver (UCD) conducted a cooperative research study with the City and County of Denver (CCD) *(42)*. Researchers implemented a backpack, tablet computer, GPS receiver, and headset to inventory curb and gutter. Data collectors physically walked all curb sections in the CCD region with the equipment and called out commands into the microphones. The voice commands were received and processed by the computers. The software developed was programmed to recognize audio cues associated with various types of curb and gutter distresses. Approximately 3,300 miles of curb and gutter were assessed over a 3-year period. At a rate of 100 miles per month and $100 per mile, this inventory technique can provide a relatively quick and cheap solution to curb and gutter management. Furthermore, agencies may find benefit in using the method for tort liability in defect litigation cases.

Iowa State University researchers used LiDAR-based elevation data for highway drainage analysis *(43)*. The study was a qualitative assessment of LiDAR capability to delineate watersheds and drainage areas. The results were compared with U.S. Geological Survey-based elevations. The study concluded that LiDAR could provide details of modified terrain, representations of channels adjacent to roadways for problematic drainage areas, and evaluation of structural surety during and after storm events. Additionally, the technology could be useful in verifying the expected drainage patterns at newly constructed highways.

2.2.8. Pole-like Objects

Pole-like objects, including utility poles (i.e. traffic lights, pedestrian signals, signs, lamp posts, pylons, flagpoles, etc.) and trees, are common in highway environments. A utility pole inventory is needed for highway planning and maintenance, while a tree inventory is important in evaluating sight distances and visual obstructions. Additionally, poles can be useful as reference targets in geomatic mapping systems and intelligent transportation systems (ITS). Studies have been conducted to detect and inventory pole-like objects using mobile laser scanners and remote sensors.

In a study by Finnish researchers, LiDAR was utilized for testing automatic methods for extracting pole-like objects. As a large amount of data are collected during mobile scans, the post-processing and pole extraction must be done automatically. A mobile 3D scan was taken along 450 meters of roadway at an average of 20 km/hr. Ground truth data were collected manually from the test site and only included objects within 30 meters of the scanner’s route. From the 3D scan, researchers could visually identify 85.5% of the poles found in the field. This inventory was used as a reference to develop an automatic pole extracting algorithm. From the visually identified poles, the algorithm detected 77.7% and had a classification correctness of 81.0%. The study found that poles obstructed by vegetation as well as tree trunks blocked by branches or cars were difficult to detect with the processing algorithm. Additionally, more than half of the false positives were pillars and more than one quarter were building structures. Traffic signs were the most difficult to extract, while lamp posts were the easiest. Researchers suggest that improved accuracy may be achieved through further development of the algorithm and additional scans of the site *(44)*.

2.3. Survey of State DOTs

The research team conducted an assessment of current asset data collection methods used by various states DOT's to gauge the methods used in collecting and maintaining an inventory of roadside asset and pavement data. Of the 50 agencies included in the survey (District of Columbia included and NC excluded), 35 (70%) responded. The following state agencies responded to the survey:

- Alaska
- Arkansas
- California
- Colorado
- Connecticut
- Delaware
- D.C.
- Florida
- Hawaii
- Idaho
- Indiana
- Kansas
- Kentucky
- Louisiana
- Maine
- Michigan
- Montana
- Nevada
- New Hampshire
- New Jersey
- New Mexico
- New York
- North Dakota
- Ohio
- Oklahoma
- Oregon
- Pennsylvania
- Rhode Island
- South Carolina
- South Dakota
- Tennessee
- Texas
- Utah
- Washington State
- Wisconsin

The survey consisted of eight brief questions. The findings from the survey were interesting and should provide some insight into what other states are doing regarding asset data collection. The questions, along with a basic summary of the findings, are provided below:

1. Does the state employ a fully automated data collection system for roadway assets or pavement data? If no, skip to question 7. *Of the 35 agencies that responded to the survey, 18 (51.4%) stated that they employed automated data collection for roadway assets or pavement data.*
2. Is the automated data collected by a vendor, in-house, or both? Of the 18 agencies that deployed automated data collection, 14 (77.8%) employ a vendor to aid with the collection, 3 (16.7%) conduct efforts in-house, and 1 uses both methods (5.5%).
3. How frequently does the state fully update the data? Of the 18 agencies that deployed automated data collection, 10 (55.6%) did not respond or said "N/A", 2 (11.1%) said annually, 5 (27.7%) said bi-annually, and 1 (5.6%) said every four years.
4. Does the state collect automated data on pavement, roadway assets, or both? Of the 18 agencies that deployed automated data collection, 7 (38.9%) collect pavement data only, 2 (11.1%) collect roadway assets only, and 9 (50%) collect both data types.
5. Does the state validate the accuracy of the data supplied by the fully automated system? Of the 18 agencies that deployed automated data collection, 13 (72.2%) do validate data received by vendors.
6. Does the state employ training or provide a catalog to ensure standards are followed while collecting data? *Of the 18 agencies that deployed automated data collection, 11 (61.1%) do provide a detailed catalog.*

7. If the State does not currently use an automated system to collect asset data, has it considered it? Of the 17 agencies responding that they did not employ automated methods, 12 (70.6%) said they had seriously considered using them.
8. If the state has considered using an automated system to collect asset data, what are the reasons for not currently employing it? *Typically the most common reasoning for not using automated methods was that in-house methods were thought to be more cost effective, and many respondents believe their data to be more accurate and less likely to miss assets. In addition, collecting data in-house allowed more flexibility by allowing the division/State to collect exactly what it wanted to and when. The frequency of updating the data for the states that employed a fully automated data collection method varied throughout from annually to every four years.*

2.4. Gaps in Literature

Following review of the current literature and synthesis of state practices, it appears that the largest gaps in automated roadway asset data collection fall into two primary categories. First and foremost, a significant focus on the communication aspect between vendors and DOT's needs to be studied to see the potential improvements that can be made through a feedback loop. Past research indicates that many of the errors in data collection are likely attributed to assumptions by DOT's that data collection is straight-forward and that instructions (verbal, written, or understood) are easy to understand. Second, new technologies such as LiDAR and automated retroreflectivity are being developed that may have applications for automated data collection; however, at this time they don't appear to be used unless for very specific applications. This is likely because little is known about their accuracy, precision, and cost at this time and other more typical methods already fit the bill. This project is focused on the first gap in the literature, the feedback loop.

3. Methodology

This study included two aspects not addressed in previous research on mobile asset data collection: 1) a visual component to the analysis using GIS software ArcMap 10, and 2) a two-way communications loop with a submission of a sample data set to be analyzed prior to the submission of a full data set This chapter provides detail on the research methods used to set up the experiment for testing automated asset data collection against a control data set for roadway features. The chapter discusses key topics such as vendor selection, communication with vendors, a description of the test route, and data collected. The following sections lay the groundwork that will aid in better understanding the findings of this research project.

3.1. Vendor Selection

The scope of this research project entailed analysis of video-based data collection vehicles similar to the 2008 Asset Expo *(45)*, with the presumption that more communication between vendors and the research team would improve accuracy and precision. The initial research project conducted in 2008 required vendors to drive a 90-mile course and provide data using their own financial resources. The team suspects that this lack of funding to vendors, along with scheduling conflicts with other contracted customers, may have led to some additional error in the data submissions. To alleviate this other potential bias, the NCDOT provided funds in the grant to cover costs incurred by the vendors.

Based on the 2008 Expo, the research team contacted all prior video-based vendors and provided them information on the upcoming research effort via email, urging them to consider submitting documentation for prequalification. In the interest of fairness to all potential vendors (known and unknown), a purchasing contract was issued by North Carolina State University. The process was two-fold. First, vendors were prequalified based on the number of assets they could reasonably collect. In total, six vendors responded to a memorandum which provided details about the project and requested a response to data the research team desired to collect data along the test track. Qualifications were then provided by each vendor (Appendix A). Based on the responses, three vendors were prequalified. Two of the vendors were traditional video-based systems; however, one vendor utilized mobile LiDAR (two LiDAR-based vendors actually responded and the research team selected the most appropriate vendor based on the prescreening process). Second, selected vendors were asked to provide a detailed cost estimate for their services. Due to the lack of available funds to study each prequalified vendor, the research team and NCDOT decided that LiDAR vendors did not fit the original intent and scope of the project; therefore, the two video-based vendors were chosen, Fugro Roadware, Inc. and Pathway Services, Inc.

3.2. Communication with Vendors

A major objective of this research effort was to evaluate the effects of two-way feedback communication between vendors and researchers. This was accomplished by the comparison of each vendors' results from the 2008 Expo and the current effort – an effort which provides a feedback mechanism through a pilot data collection effort prior to the final submission of data. Manually collected research team data were used as the control dataset to determine the location accuracy of preliminary and final datasets from the vendors, allowing the researchers to validate each vendor's initial data collection efforts, provide specific feedback for correction of data collection errors in a formal memorandum, offer an opportunity for vendor response and discussion during an informal web conference, and provide responses to any requests for clarifications throughout the process. Following the receipt of the memorandum and web conference, the researchers clarified any concerns in reference to the data collection instruction manual and provided an updated copy to the vendors. Vendors were encouraged to use the lessons learned from the formal and informal feedback events to correct specified errors and submit a final dataset. Upon receipt of the final dataset, the vendor data was compared to the same research team dataset for accuracy and comparison to the preliminary dataset.

3.3. Methods of Data Collection

The inventory of each asset is simply a set of location points or lines stored in a geodatabase. A full inventory of each asset, unless otherwise noted, was collected along the 46-mile test route by both the research team and the vendor data collection. Each asset was located by the research team with a GPS device attached to a Tablet PC, or otherwise provided by NCDOT from a Maintenance Condition Assessment Program (MCAP) database *(46)*, or orthoimagery. The data were entered into an ArcMap file, which was preloaded with aerial imagery and an individual geodatabase for quick organization of each data point or line.

For the research team data collection, the spatial location information for each data point was automatically input by indicating a data point or line in ArcMap with the Tablet PC. This file was then exported to individual map files in ArcMap 10 for viewing ease and visual analysis. The numerical data were also exported into Excel spreadsheets for numerical analysis and simplicity of display.

As inventory data were collected on each asset, various attributes of that asset such as length, width, color, or type were recorded. The attributes were stored with the locational data under a unique identification number in ArcMap. Some assets required the observation of the asset's state of repair, referred to as a condition assessment. This entry was stored as a "yes" or "no" in the data entry for "Inspection Required." For each asset, a set of condition guidelines were provided in the data collection instructions. These guidelines indicate the severity of a fault that would warrant a manual field inspection.

Each asset category presented unique challenges in individual analyses, which at times called for a more manual analysis with in the ArcMap layer. The individual assets chosen for analysis within a feature category resulted in a broad view of the data collection efforts, revealing the benefits and challenges of each category. For the evaluation of vendor-researcher feedback in this study, 13 linear elements and 15 point elements were selected to represent the various categories of asset types.

3.4. Instructions for Data Collection

To ensure the consistency of data collection efforts from the vendors and the research team, all data collection followed the guidelines provided by the Highway Asset Inventory and Data Collection Catalog, termed here as the “catalog”. A complete version of the catalog is available in Appendix B. The purpose of the catalog was to provide clear guidelines on feature elements, attributes, and condition assessments to collect for each individual roadside asset. The data collection instruction manual also included general project information, including project team contacts at NCSU/ITRE, driving directions to the project route, data submission guidelines, and post-data collection debriefing information.

The data collection instructions included a total of 28 assets which fell into one of two categories: linear or point elements. Table 1 shows all assets in each category. The categories were determined based on the most reasonable method to visually represent each element with GIS software such as ArcMap 10. Linear elements were continuous roadway features, such as a lateral ditch, guardrail, or shoulder. Point elements were elements whose locations could be defined by a finite point in space such as a bridge, a drop inlet, or a median opening. The instructions included specific details for the collection of individual element features including mile posts along the test route, type of element, the latitude and longitude of specific locations, and a yes/no assessment for inspections required. Each feature also included quantitative information such as size, length, or number of element features per specific length.

Table 1 Data categories and elements.

Linear Element (13)	Point Elements (15)
Brush & Tree	Access Points
Concrete Barriers	Attenuators/End Treatments
Curb/Gutter	Bridge Inventory
Guardrail	Centerline (Grade)
Lateral Ditches	Horizontal Curves
Median	Inlets
Pavement	Landscape Areas (Ramps Only)
Retaining Walls	Median Openings
Rumble Strips	Pavement Markings and Striping
Shoulders – Paved	Pavement Words & Symbols
Shoulders – Unpaved	Raised Pavement Markings (RPMs)
Slopes	Traffic Signs – Ground Mounted
Turf	Traffic Signs – Overhead
	Roadway Lanes
	Vertical Curves

3.5. Test Route Description

To determine the validity of the data received from the selected vendors, asset data were collected by the research team from three sources: 1) Site visits to manually collect/validate data along the test course, 2) the Maintenance Condition Assessment Program (MCAP) database provided by the NCDOT, and 3) orthoimagery and aerial photographs. Since the course included two arterials where data were not previously collected, and the MCAP assessment database included small samples, the majority of the data were manually collected and validated by members of the research team.

The data collection course consisted of three parts: 1) two test routes comprised of interstate facilities, 2) two test routes comprised of arterial facilities, and 3) an additional section of interstate highway for data collection at the on and off-ramps only. All facilities required the vendors to collect data in one direction of travel. Figure 8 shows the test course, a loop located in Charlotte, NC *(47)*.

Figure 8 Overview of data collection course in Charlotte, NC *(47)*.

The course started at point A, heading southeast along Brookshire Boulevard/NC-16 in a counterclockwise direction. The course ended at the interchange of I-485 and Moores Chapel Road, point A, followed by data collected at five on and off-ramps (points E-I). In total, the course is 46 miles in length, 30.7 miles of which are actually collected along the entire facility and 15.3 miles of which are collected only at the ramp terminals. The five varying segments are noted in Table 2.

Table 2 Course description and location.

Direction	Road	Course Type	Location	Length (mi)
SB	Brookshire Boulevard/NC-16	Arterial 1	A-B	5.9
NB	I-85	Interstate 1	B-C	8.3
WB	W.T. Harris Boulevard/NC-24	Arterial 2	C-D	7.5
SB	I-485 (Outer)	Interstate 2	D-A	5.3
SB	I-485 (Outer)	Ramp Terminals Only	E,F,G,H,I	15.3[1]

[1] *Length is of the segment; however, data were only collected at the ramp terminals.*

Interstate and arterial roadways represent two types of facilities with a variety of assets present and typical traffic conditions in rural and suburban areas needed to complete project objectives. The team chose two arterials, Brookshire and W.T. Harris Boulevards, to ensure that the vendors could collect data during normal signal operations with queues. Interstate facilities such as I-85 and I-485 were selected due to their suburban and rural locations, while still representing frequent congestion typical of similar facilities in other urban areas. Descriptions of the facilities are provided in the following sections.

3.5.1. Interstates

Southbound I-485 is a 6-lane interstate highway separated by a grass median with steel cable median barriers (Figure 9). I-485 is a partially-completed beltway around Charlotte, North Carolina. The posted speed limit for the segment is 65 MPH, the AADT ranges from 50,000 to 72,000 vehicles per day in 2010 *(48)*,and there are fourteen interchanges along the 24.3-mile segment used for data collection. The segment for the test route is rural with trees lining both lanes of travel along with noise walls at some places along the route. Inside and outside shoulders ranged from 12 to 15 feet in width from the edge of the travel-way.

Northbound I-85 of the test course is mostly an 8-lane, and at times a 10-lane, interstate highway with a continuous concrete barrier median (Figure 10). A service road runs adjacent to both directions of travel from the beginning of the route to just before each interchange (and was not considered as part of the data collection effort). The service road then picks up again following the on-ramps from each of the interchanges). The posted speed limit for the segment is 65 MPH, the AADT ranged from 109,000 to 164,000 vehicles per day in 2010 *(48)*, and there were eight interchanges along the 8.3-mile segment used for data collection. Inside and outside shoulders ranged from 6 to 12 feet in width from the edge of the travel-way and noise walls were prevalent along this stretch of roadway.

Figure 9 Southbound I-485 *(49)*.

Figure 10 Example of I-85 section with continuous concrete barrier *(49)*.

Southbound Brookshire Boulevard from I-85 to I-485 consisted of a four-lane median-separated arterial (Figure 11). The speed limit is 45 mph throughout the segment, the annual average daily traffic (AADT) ranged from 12,000 to 36,000 vehicles per day, and there were nine signalized intersections along the segment *(48)*. It includes a wide grass shoulder in both directions of travel and it is well lit by frequent street lights. The wide grass median contains large amounts of foliage in spots, posing additional challenges for data collection. The arterial also includes median openings for U-turns and driveway access.

Figure 11 Southbound Brookshire Boulevard/NC-16 near the I-485 Interchange *(49)*.

From the intersection of I-485 and Brookshire Boulevard to the intersection of Bellhaven Boulevard and Brookshire Boulevard, the arterial does not include any buildings or structures located directly adjacent to the roadway (Figure 11). Following the intersection of Bellhaven Boulevard, Brookshire Boulevard is a much more urban arterial, including heavy commercial development and a more narrow median (Figure 12). From the intersection with Lawton Road to the intersection with I-85, the median alternates between a raised concrete curb and a grass median island.

Figure 12 Southbound Brookshire Boulevard/NC-16 near the I-85 interchange *(49)*.

Westbound W.T. Harris Boulevard consisted mostly of a 6-lane roadway with grass median and additional lanes in places to accommodate turning movements (Figure 13). The posted speed limit for the segment is 50 MPH, the AADT ranged from 40,000 to 62,000 vehicles per day in 2010, and there are 17 signalized intersections per mile. At the intersection with Mallard Creek Road, a lane is dropped and the arterial becomes four lanes. A few superstreet intersection implementations can also be found after this intersection. The arterial runs by Northlake Mall shortly before reaching the on-ramp for I-485 (Figure 14).

Figure 13 Westbound W.T. Harris Boulevard near the I-85 interchange *(49)*.

Figure 14 Westbound W.T. Harris Boulevard near Northlake Mall *(49)*.

3.5.2. Interstate Ramp Terminals

As mentioned previously, the final third of the test course consisted of ramp terminals only. The five selected on and off-ramps on the final 15.3 mile section are shown in Figure 15. This figure shows an aerial of each of the ramp terminals, described briefly below:

1. **RAMP 1, Location E:** The Exit 12 ramp for Moore's Chapel Road
2. **RAMP 2, Location F:** The Exit 4 ramp for Steel Creek Road
3. **RAMP 3, Location G:** The Exit 3 ramp for Arrowood Road

4. **RAMP 4, Location H:** The Exit 1 ramp for South Tryon Street
5. **RAMP 5, Location I:** The Exit 64B ramp for Pineville-Matthews Road

Location E - Moore's Chapel Road

Location F - Steel Creek Road

Location G - Arrowood Road

Location H - South Tryon Street

Location I - Pineville-Matthews Road

Figure 15 Aerials of five different interchange ramp terminals along route.

These ramps represent five different interchange arrangements: a standard diamond interchange, a diamond interchange with roundabouts, a single-loop partial cloverleaf, a double-loop partial cloverleaf with loops serving the left turns from the freeway, and a double-loop partial cloverleaf with loops serving the left turns from the arterial. Each ramp also has varying plant bed and lateral slope configurations that presented good test scenarios for our vendors. The posted speed limit on this section of I-485 is 65 mph, the AADTs ranged from 46,000 to 115,000 vehicles per day in 2010 from the north to south portion of the course (Points E to I).

3.6. Data Collection

To effectively compare the data collection of mobile collection vehicles to human data collection, two types of data collection were conducted: a research team data collection effort and data collection by two vendors with mobile data collection vehicles - Fugro Roadware and Pathways Services, Inc. The research team and vendors completed data collection using the provided catalog along the predetermined test route described in the previous chapter. The data collection efforts of both vendors and the research team are detailed in this section of the report.

3.6.1. Research Team Data Collection

The research team data collection consisted of three efforts: 1) manual data collection along the test route, 2) extraction from MCAP database samples collected private consultants and checked by the NCDOT, and 3) supplemental data extraction from recent orthoimagery, aerial images, and video photography. As previously mentioned, the MCAP database was not able to be utilized fully for this research effort because samples that were actually spot checked by NCDOT were sparse and no MCAP data were available for analysis on the arterials. This section details the research team data collection and the resources utilized.

Manual Data Collection

The manual data collection by the research team took place along the test course with a team of two data collection technicians and two vehicle drivers. Vehicles equipped with safety hazard lights were used for travel along the route. Data were collected via a Tablet PC and a stylus, and were input into ArcMap via a GPS device attached to the Tablet PC. Information was collected from within the vehicle when possible; however, inventory that could not be determined from the vehicle (such as drop inlets and the measurements of traffic signs) were collected on foot by a research team member.

The research team data collection occurred in three parts: 1) an initial site visit and data collection (May - June 2011), 2) a quality assurance site visit (November 2011), and 3) a final site visit (March 2012) to collect video imagery. The research team data collection occurred during off-peak traffic conditions to avoid conflicts between the vehicles transporting data collectors and traffic on the test route as much as possible. Additionally, avoiding the peak hour traffic reduced the occurrence of other vehicles blocking the view of data collectors. Environmental conditions were clear with no precipitation and moderate temperatures during all research team data collection efforts.

The data collection during the months of May and June 2011 took a total of four days by two to six data collection team members each day. The May 2011 data collection effort included a team of four individuals and two vehicles. Each vehicle included two individuals: one driver and one data collector. All individuals wore safety vests during the data collection effort. During the June collection effort, three individuals completed final data collection. The quality assurance site visit (November 2011) occurred after an initial comparison of research team data to vendor data.

Drivers maneuvered the vehicles to stop as often as needed to collect the necessary element features. Data collectors approached each required feature with the best accuracy possible, whether that was from the inside the vehicle or by approaching each element feature outside of the vehicle on foot.

Research team data collectors were instructed in the use of the Tablet PC equipped with a GPS device and ArcMap software to input element features in accordance with the data collection instructions. The GPS device allowed the data collectors to view aerial imaginary and a real-time location indicator. Data entered in the Tablet PC were collected by direct entry into the ArcMap software which was preprogrammed to query the user for specific features within individual elements. Figure 16 shows an example of the ArcMap data collection fields. Additional tools used by the research team were a measuring tape and measuring wheel to verify linear segments, roadway offsets, and dimensions of roadside assets.

Figure 16 Example of data collection entry in ArcMap.

Maintenance Condition Assessment Program Database
The NCDOT created a Maintenance Condition Assessment Program (MCAP) to survey and evaluate the condition of the state's roadway assets *(46)*. This program includes a Maintenance Condition Survey Manual and recently collected data of the surveyed assets. The manual and the database containing the recently collected data were utilized only as a catalyst for the research team data collection effort.

Supplemental Resources
Additional visual resources were used to supplement the research team's roadway asset database. These supplemental resources included the 2010 orthoimagery at a 0.5-foot resolution *(52)*, supplemental online mapping tools, NCDOT LiDAR data, site visit photography, and videography of the test route with a GoPro camera mounted to the top of a vehicle *(53, 54)*.

Quality Assurance/Quality Control
To ensure the quality of the research team's compiled database, the research team conducted three separate site visits for quality control. These site visits conducted systematic review of areas where a comparison of research team data to vendor data showed significant differences. Quality control site visits were conducted in November 2011, March 2012, and June 2012.

3.6.2. Vendor Data Collection

Two separate data collection vehicle vendors (Fugro Roadware, Inc. and Pathways Services, Inc.) were contracted by the research team. Each data collection vehicle was equipped with similar collection tools such as digital right of way video, differential GPS, a laser rut measurement system (LRMS), and International Roughness Index (IRI) analysis equipment. Figure 17 shows examples of typical data collection vehicles used for similar data collection efforts.

Figure 17 Typical data collection vehicles - Fugro Roadware, Inc. *(49)* and Pathway Services, Inc *(50)*.

The vehicles were instructed to travel in the right-most lane of each roadway along the course, maintaining a speed approximate to that of the flow of traffic when appropriate. The short sections below describe when each vendor data collection took place, as well as the asset extraction, sample submission to the research team, and the final data submission.

Fugro Roadware, Inc.

Fugro Roadware is based in Mississauga, Ontario. The data collection vehicle used was an ARAN Automatic Road Analyzer (Figure 17). Fugro completed the mobile data collection with the ARAN on Thursday, June 2nd, 2011. Asset extraction was performed from the collected images only, and completed during the month of July 2011. Fugro supplied a sample of data to the research team by August 1st, 2011. Sample data were analyzed and presented to the vendor in two separate web meetings on September 22, 2011 and February 15, 2012. The final data set was submitted on April 5, 2012.

Pathways Services, Inc.

Pathway Services is based in Tulsa, Oklahoma. The data collection vehicle used was a PathRunner XP Data Collection Vehicle (Figure 17). Pathways completed the mobile data collection with the PathRunner on Sunday, June 5th, 2011. Asset extraction was performed from the collected images only, and completed during the months of August and September 2011. Pathways supplied a data sample to the research team by September 1st, 2011. The final data set was submitted on Wednesday, February 29th, 2012.

3.6.3. Creation of Data Layers

The vendor and research team data were exported from the Tablet PC into a desktop computer to display in ArcMap 10. A geodatabase for each asset was created, organized into database groups by point and linear elements.

Individual maps were created for each asset. Each map included a base map layer, a research team database layer, and a layer for each vendor-collected database. The geodatabase of each vendor and the research team data were referenced into each individual asset map for the respective asset.

Once maps were created, researchers began visual analysis of each individual asset. To aid the visual analysis process, vendor data points were joined to the single closest research team data point. For linear elements, a start/end point layer was created, enabling the data to join as point elements when this application was considered useful. Figure 18 displays a screenshot of ArcMap 10, from which a researcher could begin verifying the location accuracy of vendor data in comparison to research team data. *Note: For the particular asset shown in Figure 18, the research team only compared data from the two arterials and not I-85.*

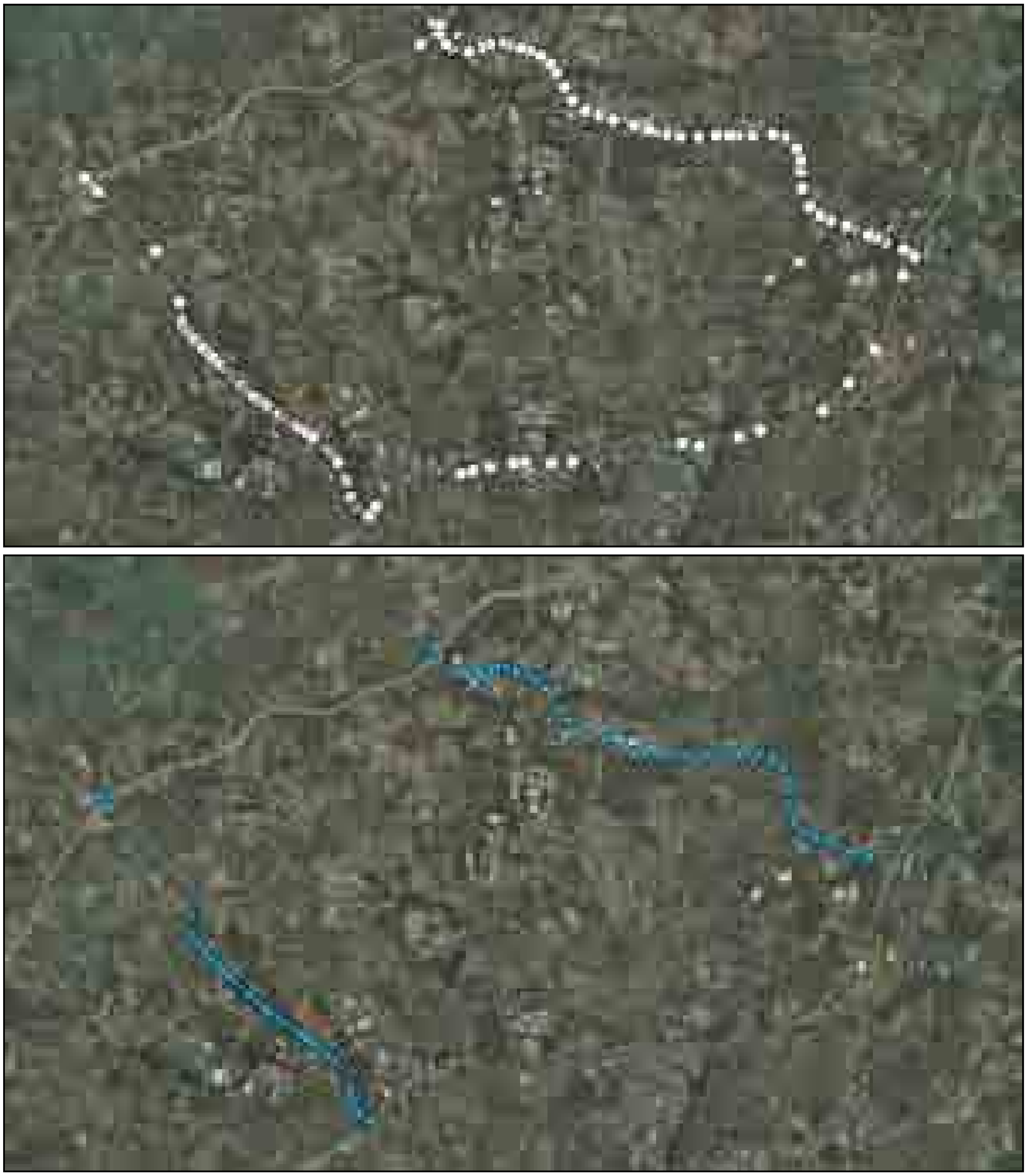

Figure 18 Visual analysis with ArcMap 10 (Top: Vendor Data, Bottom: Research Team Data).

The top portion of Figure 18 displays only the vendor data, while the bottom portion displays only data collected by the research team. The visual analysis begins by displaying both layers together and connecting the closest data points with the ArcMap join and relate features as Figure 19 shows.

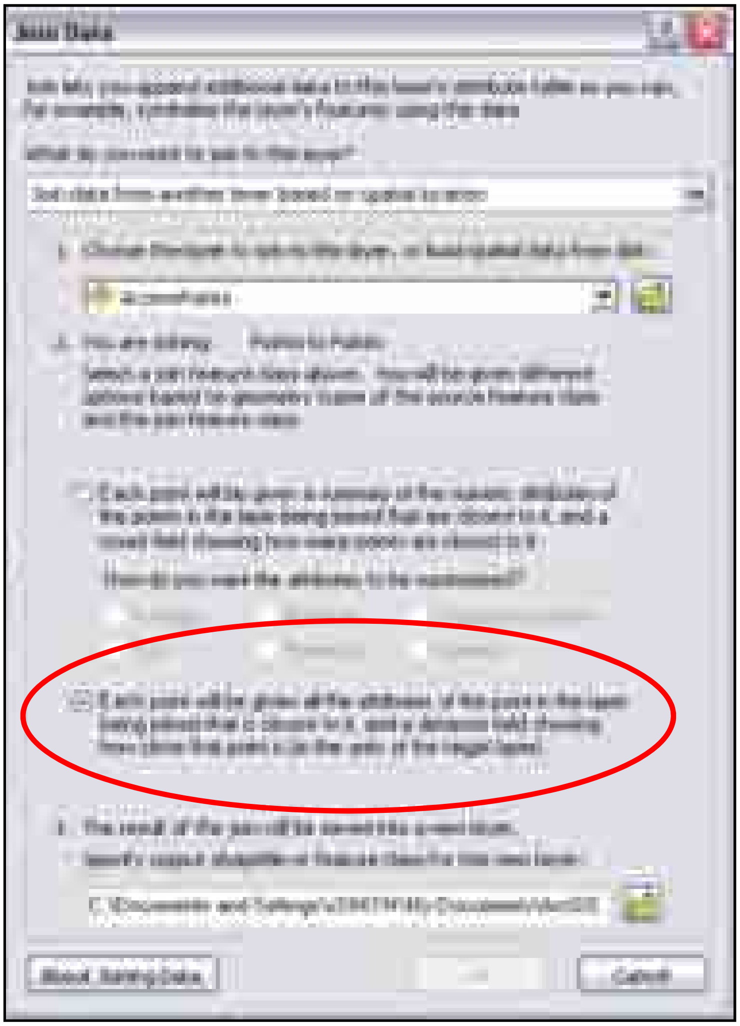

Figure 19 Join data window in ArcMap 10.

The join feature created a new layer which the program will store in accordance to the type of join that has been created. Since the join feature only acts as a join to the specific layer selected, joins of data points could be done in a number of combinations. For this analysis, join layers were created both to the vendor data layer and to the research team data. The researchers compared vendor to research team (V2R) and research team to vendor (R2V), which results in two layers for each vendor data set. When V2R and R2V matches were the same, the match was essentially considered a good match, with a very low likelihood it was a different point that should be matched.

Each individual join resulted in a field that indicated the distance been the two joined data points. The data could be sorted by distance, enabling the researcher to notice any jumps in the distance between data points. For example, if the dataset “inlets” included 260 data points, the researcher would sort the dataset from smallest distance to largest distance between the joins. The researcher might notice the first 250 inlets listed were located within 35 feet of its joined point. The next 10 joins were seen to be at 150 feet or more. This jump in distance might indicate that the last 10 data points were joined to the incorrect inlet, which indicates an error in one of the datasets (vendor or research). Natural thresholds of the data can be found in a similar fashion. While looking at the distance between data points, the researcher might notice the joined points are consistently larger than some common, "base" distance. Upon visual inspection, the researcher might notice a pattern in vendor data collection techniques that were not specified in the instruction manual. This could result in a limit in the ability of the data to be compared. For example, one vendor may have located an asset feature by indicating the location along the roadway and then providing an offset distance, while the research team may have indicated the exact global position of that same data feature. This would result in two points that are consistently 1 to 2 lane widths apart (i.e., lateral distance), plus any discrepancies in the centerline distance.

3.6.4. Locating Data Errors

While the joins help expose data limitations, searching for errors within the data was completed by observing various situations where joined data disguised errors in research team or vendor data sets. There are eight possible combinations of data collection scenarios, both positive and negative, that can be seen within a joined data set as Table 3 shows.

Table 3 Possible data collection scenarios.

Scenario	*Asset is Present*		Scenario	*Asset is Not Present*	
1	R	V	**5**	R	V
2	R		**6**		V
3		V	**7**	R	
4			**8**		

R = Research Team data point or line reported
V = Vendor data point or line reported

Table 3 displays eight scenarios within the two data sets (V = Vendor, R = Research Team). An "R" or "V" indicated in the columns represent a "hit" in the data set, i.e., the respective data collection set has identified an asset at some location, regardless of its accuracy. The column "asset is present" represents data points or lines that are actually present on the test course, regardless of whether or not the data sets have a record of that asset. The column "asset is not present" represents data points that are not on the test course, regardless of data set entry notation.

The validity of the research team collected dataset was assumed as true, given the ability for the research team to collect and confirm the data using multiple methods (i.e., NC OneMap orthoimagery, online mapping tools, and even supplementary site visits). Because of this assumed accuracy, Scenarios 3, 4, 5, and 7 are deemed implausible.

Scenario 1 and 8 are the best possible scenarios for analysis of assets, where an asset is either present or it is not, and both the vendor and research data reflects the truth in each scenario. This is called a true positive (Scenario 1 when the asset is present) or true negative (Scenario 8 when the asset is not present) for both the vendor and research team data point or line, as illustrated in

Figure 20A. In the case of Scenario 8, there are an infinite amount of points where assets are not present and are not marked as true negatives.

Scenarios 2 and 6 represent errors made by the vendor during data collection. Scenario 2 reflects when the vendor has failed to correctly identify the presence of a data point or line (a false negative). Scenario 6 is a false positive: the asset is not present, but the vendor has incorrectly noted the asset in that location. Scenario 2 and 6 are illustrated in Figure 20B.

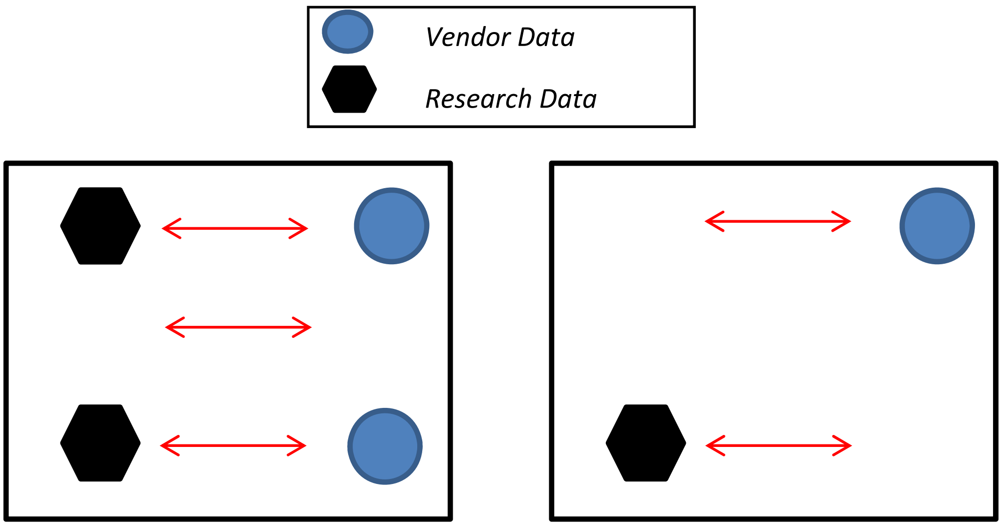

Figure 20 A) true positives and a true negative (left); B) a false positive and a false negative (right).

Given the possible scenarios described above, the research team sought to systematically remove any errors within the research dataset by revealing possible errors, as well as reveal vendor errors for comparison. Once research datasets had been relieved of any errors by checking disputed data with multiple sources, the research team recognized possible error types of vendor data and initiated revealing those errors by creating both V2R and R2V joins, and then noted the number and type of errors located.

Three possible types of errors were found in the raw dataset:

- Vendor false negatives (Scenario 2) – the vendor has failed to place a data point or line where the asset actually exists.
- Vendor false positive (Scenario 6) – The vendor has placed a data point or line where there is no existing asset.
- Bad match (point features only)

Vendor false negatives were revealed through V2R joins, while R2V joins revealed vendor false positives. Figure 21 visualizes V2R matches using the join feature created by the software, which results in the join of A to 1, B to 3, and C to 3.

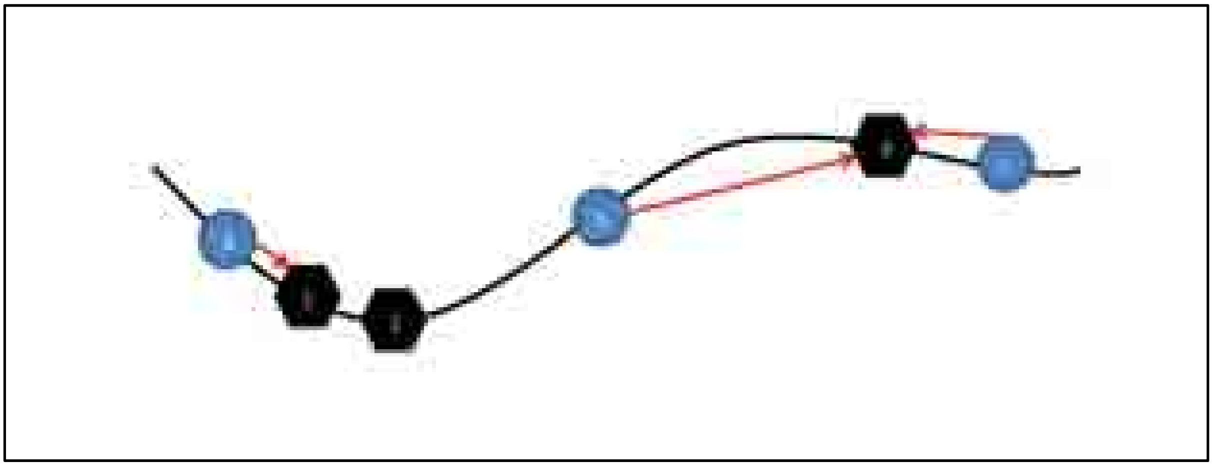

Figure 21 Vendor to research (V2R) join (vendor data point in circle and research data point in hexagon)

The multiple joins of the research data to vendor data point 3 in Figure 21 reveals a vendor false negative at research point B. Notice there is not a vendor point in close proximity to the research point B; therefore, this point is joined to the closest data point, vendor point 3. The second error in Figure 21, a vendor false positive denoted by vendor point 2, is not clear to the researcher as a result of the join tool output being observed. The join tool output will not reveal any non-joined data points; therefore, the creation of R2V joins as seen in is used to reveal the false positive vendor data point (Figure 22).

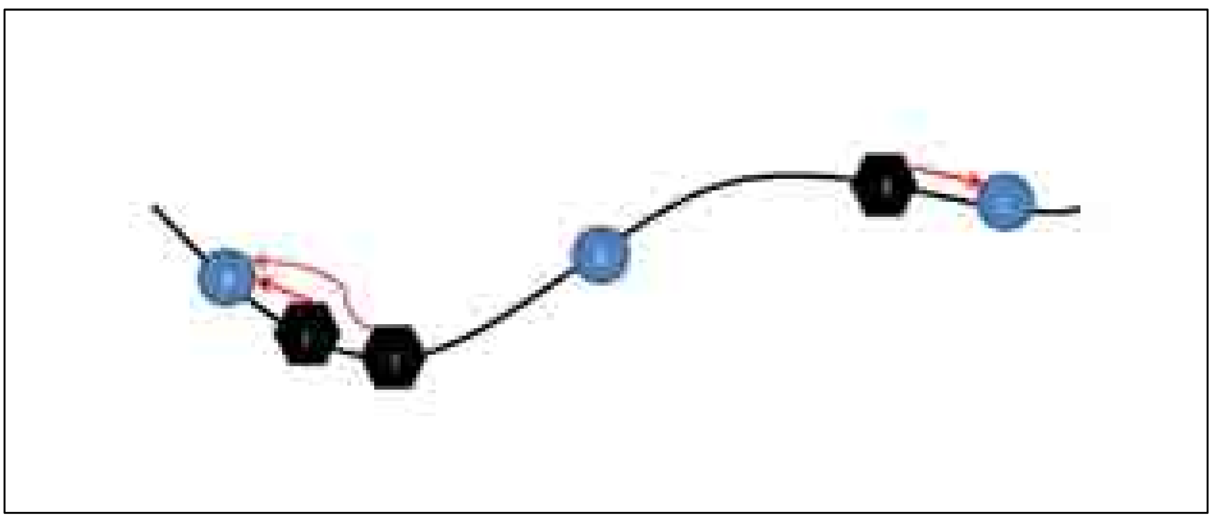

Figure 22 Research to vendor (R2V) joins (vendor data point in circle and research data point in hexagon).

The examples provided in Figure 21 and Figure 22 prompted the research team to visually confirm the presence of a false negative or positive, or both, in the dataset. If the joined sets were evaluated independently of one another, errors may not have been discovered in one joined data set that could have been discovered in the other joined data set.

The third possible type of error, a bad match, was a systematic error of the join tool due to the placement of the vendor data along this test route. This generally occurred when the vendor aligned the data points along the centerline of the traveled lane rather than on the actual roadside asset to be identified. A Bad Match is not defined by a scenario as the error is due to an incorrect join by the software due to two or more data points are placed in the same or relatively close spatial location, as seen in Figure 23. This same close spatial location causes one vendor point matched to be matched to two or more research points along the route when in reality the vendor data point should have been matched uniquely to two research data points, or vice versa. To correct this error, the researcher confirmed the accuracy of the data point through orthoimagery, online mapping tools, or a later supplemental site visit, before manually joining the correctly matched pair of data points. A visual example of a Bad Match before and after manual correction is found in Figure 23.

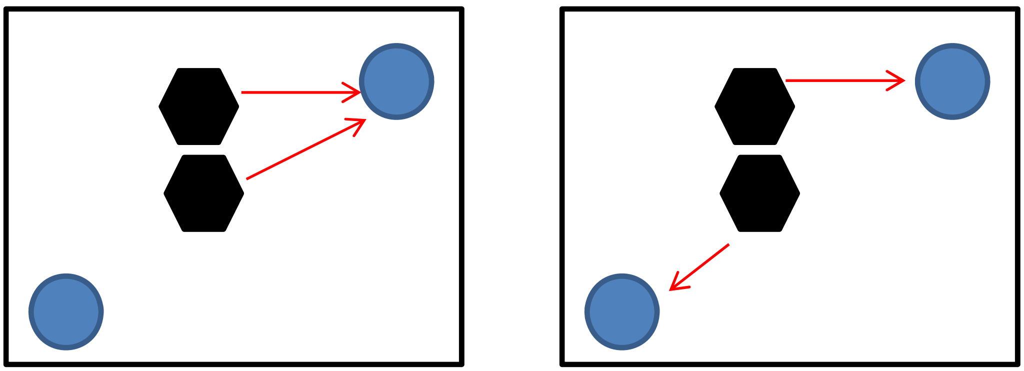

Figure 23 Bad match uncorrected, left, and corrected, right, (vendor data point in circle and research data point in hexagon).

After the data were exported in a spreadsheet, the systematic process of locating these errors was as follows:

To locate vendor false negatives (V2R):

1. Sort Vendor ID column by values.
2. Select the Vendor ID column and conditionally format for duplicate values.
3. Visually confirm the duplicate matches. Note bad match, vendor false positive, and vendor false negatives in a "diagnosis" column.
4. Remove each false positives and negatives. Save in a separate spreadsheet for future reference.
5. Correct bad matches by adding a column "true match ID" and "true match distance."
    a. Manually measure the distance between the true vendor/research match.
    b. Enter the correct vendor or research ID for each bad match.

To locate vendor false positives (R2V):

1. Sort Research ID column by values.
2. Select Research ID column and conditionally format for duplicate values.
3. Visually confirm duplicate matches. Note bad match, vendor false positive, and vendor false negatives in a "diagnosis" column.

4. Remove each false positives and negatives. Save in a separate spreadsheet for future reference.
5. Correct bad matches by adding a column "true match ID" and "true match distance."
    a. Manually measure the distance between the true vendor/research match.
    b. Enter the correct vendor or research ID for each bad match.

After all errors were accounted for, final matches could be identified with one unique Vendor ID matched to one unique Research ID, resulting in a dataset of "true matches" identified by final arbitrarily assigned ID number. Once all the true matches were established, a final comparison of vendor and research matched data points could be made. Ultimately the joined data points were fully utilized in the resulting attribute table: each vendor data point and its attributes was joined to the research data point closest to that point, thus allowing the comparison of data point information by the researcher.

Similarly, linear element datasets were imported into ArcMap and the data lines were arbitrarily assigned identification numbers. The attribute table for each layer created, which auto-populated with a layer of joined features, was exported into an MS Excel spreadsheet to compare attributes and distances between vendor and research data lines.

3.6.5. Data Cleansing and Analysis

Following the final submittal of the vendors' data collection efforts, a final data analysis was conducted by the research team. This analysis compared the data collection of the vendors to the research team by visually observing the location of assets collected, the attributes requested of each asset, and condition assessments completed (if applicable). In summary, preparation of data analysis included:

1. Creation of a geodatabase organization system for ease of data filing and location;
2. Import of vendor and research datasets to ArcMap 10;
3. Display of vendor and research datasets on appropriate layers;
4. Special variation/error elimination through ArcMap join tool or visual analysis; and
5. Export of final, true matches into a spreadsheet.

After the initial data preparation was completed, final data comparison of various asset attributes could be completed by observing distances between matched data points, differences (or similarities) in attribute descriptions, and the data accuracy. This section reviews the terminology and detailed methodology of the final analysis.

Point Elements

Point elements are any inventory whose locations could be defined by a finite, spatial data point. Fifteen point elements were analyzed for this research effort (Table 1). A sample data collection log is provided in Figure 24, while specific data collection log(s) can be found in Appendix B.

ACCESS POINTS					
Course Milepost	**Latitude**	**Longitude**	**Street Type**	**Intersection Type**	**Comments**
17.26	35.76812	78.65949	Public Street	Signalized	
18.34	35.76803	78.65948	Business Driveway	Unsignalized	
19.26	35.76809	78.12665	Residential Driveway	Unsignalized	
20.34	35.61590	78.75889	Public Street	Signalized	

Figure 24 Sample data collection log.

Point element attributes initially included milepost and location to be collected, as seen in Figure 24, which were later omitted from the final data set and simply denoted by a spatial point in the GIS layer. Other information related to feature type are present, and sometimes an assessment of the features condition is also present. Each point element's dataset collection effort and specific challenges are discussed in greater detail in the corresponding sections of this chapter.

Linear Elements

Linear elements were defined in the catalog as continuous roadway features located along or on the roadway. Linear elements collected by the research team were indicated using a 'draw linear feature' tool in ArcMap. The assets chosen to represent this feature category include Brush & Tree, Slopes, and Turf.

One challenge for linear element analysis included the format of the vendor submitted dataset. Due to the format of the example spreadsheets provided to the vendors, the linear datasets provided by vendors were displayed by a start point and an end point, thus displaying the linear element as two point features in ArcMap. To create a fair comparison of the two datasets, the research team connected the start and end points of the vendors' data, and then displayed the vendor and research data layers for evaluation in ArcMap as seen in Figure 25.

Figure 25 Data lines displayed in ArcMap 10.

However, the research team found the connection of the start to the end point to be problematic, since creating a line between the two points resulted in a line which was often not the correct shape of the asset being inventoried (i.e., a curved median or guardrail could not be displayed). As seen in Figure 26, the constructed line does not assist in visual comparison of the segment and results in an inaccurate length attribute of the created data line.

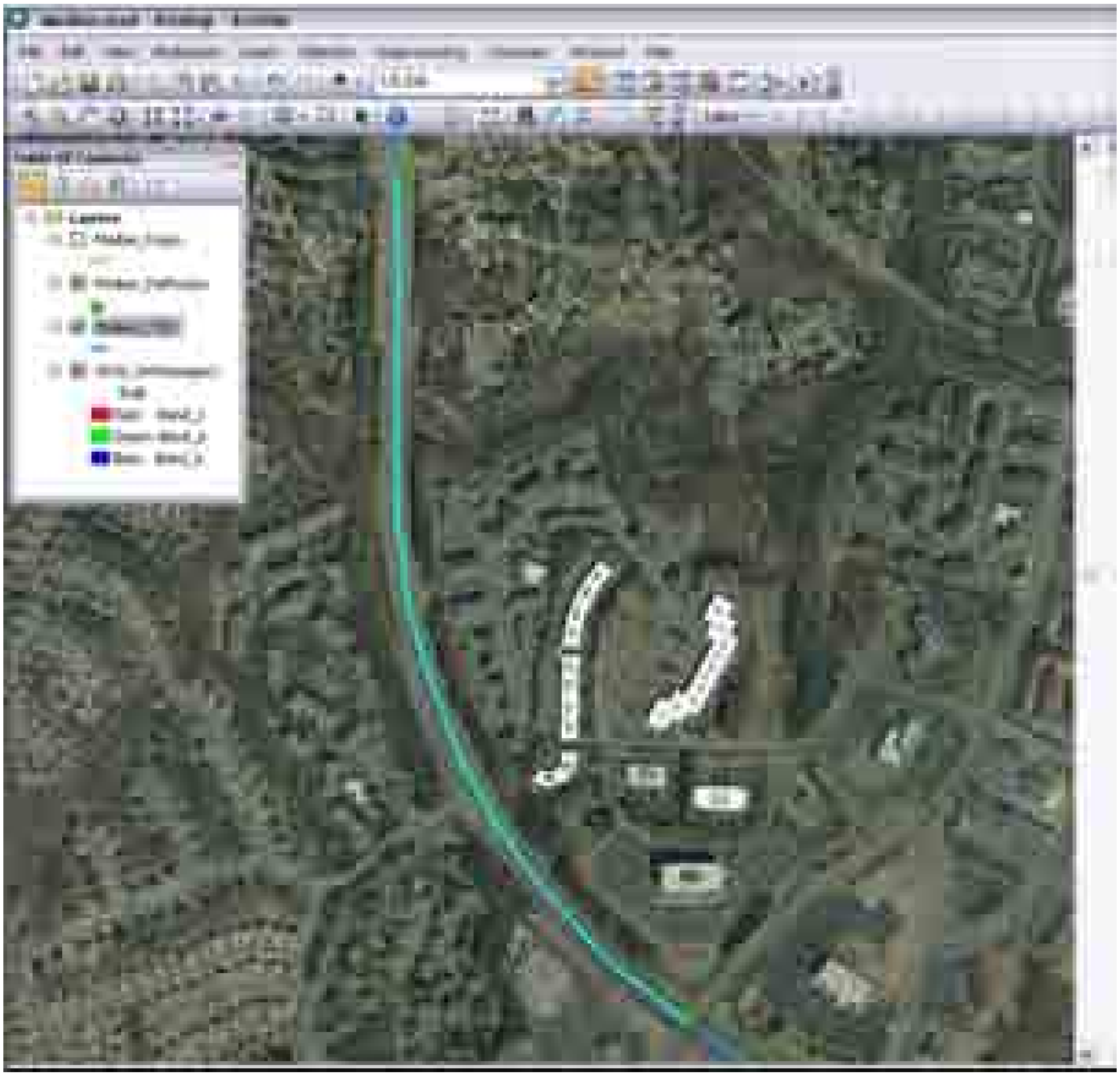

Figure 26 Example of a data line constructed from given start and end points.

To overcome this difficulty, the research team modified the format of the line to be displayed as a start and end point, thus creating a similar layer as the submitted vendor layer. The idea was that one point (end or start) provided by the vendor would likely be intended for the start or end point of the research dataset. The research team visually observed the dataset in comparison with the research team dataset to see whether the end point or start point was closest to the data point created from the research team linear feature. After selecting a start or end point, the selected layers were isolated and joined, just as the point elements were joined, to result in a comparable dataset. Generally, this method provided successful means to represent these types of roadside assets.

Vendor-Research Team Feedback & Communication

A major objective of this study was to evaluate the effectiveness of the feedback and communication efforts between the vendor and the research team. To accomplish this goal, the vendors were asked to provide a two-part data collection effort through a preliminary data collection stage and a final data collection stage. An identical analysis of the vendor's data collection efforts before and after formal feedback was recorded. The preliminary dataset and the final dataset were separated by a formal analysis and communication opportunity between the vendor and research teams. Additionally, the vendors were encouraged to contact the researchers with any and all questions by phone or email.

After the preliminary analysis, feedback was presented to the vendors through a written summary of findings memorandum, as can be seen in Appendices C and D. The memorandum included a summary of each element feature which displayed the overall preliminary analysis outcomes for linear, point, and point per segment length elements, in the following format:

1. Sample size of analysis
2. A brief location analysis
    - *How many of the sample was located incorrectly.*
3. Attributes analysis
    - *Any noteworthy errors observed in the collected features, such as accuracy of roadside location or inspection required.*
4. Possible sources of error.
    - *(a) Definition issue, (b) no apparent reason for error, (c) vendor bias or (d) impossible to collect.*

An example of the summary data presentation is seen in Table 4, including examples of each data element category: lateral ditches (a linear element), access points (a point element) and raised pavement markers (a point per segment element). Each summary includes the sample size, location analysis, attributes analysis (if applicable), and possible sources of error as identified by the researchers. Note that the scope of this study does not include full evaluation of all locations and attributes for entire samples, but instead picks a random sample along the test course to provide basic feedback.

Table 4 Example summary of data collection features in memorandum of findings.

LATERAL DITCHES
1. Sample of 131 **2.** Location Analysis • *Missing segments and differences in start/ending points of the segments create differences in total lengths. The length differences below reflect total lengths found along a particular segment of roadway. Visual street views of missing segments are provided in the attached PowerPoint.* **3.** Attributes Analysis • *Differences may be due to missing segments or differences in start/ending points.* **4.** Possible Sources of Error • *Visual examples of missed lengths and possible errors in additional lengths are included in the attached PowerPoint.*
ACCESS POINTS
1. Sample Size: 50 **2.** Location Analysis • *7* were missing **3.** Attributes Analysis • *Missing samples were found along the right side of the roadway. (6 - Right, 1 - Ramp)* **4.** Possible sources of error • *Definition Error. Include both on AND off ramps as 2 separate access points* • *Include every access point, i.e. if one business has two access points, count both separately*
RAISED PAVEMENT MARKERS (RPMs)
1. Sampled 64 segments, each 1/10th mile (528 feet) in length. • *Expected RPMs per 1/10th mile segment: 7* • *Expected RPMs for 64 segments: 448* **2.** Location Analysis • *Total Visible RPMs (Research Team): 256* • *Total Visible RPMs (Vendor): 596* **3.** Attributes Analysis • *Transition Zone Notation. 42 segments were identified as in a transition zone.* **4.** Possible Sources of Error • *Definition Issue. Only RPMs to the left of the far right thru lane should be collected; transition zone lanes should not be included (see data collection instructions).*

Once vendors were provided with feedback in the form of a memorandum of findings, a web conference was scheduled with each individual vendor to provide a visual presentation and discussion of the feedback by the research team. This web conference allowed the vendors to clarify any reasons for error and ask questions regarding the data collection instruction manual.

The web conferences' visual examples were provided to the vendors in the form of a PowerPoint presentation. The presentation included a background refresher, the process for analyzing data, the current status of analysis, a visual overview of errors founds, and a summary. The full presentation can be viewed for each vendor in Appendices E and F. Visual examples in the presentation consisted of screenshots from ArcMap 10 and other online mapping tools comparing each specific data point or line of vendor data with the corresponding research team data. Figure 27 displays an example of a visual analysis screenshot provided during the web conference, where green dots represent vendor matches of access points and the red “X” represents a missed access point.

Figure 27 Example of visual analysis presented to vendor.

The web conference allowed the vendors to voice concerns particular to each feature presented, with respect to error in the vendor data or data collection instructions given. The researchers noted each concern and adjusted the data collection instructions accordingly. Additionally, any errors with particular explanation were noted. At the conclusion of the discussion, vendors were encouraged by the research team to continue with final data collection. Once final data collection efforts were submitted to the research team, an analysis identical to the preliminary analysis (as presented earlier in this chapter) was completed on the final vendor dataset for the results detailed in the corresponding chapter.

4. RESULTS

The findings from each of the 28 features studied under this research effort are summarized in the following paragraphs. Summary findings are based on asset location, type, and condition. Further analysis on the ability of vendors to accurately measure asset features on height, width, length, offset, radius, azimuth, and grade are also presented. Last, vendors are tested on the accuracy of the collection of point features to see if irregularities exist that would cause problems with physically locating an asset in the field.

4.1. Asset Location

The location of roadway assets is the first step in vendor data collection, making it the foundation for any other feature description comparisons analyzed later in the effort. If a data item is not identified and appropriately located during the first stages of data collection, there is no opportunity for more descriptive data to be used by municipalities and DOTs. Vendors were asked to locate an inventory for each of the 28 linear and point elements along the entire course in one direction of travel. As noted earlier, vendors were encouraged to ask questions or request clarification on any information provided in the catalog when necessary. Several questions were asked by each of the vendors, leading to further clarification which was reflected in updates to the catalog. In the fall of 2011, summary data were submitted for review with input provided by the research team in late 2011 and early 2012.

Location data are provided in Table 5. These are final data from the vendors, after the web conference described above. Highlighted cells draw attention to two possible scenarios (only applicable when the research sample exceeded 20): 1) vendor data fell under 80% for the location match requirement or 2) vendor data “false positives” (i.e. extra data) exceeded 20%. Other data that meets these thresholds but have small sample sizes should be considered carefully as the small sample might not be fully representative of the population.

Using access points for illustrative purposes, the research team identified 180 possible access points in its sample over the entire course. Pathways and Fugro located a sample of 186 and 146, respectively. In all, Pathways correctly located 93% (167/180) of the access points identified by the research team and Fugro correctly located 77% (139/180). Since the research sample exceeded 20, we highlighted the finding that Fugro only located 77% correctly. “False negatives” represent the missed data points, or 100% minus the percentage of correctly located access points. Last, “false positives” represent the additional data submitted by each vendor that was not actually located on the course. In this case, Pathways submitted 11% (19/180) additional access points while Fugro submitted 3% (6/180) additional data points.

Table 5 Location of assets.

	Feature		Research Sample	Reported		Correctly Matched		False Negatives		False Positives[1]	
				Pathways	Fugro	Pathways	Fugro	Pathways	Fugro	Pathways	Fugro
Linear	Brush & Tree		99	120	126	70 (71%)	88 (89%)	29 (29%)	11 (11%)		
Linear	Concrete Barriers		25	56	23	23 (92%)	21 (84%)	2 (8%)	4 (16%)		
Linear	Curb/Gutter		79	105	117	72 (91%)	72 (91%)	7 (9%)	7 (9%)		
Linear	Guardrail		74	84	76	72 (97%)	67 (91%)	2 (3%)	7 (9%)		
Linear	Lateral Ditches		128	209	307	110 (86%)	110 (86%)	18 (14%)	18 (14%)		
Linear	Median		77	82	95	71 (92%)	74 (96%)	6 (8%)	3 (4%)		
Linear	Paved Shoulders		75	554	165	41 (55%)	58 (77%)	34 (45%)	17 (23%)		
Linear	Pavement		21	204	115	20 (95%)	19 (90%)	1 (5%)	2 (10%)		
Linear	Retaining Walls		4	18	3	4 (100%)	3 (75%)	0 (0%)	1 (25%)		
Linear	Rumble Strips		15	30	24	14 (93%)	13 (87%)	1 (7%)	2 (13%)		
Linear	Slopes		28	89	118	25 (89%)	25 (89%)	3 (11%)	3 (11%)		
Linear	Turf[2]		20	248	259	19 (95%)	17 (85%)	1 (5%)	3 (15%)		
Linear	Unpaved Shoulders		67	193	201	64 (96%)	67 (100%)	3 (4%)	0 (0%)		
Points	Access Points		180	186	146	167 (93%)	139 (77%)	13 (7%)	41 (23%)	19 (11%)	6 (3%)
Points	Attenuators/ End Treatments		90	88	86	85 (94%)	82 (91%)	5 (6%)	8 (9%)	3 (3%)	4 (4%)
Points	Bridges		17	17	17	17 (100%)	17 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Points	Centerline		1007	1007	1007	1007 (100%)	1007 (100%)	0 (0%)	0 (0%)	N/A	N/A
Points	Horizontal Curves		21	29	72	20 (95%)	20 (95%)	1 (5%)	1 (5%)	3 (14%)	16 (76%)
Points	Inlets		490	418	388	383 (78%)	364 (74%)	107 (22%)	126 (26%)	11 (2%)	22 (4%)
Points	Landscape Areas		11	9	5	10 (91%)	4 (36%)	1 (9%)	7 (64%)	0 (0%)	1 (9%)
Points	Median Openings[3]		53	50	22	50 (94%)	21 (40%)	3 (6%)	32 (60%)	0 (0%)	1 (2%)
Points	Traffic Signs	Ground	509	511	452	475 (93%)	381 (75%)	34 (7%)	128 (25%)	N/A	N/A
Points	Traffic Signs	Overhead	67	91	101	56 (84%)	55 (82%)	11 (16%)	12 (18%)	N/A	N/A
Points	Pavement Marking/Striping		300	1559	1488	300 (100%)	300 (100%)	0 (0%)	0 (0%)	11 (4%)	3 (1%)
Points	Pavement Word/Symbol		88/419[4]	53	409	53 (60%)	406 (97%)	35 (40%)	13 (3%)	N/A	N/A
Points	Raised Pavement Markers		63	297	278	59 (94%)	60 (95%)	4 (6%)	3 (5%)	N/A	N/A
Points	Roadway Lanes		166	166	175	166 (100%)	166 (100%)	0 (0%)	0 (0%)	N/A	N/A
Points	Vertical Curves		16	64	124	14 (88%)	16 (100%)	2 (13%)	0 (0%)	1 (6%)	8 (50%)

[1] No False Positives for linear features because of limited research data

[2] *Research team only collected bad turf; therefore, table only show comparison of field inspection needed.*

[3] *Fugro didn't report median openings on the arterials.*

[4] *Pathways only collected pavement words and symbols in the right-most lane.*

In general, only two assets were difficult for *both vendors* to locate: drop inlets and paved shoulders. Drop inlets were problematic for two reasons, both related to the location of drop inlets in the median. Some drop inlets were not visible due to trees and bushes planted in landscape areas. Those drop inlets that were not occluded by landscaping were likely occluded by other vehicles driving in the adjacent lanes between the vendor vans and the median. Paved shoulders were problematic because of the four foot distinction between paved and unpaved shoulders.

Instances of a *single vendor* having difficulty with a particular asset were much more prominent and indicate that collection of that data element is possible with further communication using smaller samples of data. Examples of asset data that single vendors had issues locating include brush and tree, access points, median openings, traffic signs, and pavement words and symbols.

Note that the fact that the vendors collected much more data on linear features than the research team should not be viewed as a negative for mobile data collection. The research team simply did not have the resources to conduct a full data collection effort on all linear features on the course. For linear features, then, only the number of correct matches and false negatives are important in this analysis.

4.2. Asset Type

Once the roadway asset is located, users want to know what category the specific feature falls into and a detailed description of the feature. If a data item is not categorized correctly, DOT personnel may make poor decisions and inferences about a particular feature related to operations, safety, or maintenance practices. Vendors were asked to provide descriptive information on the 28 features previously located in one direction of travel. If vendors had questions or needed clarification, they were encouraged to discuss those problems with the research team. With regard to descriptive data, there was very little communication until after the preliminary data sets were analyzed and feedback was provided in late 2011 and early 2012. Following discussions with each of the vendors, updates were made to the catalog accordingly.

4.2.1. Linear Assets

Data on roadway asset type for linear assets are provided in Table 6. As noted earlier, highlighted cells for location draw attention to the reader when the total research sample exceeded 20 and the vendor data fell under 80% for the location match requirement for that individual description. Since this data set only looks at data that were correctly located in the previous section, there exists no need to discuss false positives or false negatives. Total *research samples* for each feature sum to the total sample in the previous section, shown in Table 6. In addition, total *location samples* for each feature sum to the total correctly located for each vendor.

Using curb and gutter for illustrative purposes, the total research sample of correctly located data points is 79 (66 right side +13 in the median). The total correctly matched locations for Pathways and Fugro curb and gutter is 72 (61+11) and 72 (60+12), respectively. Following this description of curb and gutter, Pathways and Fugro correctly located 92% (61/66) and 91% (60/66) *right side* curb and gutter, respectively while correctly locating 85% (11/13) and 92% (12/13) of *median* curb and gutter, respectively. Of the right side medians they located correctly, Pathways and Fugro both correctly identified all features as a right side and median curb and gutter with 100% accuracy (Pathways = 61/61 and 11/11, Fugro = 60/60 and 12/12). Since the percent located was above threshold requirements for all categories for each vendor, none were highlighted.

Table 6 Asset type - Linear features.

Feature	Feature Category	Feature Description	Total Research Sample	Pathways		Fugro	
				Location Matches	Asset Type Matches	Location Matches	Asset Type Matches
Brush & Tree	Roadside Orientation	Right	55	34 (62%)	34 (100%)	45 (82%)	45 (100%)
		Median	44	36 (82%)	36 (100%)	43 (98%)	43 (100%)
Concrete Barrier	Roadside Orientation	Right	16	14 (88%)	14 (100%)	14 (88%)	14 (100%)
		Median	9	9 (100%)	9 (100%)	7 (78%)	7 (100%)
Curb & Gutter	Roadside Orientation	Right	66	61 (92%)	61 (100%)	60 (91%)	60 (100%)
		Median	13	11 (85%)	11 (100%)	12 (92%)	12 (100%)
Guardrail	Roadside Orientation	Right	52	51 (98%)	51 (100%)	46 (88%)	46 (100%)
		Median	22	21 (95%)	21 (100%)	21 (95%)	21 (100%)
	Material	Metal	64	63 (98%)	62 (98%)	57 (89%)	57 (100%)
		Cable Rail	9	8 (89%)	8 (100%)	9 (100%)	9 (100%)
		Rusticated Steel	1	1 (100%)	1 (100%)	1 (100%)	1 (100%)
Lateral Ditch	Roadside Orientation	Right	94	82 (87%)	82 (100%)	77 (82%)	77 (100%)
		Median	34	28 (82%)	28 (100%)	33 (97%)	33 (100%)
	Material	Unpaved	107	91 (85%)	88 (97%)	91 (85%)	74 (81%)
		Concrete	7	7 (100%)	4 (57%)	7 (100%)	6 (86%)
		Asphalt	1	1 (100%)	0 (0%)	0 (0%)	N/A
Median	Material	Grass	49	46 (94%)	46 (100%)	47 (96%)	47 (100%)
		Paved	28	25 (89%)	25 (100%)	27 (96%)	27 (100%)
Paved Shoulder	Material	Asphalt	64	35 (55%)	35 (100%)	48 (75%)	48 (100%)
		Concrete	11	6 (55%)	6 (100%)	10 (91%)	10 (100%)
Pavement	Material	Asphalt	21	20 (95%)	20 (100%)	19 (90%)	19 (100%)
		Concrete	0	N/A	N/A	N/A	N/A
Rumble Strip	Roadside Orientation	Right	12	12 (100%)	12 (100%)	12 (100%)	12 (100%)
		Median	3	2 (67%)	2 (100%)	1 (33%)	1 (100%)
Turf	Roadside Orientation	Right	14	14 (100%)	14 (100%)	12 (86%)	12 (100%)
		Median	6	5 (83%)	5 (100%)	5 (83%)	5 (100%)

Note: Asset type percentages are based on how well the vendor accurately identified the feature once it was matched and not the total research sample.

Generally speaking, vendors appear to be able to accurately describe roadway asset linear feature descriptions. It appears that *location* of the linear feature descriptions is more difficult than actually describing the linear feature type. The one exception, although not highlighted due to low sample sizes, could be concrete and asphalt lateral ditches. Unfortunately, there is not a sufficient sample size to support whether or not this is an anomaly or fact.

4.2.1. Point Assets

Table 7 provides data on point assets related to asset type. Reading this table has been described in the previous discussion – all highlighted cell assumptions are the same. For illustrative purposes, a sample of 119 access points was analyzed. Just looking at signalization as the feature category, Pathways and Fugro both correctly *located* 100% of the signalized (26/26) and unsignalized (93/93) intersections. With regards to defining the *type* correctly, Pathways and Fugro defined signalized intersections correctly in 58% (15/26) and 92% (24/26) of the cases, respectively, while defining unsignalized intersection type correctly in 97% (90/93) and 95% (88/93) of the cases, respectively. Since minimum sample size requirements were met, Pathways asset type matches for signalized access points were highlighted due to the 58% match rate.

In summary, location of point assets by type was still very good, although not as good as the linear features described in the previous section. The location results with respect to type were interesting in that no features, with the exception of drop inlets and signs, were problematic for both vendors. This leads the researchers to believe that there was still room for improvement with regards to definition or submission of complete data sets. With regards to signs and drop inlets, the likely problem with locating that feature is likely due to occlusion. For instance, both vendors struggled somewhat with collection of drop inlets in the median areas. This was likely due to the fact that some of the drop inlets were located in planting beds that were very difficult to locate from a van driving in the far right lane.

Point features were not as easily categorized by *asset type* as linear features; however, the vast majority of samples were successfully and accurately defined. The majority of errors in *asset type* for point features fell under pavement marking features (lanes and markings) or traffic sign MUTCD codes and descriptions. With regards to pavement markings, only Pathways struggled to describe the asset type (i.e. number of lanes, color or type of line), pointing to a likely misunderstanding of the definition since Fugro did not seem to have similar issues. On the contrary, traffic signs were problematic for both vendors, which likely indicate that while this feature can be located fairly easily, it is very hard to describe accurately.

Table 7 Asset type - Point features.

Feature	Feature Category	Feature Description	Total Research Sample[1]	Pathways		Fugro	
				Location Matches	Asset Type Matches	Location Matches	Asset Type Matches
Access Points	Signalization	Signalized	26	26 (100%)	15 (58%)	26 (100%)	24 (92%)
		Unsignalized	93	93 (100%)	90 (97%)	93 (100%)	88 (95%)
	Roadway	Public Street	53	53 (100%)	44 (83%)	53 (100%)	53 (100%)
		Business Driveway	62	62 (100%)	54 (87%)	62 (100%)	56 (90%)
		Residential Driveway	4	4 (100%)	2 (50%)	4 (100%)	3 (75%)
Attenuator/ End Treatment	Type	Curved W-Beam End Treatment	33	30 (91%)	1 (3%)	29 (88%)	28 (97%)
		Type 350 Attenuator	4	4 (100%)	3 (75%)	3 (75%)	3 (100%)
		Other	1	1 (100%)	1 (100%)	1 (100%)	0 (0%)
	Roadside Orientation	Right	36	33 (92%)	32 (97%)	31 (86%)	30 (97%)
		Median	2	2 (100%)	2 (100%)	2 (100%)	2 (100%)
Horizontal Curve	Arc Direction	Right	10	No Data		10 (100%)	10 (100%)
		Left	11	No Data		10 (91%)	10 (100%)
Inlet	Roadside Orientation	Right	92	78 (85%)	73 (94%)	71 (77%)	71 (100%)
		Median	121	91 (75%)	90 (99%)	93 (77%)	91 (98%)
Roadway Lanes	Number of Lanes	Two	43	43 (100%)	42 (98%)	43 (100%)	40 (93%)
		Three	57	57 (100%)	39 (68%)	57 (100%)	45 (79%)
		Four	38	38 (100%)	29 (76%)	38 (100%)	31 (82%)
		Five	23	23 (100%)	20 (87%)	23 (100%)	21 (91%)
		Six	5	5 (100%)	4 (80%)	5 (100%)	5 (100%)
Pavement Markings & Striping	Color	Yellow	100	100 (100%)	0 (0%)	100 (100%)	89 (89%)
		White	200	200 (100%)	200 (100%)	200 (100%)	200 (100%)
	Line Type	Edgeline	100	100 (100%)	81 (81%)	100 (100%)	97 (97%)
		Skipline	99	99 (100%)	99 (100%)	99 (100%)	89 (90%)
		Centerline	101	101 (100%)	0 (0%)	101 (100%)	101 (100%)
Pavement Words & Symbols	Word/Symbol Type[1]	Right Turn Arrow	14/115	12 (86%)	12 (100%)	114 (99%)	114 (100%)
		Left Turn Arrow	6/115	6 (100%)	6 (100%)	111 (97%)	111 (100%)
		Stop Bar	32/32	0 (0%)	N/A	32 (100%)	32 (100%)
		Merge Left Arrow	2/28	2 (100%)	2 (100%)	28 (100%)	28 (100%)
		Merge Right Arrow	0/4	N/A	N/A	4 (100%)	4 (100%)
		Thru Arrow	26/82	25 (96%)	25 (100%)	75 (91%)	75 (100%)
		Triangle Bar	1/1	1 (100%)	1 (100%)	1 (100%)	1 (100%)
		Bicycle Lane Symbol	0/6	N/A	N/A	5 (83%)	5 (100%)
		Bicycle Lane Thru Arrow	0/5	N/A	N/A	4 (80%)	4 (100%)
		Pedestrian Crossing	0/7	N/A	N/A	7 (100%)	7 (100%)
		Railroad Crossing	1/1	1 (100%)	1 (100%)	1 (100%)	1 (100%)
		"Only"	4/17	4 (100%)	4 (100%)	17 (100%)	17 (100%)
		Thru Right Arrow	2/5	2 (100%)	2 (100%)	5 (100%)	5 (100%)
		Horizontal Line	0/2	N/A	N/A	2 (100%)	2 (100%)
Traffic Signs (Ground)	Roadside Orientation	Right	352	328 (93%)	302 (92%)	259 (74%)	253 (98%)
		Median	157	147 (94%)	123 (84%)	139 (89%)	133 (96%)
	MUTCD Code	Letter	481	449 (93%)	309 (69%)	364 (76%)	267 (73%)
		Number			249 (55%)		265 (73%)
		After Dash			247 (55%)		240 (66%)
	Description	Description	505	471 (93%)	455 (97%)	379 (75%)	374 (99%)
Traffic Signs (Overhead)	MUTCD Code	Letter	60	42 (70%)	13 (31%)	45 (75%)	14 (31%)
		Number	60		4 (10%)		13 (29%)
		After Dash	60		2 (5%)		8 (18%)
	Description	Description	85	56 (66%)	56 (100%)	58 (68%)	50 (86%)
Vertical Curve	Sag/Crest	Sag	9	8 (89%)	No Data	9 (100%)	9 (100%)
		Crest	7	6 (86%)	No Data	7 (100%)	6 (86%)

Note: Percentages are based on how well the vendor identified the feature once it has been matched.
[1] "Total Research Samples" for "Pavement Words and Symbols" sum to the research sample by vendor in Table 5

4.3. Asset Condition

Another key consideration with respect to roadway assets is the condition. Condition of assets is especially important to those in traffic safety and maintenance because assets in need of repair and not working as intended could lead to serious hazards or even litigation in extreme circumstances. Vendors were asked to provide information related to condition for each of the 28 features in one direction of travel. Vendor questions prior to the first sample data submission primarily revolved around definitions of condition within the identified landscape areas and collection of raised pavement markers. Following feedback in late 2011 and early 2012, other questions arose with regards to other qualitative data types such as brush and tree and turf. Following all discussions, updates were made to the catalog and the team redistributed the revised catalog to both vendors accordingly.

Table 8 shows the findings with regard to asset condition. This table should be read in the same manner as Table 5, Table 6, and Table 7. For feature descriptions with "Field Inspection Required", the specific requirements are provided in the catalog in Appendix B. Looking at pavement marking and striping provides a good example. Here, a sample of 324 (17 requiring inspection +307 not requiring inspection) total pavement marking features was included in the research sample for analysis of asset condition. Pathways and Fugro correctly *located* the condition samples needing a field inspection 0% (0/17) and 100% (17/17) of the time, respectively, while correctly *locating* attenuators not needing inspection 58% (179/307) and 100% (307/307) of the time, respectively. Of the pavement markings needing inspection that were correctly located, Pathways was not analyzed (N/A) because the sample of correctly located markings was zero for this category, while Fugro correctly identified the *condition* as needing inspection 35% (6/17) of the time. Of the pavement markings not needing inspection that were correctly located, Pathways and Fugro identified the *condition* 92% (164/179) and 85% (262/307) of the time, respectively. Since minimum sample size requirements were met only for "No Field Inspection Required", Pathways location matches for this pavement marking feature was highlighted with only a 58% match.

In summary, with regards to correctly *locating* features by condition, only paved shoulders and drop inlets were somewhat problematic for both vendors. The research team suspects that paved shoulder identification, by its current definition, is hard to capture because of the rigid definition of four foot of asphalt required. Drop inlets, discussed previously, are hard to capture due occlusion and offset distance from the vehicle, especially those in the median. With regards to correctly identifying the *condition* of the correctly located features, both vendors were fairly accurate with the exception of raised pavement markings. Other condition assessment issues were exclusive to the vendor and likely involved definition errors or qualitative features that were not easily defined (such as slope).

Table 8 Condition analysis.

Feature	Feature Desciption	Condition	Total Research Sample[1]	Pathways		Fugro	
				Location Matches	Condition Matches	Location Matches	Condition Matches
Brush & Tree	Field Inspection Required	Yes	1	1 (100%)	1 (100%)	0 (0%)	N/A
		No	98	69 (70%)	66 (96%)	88 (90%)	72 (82%)
Concrete Barrier	Field Inspection Required	Yes	0	N/A	N/A	N/A	N/A
		No	25	23 (92%)	21 (91%)	21 (84%)	20 (95%)
Curb & Gutter	Field Inspection Required	Yes	5	3 (60%)	1 (33%)	4 (80%)	3 (75%)
		No	76	55 (72%)	51 (93%)	56 (74%)	47 (84%)
Guardrail	Field Inspection Required	Yes	4	4 (100%)	4 (100%)	4 (100%)	0 (0%)
		No	16	16 (100%)	13 (81%)	15 (94%)	13 (87%)
Paved Shoulder	Field Inspection Required	Yes	21	12 (57%)	5 (42%)	20 (95%)	12 (60%)
		No	27	11 (41%)	7 (64%)	15 (56%)	12 (80%)
Pavement	Field Inspection Required	Yes	21	20 (95%)	11 (55%)	19 (90%)	15 (79%)
		No	0	N/A	N/A	N/A	N/A
Retaining Wall	Field Inspection Required	Yes	1	1 (100%)	0 (0%)	N/A	N/A
		No	3	3 (100%)	3 (100%)	3 (100%)	3 (100%)
Slope	Field Inspection Required	Yes	26	23 (88%)	20 (87%)	23 (88%)	16 (70%)
		No	2	2 (100%)	0 (0%)	2 (100%)	1 (50%)
Unpaved Shoulder	Field Inspection Required	Yes	32	31 (97%)	31 (100%)	31 (97%)	31 (100%)
		No	36	32 (89%)	2 (6%)	35 (97%)	0 (0%)
Turf	Field Inspection Required	Yes	20	19 (95%)	17 (89%)	17 (85%)	17 (100%)
		No	0*	N/A	N/A	N/A	N/A
Attenuator/ End Treatment	Field Inspection Required	Yes	7	6 (86%)	4 (67%)	6 (86%)	4 (67%)
		No	31	29 (94%)	28 (97%)	27 (87%)	26 (96%)
Inlet	Field Inspection Required	Yes	21	16 (76%)	10 (63%)	15 (71%)	8 (53%)
		No	172	138 (80%)	125 (91%)	131 (76%)	129 (98%)
Landscape Area	Bed Quality	Plant Quality	10	9 (90%)	9 (100%)	4 (40%)	4 (100%)
		Mulch Quality	10		0 (0%)		4 (100%)
		Undesirable Vegetation	10		8 (89%)		3 (75%)
		Pruning	10		7 (78%)		4 (100%)
	Field Inspection Required	Yes	1	1 (100%)	0 (0%)	0 (0%)	N/A
		No	9	8 (89%)	8 (100%)	4 (44%)	2 (50%)
Raised Pavement Marker (RPMs)	Count	Within 2 RPMs	63	59 (94%)	45 (76%)	60 (95%)	40 (67%)
	Field Inspection Required	Missing or damaged RPM	63	59 (94%)	52 (88%)	60 (95%)	59 (98%)
		Not Needed	0	N/A	N/A	N/A	N/A
Pavement Marking/Striping	Field Inspection Required	Yes	17	0 (0%)	N/A	17 (100%)	6 (35%)
		No	307	179 (58%)	164 (92%)	307 (100%)	262 (85%)
Pavement Word/Symbol	Field Inspection Required[2]	Yes	4/25	4 (100%)	4 (100%)	25 (100%)	13 (52%)
		No	3/203	3 (100%)	2 (67%)	196 (97%)	176 (90%)

Note: Asset type percentages are based on how well the vendor accurately identified the feature once it was matched and not the total research sample.

[1] *"Total Research Samples" for "Pavement Words and Symbols" sum to the research sample by vendor in the "Location" Table 5*

[2] *Pathways reported pavement words and symbols in the right-most lane only.*

4.4. Asset Measurement

How well a vendor can accurately measure key pieces of information related to a feature can be very important to DOTs. This section looks at two key pieces of information related to measurement. First, features that have measurements related to height, width, offset (from edge line), radius, grade, and/or azimuth are analyzed using tolerances to see how well they can replicate manually collected data. Second, features that have measurement of length are analyzed to see how well they can replicate linear feature measurements. The sections below present the findings.

4.4.1. Measurement Analysis using Tolerance

Certain elements such as concrete barriers, attenuators, and roadway lanes provide the opportunity to collect descriptive data such as height, width, or offset from the outside the pavement edge. Other elements such as roadway centerline and horizontal curves provide the opportunity to collect data related to grade, azimuth, or radius of curve. This section utilizes tolerances for each key feature based on past research efforts and discussions with NCDOT personnel to analyze how well vendors are able to replicate measurements.

Table 9 provides the tolerances utilized along with the measurement findings for each of 10 applicable features. The table provides a feature, its description, the tolerance used for measurement matching, and the sample and percent matched within the given tolerance for that feature description.

Table 9 Analysis of measurements tolerance threshold.

Feature	Feature Description	Tolerance	Pathways Measurement Matches	Fugro Measurement Matches
Concrete Barrier	Offset	± 2 ft.	55 (60%)	22 (27%)
	Height	± 6 in.	17 (88%)	15 (47%)
Guardrail	Offset	± 2 ft.	60 (47%)	55 (27%)
	Height	± 6 in.	43 (100%)	41 (85%)
Lateral Ditch	Offset	± 2 ft.	98 (18%)	79 (14%)
Median[1]	Width	± 2 ft.	61 *	59 *
Paved Shoulder	Width	± 2 ft.	11 (73%)	45 (84%)
Unpaved Shoulders	Width	± 2 ft.	54 (69%)	41 (59%)
Attenuator	Offset	± 2 ft.	35 (46%)	33 (45%)
	Height	± 6 in.	35 (97%)	33 (76%)
Centerline	Grade	± 1%	239 (76%)	230 (92%)
	Azimuth	± 5°	630 (100%)	669 (97%)
Horizontal Curve[2]	Radius	± 1LG	20 (90%)	20 (95%)
Roadway Lane	Width	± 2 ft.	166 (73%)	166 (79%)

[1] *Catalog did not specify the exact location to measure the width of the median thereby making the comparison unfeasible (see *).*

[2] *"LG" refers to "letter grade" as defined by the HPMS.*

For example, attenuator measurements were analyzed using offset from the outside roadway lane along with the measured height. Tolerances of ±2 feet and ±6 inches were used for offset and height, respectively. Looking at offset distance of correctly located attenuators from the outside travel lane, Pathways and Fugro were within a two-foot tolerance for 46% and 45% of the measurements, respectively. With regards to height, Pathways and Fugro were within a six-inch tolerance for 97% and 76% of the measurements, respectively. Since sufficient samples were present, 3 of the 4 findings were below the 80% threshold requiring them to be highlighted.

Summarizing, measurements with specified tolerances tend to be problematic when vendors have to take measurement perpendicular to the roadway. For the features described in this report, these are measurements associated with offset and width. Measurement of features related to height was typically only a problem for one vendor, which indicates this is likely an error on the part of that specific vendor. Supplemental measurements such as grade, azimuth, and radius of curve were very promising.

4.4.1. Measurement Analysis using Length

Other less discrete measurements exist that require a different method of analysis. For instance, features that require a measurement of length are not practical to measure with tolerance thresholds because the lengths vary significantly from link to link. In lieu of this problem, the team decided to analyze all features with length measurements using the difference of the weighted averages. Weighted averages allow the linear segments to be analyzed on a similar plane. Just using average of the percent differences would mean that differences in length for shorter segments would bias the data set negatively, and vice versa for longer segments. The equation used for the weighted average of the difference between research (RL) and vendor (VL) segment lengths is as follows:

$$\text{Percent Difference} = \sum_{k=1}^{n} \frac{|RL_k - VL_k|}{RL_k}$$

Table 10 provides the analysis of measurements with regards to length. Total measurement matches with samples that exceeded 20 and exceeded a percent difference of 20% were highlighted to show where larger differences exist. For illustrative purposes we will consider guardrail. Of the guardrails that were correctly located by each vendor, Pathways and Fugro measured guardrails accurately within 35% and 7%, respectively. Since meaningful samples exist for each vendor, Pathways was highlighted to show excessive variation from the actual mean lengths.

In summary, vendors struggled to get measurements of length correctly identified for about half of the eleven features studied. The findings were generally within 25 to 30 percent, with the exception of lateral ditch. The primary reason for these larger differences likely stems from the qualitative aspects of collecting many of these linear features. For instance, where does lateral ditch begin and end, assuming one even identified it correctly? Locating the beginning and end of horizontal curves is difficult even with a careful manual data collection effort. Last, although measurement of length of segments obviously posed some challenges to the vendors, they were typically within 20 to 30%. These findings were still better than the offset and width findings from the previous section.

Table 10 Analysis of measurements length

Feature	Pathways		Fugro	
	n	% diff.	n	% diff.
Brush & Tree	70	22%	88	12%
Concrete Barrier	23	5%	21	3%
Curb & Gutter	72	29%	73	27%
Guardrail	69	25%	67	7%
Lateral Ditch	110	94%	102	95%
Median	71	2%	74	4%
Paved Shoulder	41	25%	58	26%
Retaining Wall	4	7%	3	2%
Rumble Strip	14	29%	13	20%
Slope	25	26%	25	21%
Turf	19	228%	17	390%
Horizontal Curve	20	53%	20	64%

*"% diff" is the absolute value of the difference between vendor and research segment lengths, expressed as a percent

4.5. Accuracy of Measurements

For many features studied under this project, accurate location of features in the field is critical to traffic maintenance and operations activities. This section looks at thirteen point features exclusively and determines the accuracy at which both vendors were able to locate these point features. Table 11 provides the samples for each vendor that were correctly identified (i.e., points must be found to determine the accuracy at which they were collected), along with the average distance between points and the standard deviation.

Drop inlets provide a good example for illustrative purposes. The samples of correctly located drop inlets for Pathways and Fugro was 383 and 364, respectively. Of these correctly located points, Pathways and Fugro were able to locate the point feature within 39.3 feet (± 32.6 feet) and 9.1 feet (± 17.6 feet), respectively. Examining the actual GIS inputs, the primary difference for these large differences was that Pathways did not geo-locate the points, but instead located their points relative to the position of the van in the right-most lane. The large majority of the difference provided is actually in the lateral direction to the point, whereas the distance in the direction of travel is null. However, from a maintenance standpoint, the additional information provided by the vendor related to asset type (right side or median) would help find the correct drop inlet. It should be noted that several of the data items collected were not direct point features, but instead may have been linear features denoted by a point (i.e. horizontal curve) or short linear sections denoted by a point (i.e. raised pavement markers collected over 100' sections). These have special footnotes to denote these differences.

Given the human error associated with physically locating point features and the fact that many of the feature locations are not associated with a physical point on the ground, it appears that the accuracy by which vendors locate point features is reasonable. From the standpoint of maintenance personnel, features should be easy to locate. If similar points are located in close proximity, other information such as asset type could be used to help identify where a maintenance issue exists. From the standpoint of design and operations, some additional specificity may be needed. For instance, detailed location of drop inlets may be important to trace those utilities underground. If that is the case, specifics should be given in the catalog to make sure that points are geo-located with enough precision.

Table 11 Accuracy of measurements

Feature	Pathways			Fugro		
	Research Matched	Average (ft)	Standard Deviation (ft)	Research Matched	Average (ft)	Standard Deviation (ft)
Access Point[1]	168	38.0	33.3	139	43.8	54.6
Attenuator	85	30.3	10.7	82	6.1	4.2
Bridge[1]	17	35.0	15.6	17	29.0	7.6
Horizontal Curve[1]	20	840.1	331.4	20	253.5	212.4
Inlet	383	39.3	32.6	364	9.1	17.6
Landscape Area[1]	10	438.4	244.7	4	75.0	63.3
Median Opening[1]	50	59.3	21.7	21	30.7	28.0
Roadway Lane[2]	125	79.7	109.7	150	36.7	39.7
Raised Pavement Marker[2]	59	135.9	74.6	60	136.3	73.7
Pavement Marking/Striping	325	39.3	8.8	325	34.2	13.8
Pavement Word/Symbol	53	11.1	10.6	406	7.6	7.4
Traffic Signs - Ground	477	29.2	18.7	382	18.3	17.4
Traffic Signs - Overhead	56	33.8	29.3	55	45.8	28.7

[1] Asset features are located in the area of the feature. For instance vendors may locate the bridge at the first crossing point; whereas, research team members locate the bridge in the center of two structures.
[2] Asset features are located along short segments of 100' or 1/10th of a mile, which points could vary while driving the course route.

4.6. Impacts of Communication

The research team's review of a sample set of data prior to the final deliverable from the vendor led to several clarifications among definitions and requested data elements. This interim evaluation demonstrates the potential for data improvements when vendors are given the opportunity to receive constructive feedback to reduce further errors on a larger dataset. The following list illustrates some of the misinterpretations of information in the catalog or lack of specificity that created differences between vendor and research data. Most of the changes are noted in red in the catalog located in Appendix B:

- **Access points:** Clarified that all access points (including ingress and egress locations) should be included. Typical locations that were missed in the initial data submission included on and off ramps to interstate facilities and the inclusion of each driveway when multiple driveways existed at a business.
- **Brush and tree:** Clarified the intention of the brush and tree element where all brush and trees maintained by the DOT should be included. However, this intention is difficult to define because right of way widths vary along arterial streets. Therefore, a distance of 50' of the edge of the roadway was decided upon as a threshold for identifying any brush or trees. This observation also applies to the slope data element.
- **Concrete barrier**: Clarified that all occurrences of concrete barrier should be collected individually, even when they are part of a larger element, such as a bridge. This observation also applies to the retaining wall data element.
- **Curb and gutter:** Clarified that any linear element should be split when disrupted by other elements. For instance, when a curb and gutter is terminated because of an access point, the linear display in GIS should also terminate and restart at the other side of the access point, if applicable. This observation applies to other linear elements as well, such as turf.
- **Paved shoulder:** Clarified that due to the threshold condition of 4' of width for paved vs. unpaved shoulders, a shoulder should be identified as paved for any widths greater than 1', so that a comparison can be made to manual data collection. For instance, if a manual measurement of 48" was compared to a vendor measurement of 46", a different category would be selected, paved shoulder versus unpaved shoulder, respectively. However, for all practical intents and purposes, the vendor submission represents a fairly accurate measurement compared to the manual measurement.

5. FINDINGS & CONCLUSIONS

The specific aims for this project were to provide NCDOT with evidence on the viability of automated data collection vehicles in comparison to human collection methods to gather inventory data efficiently, accurately, and reliably. Previous studies to compare manual to mobile inventory data collection did not allow the researchers to interact with the individual vendors directly to calibrate the data collection equipment, because the team had to treat multiple vendors in an unbiased manner. While this restriction was necessary for the intended comparison of different vendors, it also contributed to some miscommunication and confusion. For this particular effort, the approach shifted away from a performance comparison amongst multiple vendors to a more targeted comparison of a vendor's "best effort" to manually collected data. This approach focused on better calibrated automated data collection that more accurately replicated an actual deployment of vehicle-based technology.

This research project evaluated the potential of two mobile asset data collection vendors to collect location and feature attributes of 28 roadway and roadside assets. A test track 30.7 miles in length was utilized along with five ramp terminal facilities which required specific data be collected outside the test track. Although research in this area has been done before, most recently in the 2008 Asset Expo *(22)*, this project evaluated the potential of vendors with the additional provision of information through a feedback loop where sample data were generated by the vendors prior to submitting the full data set. Generally speaking, the majority of the 28 features had promising results, although there is still room for improvement in the data collection catalog provided and in additional correspondence and samples to more accurately collect the necessary data. This research confirms the critical importance of open communication, well-defined attributes, preliminary and/or intermediate feedback, and clear expectations. More detailed summary findings are provided below.

The foundation for any asset data collection program is physically *locating the attribute*. One or both vendors were successful in locating the vast majority of features. Although a small subset of certain assets were problems for *individual vendors*, the fact that one of the vendors was able to accurately locate the asset shows there is potential for success along with room for improvement. In total, only two features were troublesome for both vendors: drop inlets and paved shoulders. Even before the project started, research team members and NCDOT personnel noted that these two attributes may be problematic due to line-of-sight and occlusion issues with locating drop inlets and the strict definition associated with paved versus unpaved shoulders. Future efforts to collect paved and unpaved shoulders should consider collecting all paved shoulders above one foot in width. In addition, DOTs should consider collecting paved and unpaved shoulders together since the associated attributes are the same. As for drop inlets, occlusion from vehicles or other line of sight issues are not as easily remedied. Engineers needing more detailed information may need to collect this dataset manually. However, the results from this project should be representative of other similar roadway types.

Once assets are actually located, detailed analysis of *asset type* and *condition* were completed. The general findings of this analysis are provided below:

- **Linear Asset Type:** In general, if the linear asset was located correctly, asset types were described accurately. Location of the asset was located and matched with a high level of accuracy by both vendors; in fact, the only asset where location by asset type was an issue was the asphalt paved shoulder. We suspect the old definition that required vendors to delineate the four-foot requirement from paved to unpaved shoulder was the culprit and believe that the modifications to the catalog will alleviate many of these issues. Only one other location of asset type was problematic for a single vendor. This was brush and tree along the right side of the road. The right-of-way requirement made this asset hard to distinguish. The team has modified the catalog for future efforts to include brush and tree within fifty feet of the outside edge of pavement.

- **Point Asset Type:** Compared to linear asset type, point asset type was much more difficult for vendors to locate and describe correctly. Several asset location and asset types were difficult for a single vendor, meaning there was still room for improvement since one vendor was successful. However, there were two assets on which both vendors struggled with regards to asset type. First, drop inlets were difficult to locate in the median; however, those that were located were described with a high level of accuracy. Second, vendors had difficulty collecting some categorical data on traffic signs. For ground mounted signs, the primary issue was not locating the sign, but instead the MUTCD sign designation code. However, for overhead signs, there were some location issues in addition to the MUTCD sign designation code.

- **Condition:** Several location and condition assessments were problematic for a single vendor, meaning there was still room for improvement since one of the vendors was successful. However, two assets were difficult to locate; drop inlets and paved shoulders. This problem was described previously. With regards to condition, only two assets stood out as problematic for both vendors: count of visible raised pavement markers and unpaved shoulder with no inspection required. There did appear to be other notable assets that vendors appear to struggle collecting the *condition*; however, they were not highlighted due to low sample sizes. These include paved shoulder inspections, attenuators, and drop inlets needing inspection.

An analysis of asset *measurements* indicates that vendors are able to provide much better measurement accuracy for height compared to offset or width. The team suspects that the further the asset is away from the data collection van, and the flatter the measurement (parallel to the roadway), the harder it is to capture its true measurement. Measurement of grade, azimuth, and curve radius were well within tolerances, with the exception of one vendor collecting grades. With regards to measurements of length, there were some issues with the comparison of lengths; however, this was expected since most of the measurement beginning and end points were based on human perception. Even so, the vast majority were within 30% of the research team's field measurement, with horizontal curve and lateral ditch lengths well outside this tolerance.

Last, the *accuracy* of data related to point features was analyzed. Based on the type of point feature (some were collected over a short segment, 1/10th mile or 100'), results were very reasonable and should not cause problems for maintenance, operations, safety, or design engineers trying to identify features. The primary reason for error between manual and vendor collected data was the location of the actual point. For instance, some specific point features, such as drop inlets or attenuators, were provided from the vendors vehicle position; therefore, the majority of the error was lateral and not in the direction of travel. Other error was more prominent when it was an asset collected over a specified length, such as landscape areas or horizontal curves. The point defined by vendors could be drastically different from that of the research team. In short, unless there is a desire for engineers and planners to identify very specific point data, the accuracy is sufficient to find the location in the field, especially with supplemental data attributes such as location on the median or right hand side of the road. If more detailed information is needed for a specific attribute, it should be possible to acquire that with detailed instructions to geo-locate that asset feature, else it could be collected manually by DOT personnel.

Finally, in retrospect, the authors believe it would be advisable for agencies and vendors to collect linear features using a continuous segment. Using turf for illustrative purposes, the research teams' original instructions asked that vendors collect turf until an access point or median open compromises the segment, at which time the segment would end and start back up on the other side of the access point or median opening. The only other reason to stop the linear segment was if a poor segment of turf was identified, at which time the good turf segment would end and a new turf segment would start identifying that section as "needing inspection." Once the bad turf was identified, that section would end followed by another segment of good turf. Two problems arose using this method. First, vendors tend to put a point at the beginning of each turf segment where good and bad turf condition are present (i.e. "needing inspection") instead of a line over the entire segment. For visual purposes, our team recommends a line be utilized. Second, and more importantly, the team now recommends that a continuous segment of turf be provided for inventories regardless of inspection need, and only stop where an access point or median opening are present. If a section of poor turf was identified, this section should be given with a separate linear segment to allow the feature to be erased after maintenance crews have "inspected" the poor turf area. In this way, the inventory of turf is not compromised.

Differences between data collected manually and by vendor were noted in each of the analyses completed by the research team. For summary purposes, the differences can be explained by a few possible scenarios:

- <u>Qualitative Features:</u> Even with a detailed catalog, some features rely on trained observers to consistently and accurately record the asset based on the qualitative nature of the element. These elements could be collected differently based on who is collecting the data, but extensive training and clear definitions with visual examples can alleviate some error. Features that fall into this category are 1) brush and tree and 2) paved and unpaved shoulders. *Example: The threshold between considering a shoulder paved or unpaved is 4 feet of width; the transition of this is hard to measure accurately. Brush and tree elements which seek to identify all features within 50 feet of the edge of travel-way while determining instances of sight distance encroachment are also difficult to consistently report. This is evident by the asset type analysis where nearly all median brush and tree were found (82-98%), while brush and tree on the right side of the road were less successful (62-82%).*

- Feature Definitions: In some cases, the definition can cause confusion or be open to interpretation through the omission of key details. In this study, example features affected could include 1) access points and 2) traffic signs. *Example: Access points include private or business driveways and public streets. One of these items could easily be misinterpreted or forgotten during data collection. In addition, multiple openings to a location would need to be counted separately. Another example is traffic signs. Overhead traffic signs must be on a rigid structure, mounted horizontally. Signs on span wire or mounted on the vertical base of a rigid structure would be classified as ground mounted. The differences, although defined in the catalog, can easily be forgotten.*
- Visual Occlusions: When using vehicles to collect asset data, it is imperative to have a visual line of sight between the vehicle and the object of interest. If the line of sight is compromised due to vegetation, vehicles, or other obstructions, the element is unlikely to be accurately or consistently collected. Features that typically fall into this category are 1) drop inlets, 2) curb and gutter, 3) traffic signs, and 4) pavement words and symbols. *Example:* Curb and gutter location was defined by the median and right side of the road. Curb and gutter in the median was found *37% to 43% of the time versus 91% to 92% along the right side of the road.*
- Vendor Bias: Vendors with multiple clients, who might have conflicting definitions of elements, have a difficult task of delivering similar products while maintaining inconsistent definitions or standards from multiple vendors. These conflicting definitions or standards can create a bias when the observer incorrectly utilizes another client's definition. It is always a good idea to check with the vendor on their current internal definitions to see if those can be utilized for your agency's purposes.
- Human Error: The involvement of human observers in an activity will inevitably lead to some errors even after careful and thorough training and documentation. Therefore, 100% accuracy throughout all data elements is unlikely to be achieved at a reasonable cost and level of effort to be affordable for asset management.

6. OPPORTUNITIES FOR FUTURE RESEARCH

Findings from this study could be supplemented by research that provides a feedback loop through several iterations, each iteration evaluating a large sample of each attribute over the entire course. Although much was learned in this initial effort on the feedback loop and improvements that were made by the vendor and research team (via catalog improvements), available funding and time did not allow for more improvements. Second, a similar study using a third party to analyze vendor and manually collected data (much of the manual data was collected by the research team) could be advisable. The research team was very careful to make sure that analysis of vendor data did not overstate where problems existed and always tried to give the benefit-of-the-doubt. Last but not least, no vendors collected data on sign retroreflectivity, a very important asset that will be important for sign inventory and assessments required by the FHWA in the very near future. In preparation for this requirement, private contractors are developing tools that could be very useful to NCDOT in conducting sign inventory and retroreflectivity (see Section 2.2.4, Figure 6). Many of these vendors also have the ability to collect other attributes similar to that collected in this effort.

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1. APPENDICES

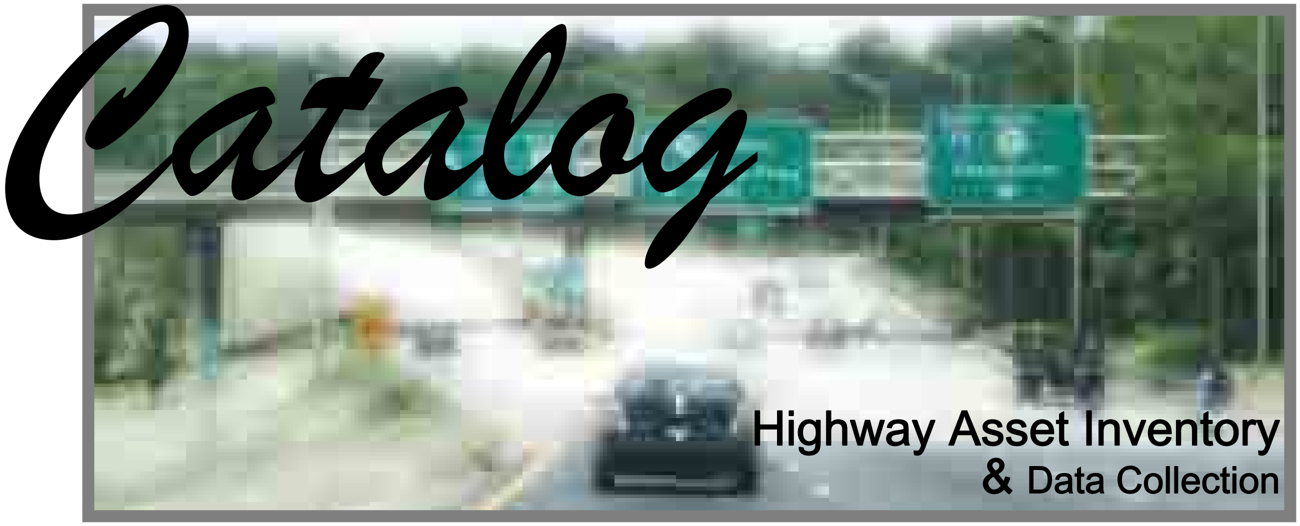
1.1. Appendix A: Vendor Qualifications

Category	Data Collection Element	Element Properties	Y/N/Maybe	Explanation of "Maybes"
Signs	*Signs*	Point Location (Lat and Long)		
		Number of Signs per Post		
		Type (MUTCD Code)		
		Quality (Poor, Fair, Good, New, Damage)		
		Measurements (Height, Width)		
		Retroreflectivity		
Pavement Markings	*Lane Striping*	Point Location (Lat and Long)		
		Color		
		Width		
		Material Type (Paint, Thermoplastic, Polyurea)		
		Quality (General, % present)		
		Retroreflectivity		
	Special Markings (NOT lane striping)	Point Location (Lat and Long)		
		Material Type (Paint, Thermoplastic, Polyurea)		
		Type (Left/Right Turn Arrows, Railroad Crossings, School, etc.)		
		Quality (General, % present)		
		Retroreflectivity		
	Raised Pavement Markings	Starting/Endings Points		
		Type (Stick-on, Snowplowable)		
		Functional		
		Retroreflectivity		
Road Geometry	*Centerline*	Point/Line Location (Lat and Long)		
		Direction *(Bearing or azimuth)*		
		Grades		
	Veritcal Curve	Starting/Ending Points		
		Length		
	Horizontal Curve	Starting/Ending Points		
		Curve Length		
		Curve Radius		
		Maximum Cross Slope Encountered		
	Lanes	Location		
		Number		
		Width		
	Intersections	Location		
		Number of Approaches in Travel Direction		
		Configuration *(Skew angle)*		

Category	Data Collection Element	Element Properties	Y/N/Maybe	Explanation of "Maybes"
Roadside	*Shoulder*	Location		
		Type (Paved, Gravel, Earth, Composite)		
		Width		
		Condition (High, Normal, Low)		
	Rumble Strip	Starting/Ending Points		
		Type (Milled or Thermo)		
	Barrier	Location - Begin and End Points (Lat and Long)		
		Type (W-Beam, Cable, Concrete, Other)		
		Offset		
		Condition (Functioning, Non-Functioning)		
		Height		
	Attenuators	Point Location (Lat and Long)		
		Type (End Treatment, Attenuator)		
		Condition (Functioning, Non-Functioning)		
	Curb	Location - Begin and End Points (Lat and Long)		
		Identify Gutter Blockage and Damage		
		Type (Vertical, Sloping, Other)		
	Drop Inlet	Point Location (Lat and Long)		
		Identify Blockage and Damage		
	Driveways	Point Location (Lat and Long, *where radius of driveway starts*)		
	Median Openings	Point Location (Lat and Long, *include: Emergency crossovers on freeways not open to public and crossovers serving private and unsignalized access points. DO NOT Include: Openings that serve intersections with public streets.*)		
	Median	Location - Begin and End Points (Lat and Long) (*avoid transition areas: tapers, etc.*)		
		Width		
		Type (Grass, Raised Concrete, Jersey Barrier)		
	Ditches (Unpaved)	Location - Begin and End Points (Lat and Long)		
		Type (Turf, Rip Rap)		
		Condition *(Blockage, Erosion Depth where occuring)*		
	Ditches (Paved)	Location - Begin and End Points (Lat and Long)		
		Type (Concrete, Other)		
		Condition *(Joint Separation, Misalignment, Undermining where occuring)*		
	Brush and Trees	Location - Begin and End Points by Inventory and Performance Criteria (Lat and Long)		
		Condition *(Sight Restrictions, "Brown-Out" where occuring)*		
	Turf Condition	Location - Begin and End Points by Inventory and Performance Criteria (Lat and Long)		
		Condition *("Brown-Out" where occuring)*		
	Slope	Location - Begin and End Points by Inventory and Performance Criteria (Lat and Long)		
		Condition *(Stability)*		

Category	Data Collection Element	Element Properties	Y/N/Maybe	Explanation of "Maybes"
Pavement Condition	*Asphalt*	Cracking (Alligator/Fatigue, Transverse, Block, Edge, Longitudinal, Reflection)		
		Raveling		
		Oxidation		
		Bleeding		
		Patching		
		Ride Quality *(Roughness)*		
		Potholes		
		Rutting		
		Texture		
		Friction		
		Shoving		
		Polished Aggregate		
		Lane-to-Shoulder Drop-off		
		Water Bleeding and Pumping		
	General Concrete	Shoulder Condition		
		Surface Wear		
		Pumping		
		Ride Quality		
		Texture		
		Friction		
		Roughness		
	Jointed Concrete Pavement (JCP)	Patches		
		Cracking (Longitudinal, Transverse, Corner, Durability, Map)		
		Spalling		
		Joint Seal Damage		
		Lane-Joint Seal Damage		
		Faulting of Transverse Joints		
		Drop-Off		
		Scaling		
		Polished Aggregate		
		Blow up		
		Lane-to-shoulder Separation		
		Transverse Construction Joint Deterioration		
		Surface Wear *(Water Bleeding)*		
		Pumping		
	Continuously Reinforced Concrete Pavement (CRCP)	Patches		
		Cracking (Longitudinal, Transverse, Narrow Cracks, 'Y' Cracks, Durability, Map)		
		Punchouts		
		Drop-off		
		Lane-Joint Seal Damage		
		Scaling		
		Polished Aggregate		
		Blow Up		
		Lane-to-Shoulder Separation		
		Lane-to-Shoulder Drop Off		
		Transverse Construction Joint Deterioration		
		Spalling of Longitudinal Joint		
		Surface Wear *(Water Bleeding)*		
		Pumping		

1.2. Appendix B: Data Collection Catalog (updates shown in red)



Welcome to the 2011 Highway Asset Inventory and Data Collection test track. We thank you for your participation in this exciting project. We hope you are eager to take this opportunity to showcase the services your company has to offer. As you are already aware, the research team has identified a 26-mile course in Charlotte, North Carolina. This course covers various roadway types and should prove to be a quality test track for comparing your data to manually-collected data.

This catalog provides information related to roadside appurtenance data collection, as well as specific points of contact, general information, driving directions, data collection sheets, and supplemental information on how to collect certain types of data. If at any time you have questions about some part of this process, please feel free to call the appropriate contact person.

TABLE OF CONTENTS

General Information

The purpose of this document is to make sure that you, the project data collection participants in the pavement and roadside areas, have all the information you need to provide data which represents the best possible look at the capabilities of your equipment. Project staff members are striving to ensure that this exercise is as fair and productive as possible. If there is anything that you need from the project staff during data collection, during post-processing, or leading up to the project itself that would help us all achieve our objectives, please ask.

Project Contacts. This catalog contains a list of project team contacts at NCSU/ITRE. All questions regarding the project should be directed to an NCSU/ITRE team member.

Driving Directions. Driving directions along the Project Route are found the following pages of this catalog. The project route begins just off of I-485, Exit 16: Brookshire Boulevard/NC 16 South in Charlotte, NC. For data consistency purposes, please follow these directions as precisely as possible. Please note that the project team will not be analyzing data collected in transition areas and lane changes, so make your transitions and lane changes as safely as possible without worrying about data collection at those spots. In addition, you should not collect data in any roadway work zones you may encounter.

Post Data Collection. After driving the course, we ask that you call your designated project staff person for a quick debrief. We would like to know that you finished the course successfully and whether you encountered problems. Also call this staff person in the event that weather or some other circumstance interrupts your drive of the course.

Data Submission & Acknowledgement of NCDOT Data Ownership. Detailed data submission is included on Page 80 of the Catalog. Additionally, we ask for acknowledgement that the NCDOT will become the owner of the data that you submit to the Project. Please complete and return the form found on Page 179 of the Catalog.

Thank you for participating in this project!

NCSU/ITRE Project Contacts

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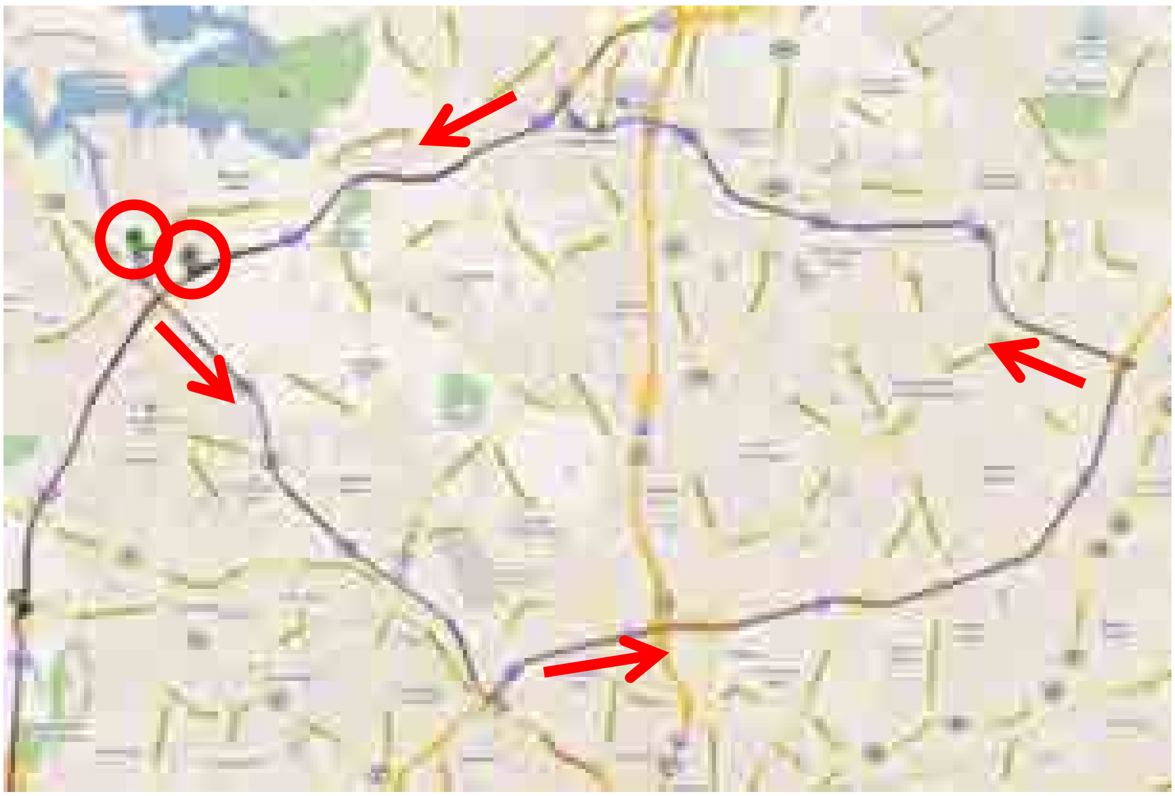
Data Collection: Part I & II

A 2-part tour of the course will be required for data collection.

Part I: Full Route Data Collection. During Part I, data collection will only take place on roadways in a single direction, and not ramps.

- The project route Part I begins just off of I-485, Exit 16: Brookshire Boulevard/NC 16 South. We advise going NB on Brookshire to the nearby Walmart Supercenter (Map 1: Location A). Any calibration of equipment can be done here just prior to starting the actual course.



Map 1: Overview of Data Collection Course in Charlotte, NC

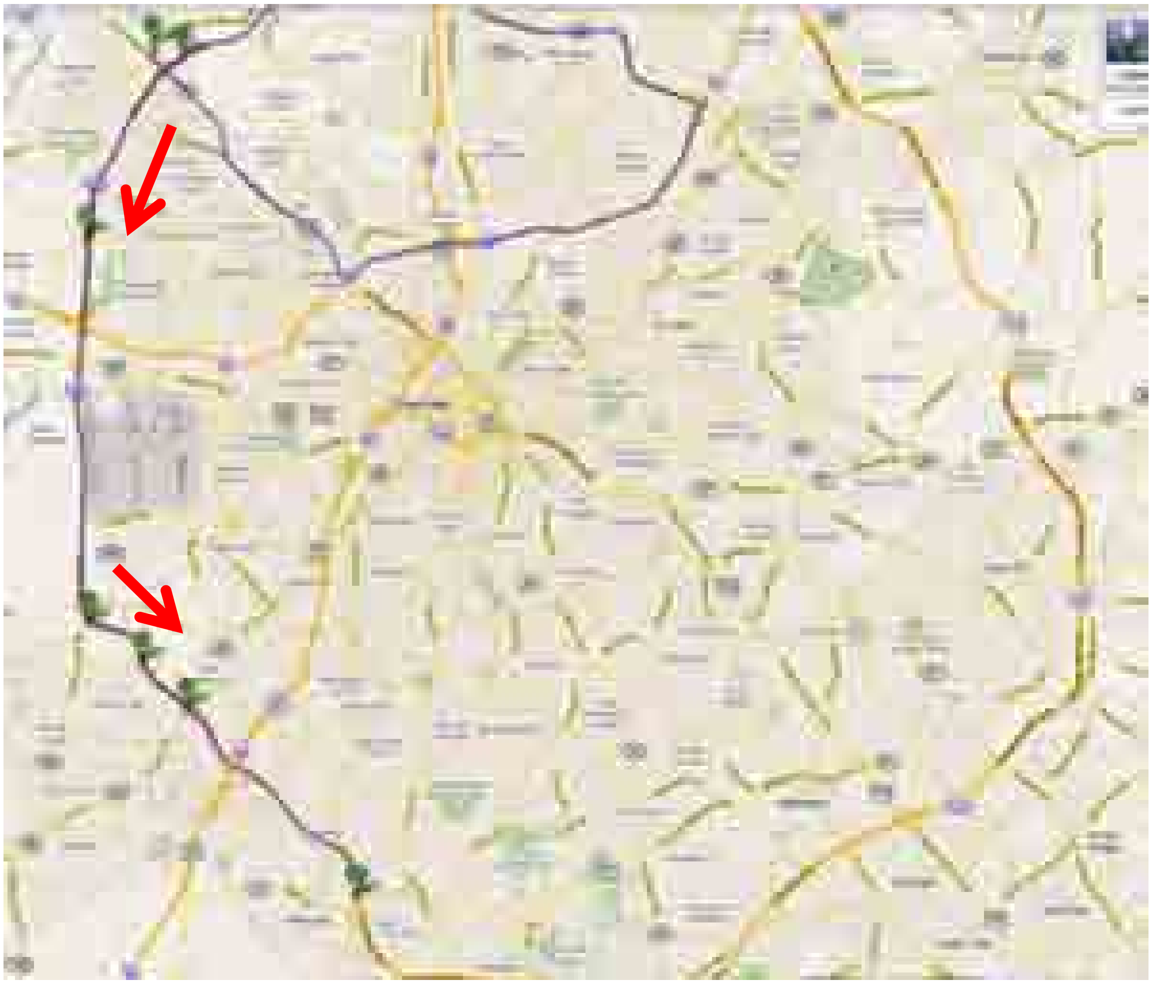
- When the vendor is ready, head SB on Brookshire Boulevard/NC 16. You will be driving the course in a counter-clockwise direction (see arrows). Begin data collection at the stopbar of the first signal just North of the I-485 overpass. This is Project Route Part I Milepost 0.00. Map 2 shows the location of this stop bar with a red arrow indication.

Map 2: Starting Point (Milepost 0.00) at I-485 and Brookshire Blvd./NC 16.

- Travel along Brookshire Boulevard/NC 16 South for 5.7 miles.
- Turn left to exit onto I-85 North. Take I-85 North for 8.3 miles.
- At Exit 45B, merge onto W.T. Harris Boulevard/NC 24 West. Take W.T. Harris Boulevard/NC 24 West for 7.4 miles, past North Lake Mall (on the right) and continue on W.T. Harris Boulevard/NC 24 to the exit ramp for Outer I-485/South I-485.
- Take the ramp onto Outer I-485/South I-485. Travel along I-485 for 4.9 Miles to Exit 16, Brookshire Boulevard/NC 16 South to complete Part I of the Project Route at the gore of the off ramp (Map 1: Location B).
- Stay on I-485 to continue to Part II of the data collection effort, ramps. Continue with mileposts from Part I.

Part II: Ramp Only Data Collection. During Part II, data will only be collected on selected ramps along the course. Collect data along ramps in the direction of travel only (i.e. take the off-ramp and then the on-ramp directly back onto interstate facility.

- Map 3 shows the project route Part II. There will be **5 on-ramps** and **5 off ramps** for data collection during Part II.



Map 3: Ramp Only Data Collection Route

- After passing NC 16 on I-485 South (the end of Part I), travel along I-485 South for 3.5 miles.
- You will collect data on the following 5 on and off-ramps starting and ending at the gore point of each pair.
  - **RAMP 1:** Take the Exit 12 ramp for Moore's Chapel Road to collect ramp data. Continue through the intersection to the on ramp for I-485 South (Map 3: Location C).
  - **RAMP 2:** Take the Exit 4 ramp for Steel Creek Road to collect ramp data. Continue through the intersection to the on ramp for I-485 South (Map 3: Location D).

- **RAMP 3:** Take the Exit 3 ramp for Arrowood Road to collect ramp data. Continue through the intersection to the on ramp for I-485 South (Map 3: Location E).
- **RAMP 4:** Take the Exit 1 ramp for South Tryon Street to collect ramp data. Continue through the intersection to the on ramp for I-485 South (Map 3: Location F).
- **RAMP 5:** Take the Exit 64B ramp for Pineville-Matthews Road to collect ramp data (Map 3: Location G). After completing the Exit 64B on and off ramps, discontinue data collection.

Instructions for Submitting Data

Data Submission and Deadlines. Two separate submissions should take place. Submit all data to Chris Cunningham at ITRE. See Page 75 for contact information.

1. A preliminary dataset should be sent as a reference check. Past work in this area concluded that more communication needed to be had between the vendor and ITRE. Therefore, we suggest submitting no more than 2 miles (each) of data from an interstate and arterial. The submission deadline for this preliminary dataset will be Thursday, July 31st, 2011. Earlier submissions are appreciated. Data will be analyzed and submitted back to each vendor within 1 month.

2. The final submission of data along the course is due March 2, 2012. Any late submissions should be pre-approved by Chris Cunningham.

Format. Data should be submitted electronically in two (2) formats by removable media or FTP site:

1. ArcGIS Shapefiles or Geodatabase
2. Microsoft Office Excel Spreadsheets

Specific descriptions, photo examples, and instructions of each data element are found in the Data Collection Sheets provided for your use in the following section. Please complete all data collection as determined by each element's Data Collection sheet. Where mileposts are required, please start at 0.00 at the beginning stop bar on NC 16 and run continuously through the course. We understand that the sections between the ramps will have no data. We also understand that the gore starting and ending points at ramps will not start at $1/10^{th}$ mile increments.

We require <u>one table per data element</u>. In each table, one row of data will pertain to one particular item being measured (e.g., each sign). Data items should be listed in each table sequentially, as encountered in your drive along the course. This document provides detailed definitions and desired units of measure for each variable and data element. Be as precise as possible.

Photographs. Pictures are encouraged where data elements may need further evidence provided. Examples could include blocked drop inlets, curb and gutter, severe pavement distress. This will also help with subjectivity during the analysis.

Units. Generally, English units of measure will be requested unless the current custom for that particular variable is to use metric units.

Accuracy. Please provide the team with the tolerances for roadway feature collected if a unit of length is required (i.e. sign size, median width, lane width, bridge clearance, etc.).

Data Collection Guidelines

To prevent any confusion during data collection, we would like to stress the importance of familiarization with NCDOT's data collection methods. As noted in the cover letter, our objective is to be as informative as possible. Therefore, if there is any confusion during post-processing please contact someone at NCSU/ITRE.

To familiarize your team with data collection methods used during NCDOT's manual data collection, we have assembled a detailed supplemental guide based on relevant pages from NCDOT's 2010 Maintenance Condition Assessment Manual, the 2009 Manual on Uniform Traffic Control Devices (MUTCD), and the 2004 AASHTO Policy on Geometric Design of Highways and Streets ("Greenbook").

Note: Data collected is of a linear or point nature. We have separated the two forms of data collection in the following sections.

Linear Elements

Linear elements are elements which are continuous and run on or adjacent to the roadway. A complete inventory of each feature should be given when present. A new row should be created in each of the tables for the following elements whenever there is a change in any of the data collection fields (i.e. width, condition, field inspection requirement, etc.). These elements include:

- Paved Shoulders
- Unpaved Shoulders
- Lateral Ditches
- Curb/Gutters
- Brush & Tree Control
- Turf Condition
- Slopes
- Landscape Areas (Collect on Ramp Sections Only – Part II of Data Collection Maps)
- Concrete Barriers
- Guardrail
- Pavement
- Retaining Walls
- Median
- Raised Pavement Markers
- Roadway Lanes
- Rumble Strips

Paved Shoulders (Linear)

Feature Description

Intact quality shoulders allow vehicles to pull off the road in the event of emergencies or breakdowns. The shoulder condition should allow the driver to maintain control while slowing from driving speed to a stop.

Data Collection Instructions

- Collect Paved Shoulder inventory along the entire route as linear data.
- Collect Paved Shoulders equal to or greater than 1 foot (12 inches) in width.
- Anything less than 1 foot (12 inches) should be collected as an Unpaved Shoulder (see page 14).
- Measure width of Paved Shoulder from the edge of solid white line to the far right of the travel way.

Data Collection Fields

Starting/End Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.** An end point should only be noted when the width of shoulder changes by approximately 1 foot or the shoulder is discontinued.

Width: Measured in feet, from the edge of the travel way to the edge of the shoulder. Values should be rounded to the nearest foot.

Total Length: Total length of the shoulder should be measured in linear feet by using the starting/ending points.

Roadside Location: Right or Median

Material Type: **Concrete** or **Asphalt**

Field Inspection Required: Yes or No (i.e. no signs of ruts, potholes, cracks, or other distresses.

If Yes, one of the following notes should be added in the comments section:

- **Rutted**: Rut depths > 0.75"
- **Potholes:** Pavement failures greater than 1 sq. ft. x 1.5 inches deep.
- **Unsealed Cracks:** Any cracks greater than 0.5" wide and more than 50' cumulative in section.
- **Transverse Settlements:** No vertical differential greater than 2.0" in height where settlement has occurred.
- **Other:** Any additional obstruction or distress that is not defined above.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 1: Paved Shoulders - Rutting

Exhibit 2: Paved Shoulders – Unsealed crack with vegetation (Right of travel way).

Exhibit 3: Paved Shoulders

Paved Shoulders											
Starting Point			Ending Point			Width (ft)	Total Length (ft)	Material Type	Roadside Location	Field Inspection Required	Comments
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude						
0.0	35.76704	78.65841	2.01	35.76809	78.65912	6	10613	Asphalt	RIGHT	NO	
2.01	35.76809	78.65912	2.51	35.76748	78.65564	8	2640	Asphalt	RIGHT	NO	
2.51 (Exhibit 1)	35.76748	78.65564	2.59	35.73325	78.65574	8	422	Asphalt	RIGHT	YES	Pothole
2.59	35.73325	78.65574	3.01	35.76748	78.65564	8	2218	Asphalt	RIGHT	NO	
3.01 (Exhibit 2)	35.76748	78.65564	3.05	35.71225	78.65582	8	211	Asphalt	RIGHT	YES	Unsealed Crack - Vegetation
3.05	35.71225	78.65582	3.56	35.76150	78.65948	8	2693	Asphalt	RIGHT	NO	
3.56 (Exhibit 3)	35.76150	78.65948	3.67	35.76803	78.71220	6	580	Asphalt	RIGHT	NO	
3.67	35.76803	78.71220	4.48	35.7715	78.65911	8	4277	Asphalt	RIGHT	NO	
4.48	35.7715	78.65911	4.49	35.76266	78.65948	6	53	Concrete	RIGHT	NO	
4.49	35.76266	78.65948	5.9	35.7001	78.65899	8	7445	Concrete	RIGHT	NO	
5.9	35.7001	78.65899	5.92	35.76202	78.65125	6	106	Concrete	RIGHT	NO	

*** NOTE: Right side and Median paved shoulders should be collected, this table only shows Right side paved shoulders, but a similar table should be developed for Median paved shoulders and denoted in the “Roadside Location” column.**

Unpaved Shoulders (Linear)

Feature Description

Unpaved Shoulders (Low & High) are located on the right and median sides of the roadway, not to exceed 10 feet from the edge of the travel way. A low shoulder can result in an unsafe vehicle recovery and undermining of the pavement. A high shoulder can restrict water drainage and result in ponding at the edge of roadway, which can infiltrate the base and subgrade and weaken the roadway or scour the shoulder and front slope. Ponding can also lead to vehicle hydroplaning should a vehicle leave the roadway.

Data Collection Instructions

- Collect Unpaved Shoulder inventory along the entire route as linear data.
- Only collect Unpaved Shoulders up to 10 feet from the edge of the travelway.
- Measure width of Unpaved Shoulder from the edge of the pavement.
- It is possible to have both Paved and Unpaved Shoulder in the same location. For example, if a paved shoulder is 6 feet wide, an additional 4 feet of unpaved shoulder should be evaluated.

Data Collection Fields

Starting/Ending Points: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.** An end point should only be noted when the width of shoulder changes by 1 foot (rounded) or the shoulder is discontinued.

Location: Right or Median

Width: Total width of shoulder from edge of travel way. Values should be rounded to the nearest foot and not exceed 10’.

Total Length: Total length of the shoulder in linear feet.

Field Inspection Required: Yes or No (i.e. no signs of a low or high shoulder condition as seen).

If Yes, one of the following notes should be added in the comments section:

- **Low:** An unpaved shoulder elevation is more than **3” lower** than the roadway within **10’** from the edge of pavement.
- **High:** An unpaved shoulder elevation is more than **2” higher** than the roadway within **10’** from the edge of pavement.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 4: Low Shoulder

Exhibit 5: Low Shoulder

Exhibit 6: High Shoulder

Exhibit 7: High Shoulder

Unpaved Shoulders										
Starting Point			Ending Point			Width (ft)	Total Length (ft)	Roadside Location	Field Inspection Required	Comments
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude					
0.0	35.76704	78.65841	2.01	35.76809	78.65912	10	10613	RIGHT	NO	
2.01	35.76809	78.65912	3.01	35.76748	78.65564	6	5280	RIGHT	NO	
3.01 (Exhibit 4)	35.76748	78.65564	3.05	35.71225	78.65582	6	211	RIGHT	YES	LOW
3.05	35.71225	78.65582	3.56	35.76150	78.65948	10	2693	RIGHT	NO	
3.56 (Exhibit 5)	35.76150	78.65948	3.67	35.76803	78.71220	10	580	RIGHT	YES	LOW
3.67	35.76803	78.71220	4.48	35.7715	78.65911	5	4277	RIGHT	NO	
4.48 (Exhibit 6)	35.7715	78.65911	4.49	35.76266	78.65948	5	53	RIGHT	YES	HIGH
4.49	35.76266	78.65948	5.90	35.7001	78.65899	5	7445	RIGHT	NO	
5.9 (Exhibit 7)	35.7001	78.65899	5.92	35.76202	78.65125	5	106	RIGHT	YES	HIGH

*** NOTE: Right side and Median unpaved shoulders should be collected, this table only shows Right side unpaved shoulders, but a similar table should be developed for Median unpaved shoulders and denoted in the "Roadside Location" column.**

Lateral Ditch (Linear)

Feature Description

Lateral ditches are trough-shaped channels oriented parallel to the roadway. Lateral ditches are used to collect and redirect surface water.

Data Collection Instructions

- Collect Lateral Ditch inventory along the entire route as linear data.
- Only collect Lateral Ditches within 50 feet from the edge of the travelway.
- Measure the offset of Lateral Ditch from the edge of the pavement to the middle of the ditch.

Data Collection Fields

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Offset: Distance measured from the **roadway edgeline to the ditch.**

Length: Note the total length of the ditch in **linear feet**.

Type (Material): Note the type of ditch as **Paved**, **Unpaved**, or **Unknown**. Note paved ditch material as Concrete or Asphalt in parenthesis. For example: Paved (Concrete) or Paved (Asphalt).

Roadside Location: **Right** or **Median**

Field Inspection Required: Yes or No (i.e. no signs of flow-line blockage, erosion, structural distress, standing water, or other obstructions.)

If Yes, one of the following notes should be added in the comments section:

- **Flow Line Blockage:** Lateral ditches that are 50% or more blocked (Exhibit 9).
- **Eroded:** An eroded lateral ditch should be noted when there is a lining loss of 1 foot below the original ditch line, or lower (Exhibit 46).
- **Structural Distress:** Paved lateral ditches with joint separation, misalignment, or undermining (water flowing underneath the pavement) (Exhibit 8).
- **Standing Water:** Lateral ditches that appear to be flooded with water that is not moving.
- **Other:** Any additional obstruction or distress that is not defined above.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 8: Structural Distress

Exhibit 9: Ditch Blocked

Exhibit 10: Ditch Eroded

Lateral Ditches												
Starting Point			Ending Point			Offset (ft)	Total Length (ft)	Type	Paved Ditch Material	Roadside Location	Field Inspection Required?	Comments
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude							
15.00	35.74548	78.65214	16.74	35.75412	78.65424	12	9187	UNPAVED	N/A	RIGHT	NO	
16.74	35.75412	78.65424	17.26	35.76809	78.65912	10	2746	PAVED	CONCRETE	RIGHT	NO	
17.26 (Exhibit 8)	35.76809	78.65912	17.27	35.71225	78.65582	10	53	PAVED	CONCRETE	RIGHT	YES	STRUCTURAL DISTRESS
17.27	35.71225	78.65582	17.84	35.76150	78.65948	10	3010	PAVED	CONCRETE	RIGHT	NO	
17.84 (Exhibit 9)	35.76150	78.65948	17.86	35.76803	78.71220	10	106	PAVED	CONCRETE	RIGHT	YES	BLOCKED
17.86	35.76803	78.71220	18.21	35.76654	78.71235	10	1848	PAVED	CONCRETE	RIGHT	NO	
18.21	35.76654	78.71235	18.60	35.7715	78.65911	10	2059	PAVED	CONCRETE	RIGHT	NO	
18.60 (Exhibit 10)	35.7715	78.65911	18.63	35.76266	78.65948	12	159	UNPAVED	N/A	RIGHT	YES	ERODED

*** NOTE: Right side and Median lateral ditches should be collected, this table only shows Right side lateral ditches, but a similar table should be developed for Median lateral ditches and denoted in the “Roadside Location” column.**

Curb/Gutters (Linear)

Feature Description

Gutters are paved, open drainage channels that direct the flow of water from the road surface and roadside area to a catch basin or other outlet. A blockage in the gutter may divert water flow onto the travelway and cause vehicle hydroplaning. Examples of open-channel gutters are curb and gutter, valley gutter, and the drainage at the base of a concrete barrier.

Data Collection Instructions

- Collect Curb/Gutter inventory along the entire route as linear data.
- Only collect Curb/Gutter directly adjacent to the edge of the travelway.
- While collecting a continuous length of Curb/Gutter, be sure to end the Curb/Gutter segment and beginning a new segment after each access point or median opening.

Data Collection Fields

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Roadside Location: **Right** or **Median**

Length: Note the total length of the curb/gutter in **linear feet**.

Field Inspection Required: Yes or No (i.e. no visible signs of blockages or damage. The curb/gutter is able to function as intended.)

If Yes, one of the following notes should be added in the comments section:

- **Blockage:** Curb/Gutters that are not functioning as designed due to an obstruction **2 inches or greater for at least 2 feet** of gutter length should be noted. Additionally, blockage has occurred if runoff spreads into the travelway for a distance of half the lane width or more.
- **Damage:** Any **damaged** gutter should be noted, such as cracking, settlement, misalignment, or deterioration.
- **Other:** Any additional obstruction or distress that is not defined above.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the "Field Inspection Required."

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 11: Curb/Gutter Blocked

Exhibit 12: Curb/Gutter Blocked

Exhibit 13: Curb/Gutter Damaged

Exhibit 14: Curb/Gutter Damaged

Curb/Gutter									
Starting Point			Ending Point			Length (ft)	Roadside Location	Field Inspection Required	Comments
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude				
0.0	35.76704	78.65841	2.01	35.76809	78.65912	10613	RIGHT	NO	
2.01	35.76809	78.65912	3.01	35.76748	78.65564	5280	RIGHT	NO	
3.01 (Exhibit 11)	35.76748	78.65564	3.05	35.71225	78.65582	211	RIGHT	YES	BLOCKAGE
3.05	35.71225	78.65582	3.56	35.76150	78.65948	2693	RIGHT	NO	
3.56 (Exhibit 12)	35.76150	78.65948	3.67	35.76803	78.71220	581	RIGHT	YES	BLOCKAGE
3.67	35.76803	78.71220	4.48	35.7715	78.65911	4277	RIGHT	NO	
4.48 (Exhibit 13)	35.7715	78.65911	4.49	35.76266	78.65948	53	RIGHT	YES	DAMAGE
4.49	35.76266	78.65948	5.9	35.7001	78.65899	7445	RIGHT	NO	
5.9 (Exhibit 14)	35.7001	78.65899	5.92	35.76202	78.65125	106	RIGHT	YES	DAMAGE

*** NOTE: Right side and Median curb/gutter should be collected, this table only shows Right side curb/gutter, but a similar table should be developed for Median curb/gutter and denoted in the “Roadside Location” column.**

Brush & Tree (Linear)

Feature Description

Brush and tree control involves the removal of large vegetation for safety reasons, such as to maintain a roadway clear zone and providing adequate sight distance. Anything that is handled by normal mowing operations would not count as "brush and tree".

Data Collection Instructions

- Collect Brush & Tree inventory along the entire route as linear data.
- Collect all Brush & Tree inventory within 50 feet of the edge of travelway and within all grassed medians.

Data Collection Fields

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of the brush & tree control in **linear feet**.

Roadside Location: **Right** or **Median**

Field Inspection Required: Yes or No

If Yes, one of the following notes should be added in the comments section:

- **Sight Distance Obstruction:** Sight distance is limited for roadway users due to brush/tree growth.
- **Sign Obstruction:** Trees/brush prevent a roadway sign from being seen by the roadway user.
- **Vertical Clearance Obstruction:** A vertical clearance of less than 15 feet over the roadway.
- **Fallen Brush/Tree:** Dead or leaning trees/brush that presents a hazard.
- **Clear Zone Obstruction:** Trees or woody growth are within 45' of travelway or less than 10' behind guardrail or concrete barriers (excluding ornamental plantings). This field inspection requirement should only be used for interstate facilities!
- **Brownout:** More than 10% of the brush/tree in a given length is not the appropriate vegetation coloring.
- **Other:** Any additional obstruction or distress that is not defined above.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the "Field Inspection Required."

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 15: Brush & Tree Control – Site Distance Obstruction

Exhibit 16: Brush & Tree Control – Clear Zone Obstruction

Brush & Tree Control									
Starting Point			**Ending Point**			**Roadside Location**	**Length (ft)**	**Field Inspection Required**	**Comments**
Course Milepost	**Latitude**	**Longitude**	**Course Milepost**	**Latitude**	**Longitude**				
0.0	35.76704	78.65841	2.01	35.76809	78.65912	RIGHT	10613	NO	
2.01	35.76809	78.65912	5.25	35.76748	78.65564	RIGHT	17107	NO	
5.25 (Exhibit 15)	35.76809	78.65954	5.34	35.76803	78.65948	RIGHT	475	YES	Site Distance Obstruction
5.34	35.76803	78.65948	6.26	35.76809	78.12665	RIGHT	4858	NO	
6.26 (Exhibit 16)	35.76809	78.12665	6.34	35.76803	78.65948	RIGHT	422	YES	Clear Zone Obstruction

Turf (Linear)

Feature Description

Turf cover condition is essential to maintaining the stability of unpaved shoulders, slopes, and the ditch line. Without proper vegetation, soil erosion can lead to water infiltration and loss of roadbed support, and even contamination of natural drainage areas due to sediment loss.

Data Collection Instructions

- Collect Turf inventory along the entire route as linear data.
- Only collect Turf directly adjacent to the edge of the travelway and within grassed medians.
- While collecting a continuous length of Turf, be sure to end the Turf segment and begin a new segment after each access point or median opening.

Data Collection Fields

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.** An endpoint should only be given where turf ends or a field inspection is required due to failure. If an inspection is required, give the entire length of the failure in a new row, then another row starting with acceptable turf.

Length: Note the total length of the turf area in **linear feet**. If turf is adjacent to the roadway, the entire inventory length should be collected.

Roadside Location: **Right** or **Median**

Field Inspection Required: Yes or No (i.e. no signs of browned-out or erosion on turf cover.)

If Yes, one of the following notes should be added in the comments section:

- **Brownout:** Brownout occurs when more than 50’ length in approximately 1/10th mile (i.e. brownout does not have to be 50’ or more continuous) is not the appropriate vegetation coloring. We do not expect vendors to provide 1/10th mile segments, only when the condition above is met.
- **Bare/Eroded:** More than 50’ length in approximately 1/10th mile (i.e. bare/eroded areas does not have to be 50’ or more continuous) is missing or eroded. We do not expect vendors to provide 1/10th mile segments, only when the condition above is met.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 17: Turf Condition – Eroded/Bare

Exhibit 18: Turf Condition - Brownout

Turf Condition									
Starting Point				Ending Point		Length (ft)	Roadside Location	Field Inspection Required	COMMENTS
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude				
0.0	35.76704	78.65841	2.01	35.76809	78.65912	10613	Right	NO	
2.01	35.76809	78.65912	5.25	35.76748	78.65564	17107	Right	NO	
5.25 (Exhibit 17)	35.76809	78.65948	5.75	35.85500	78.65948	2640	Right	YES	Eroded/Bare
5.34	35.76803	78.65948	6.26	35.76809	78.12665	4858	Right	NO	
6.26	35.76809	78.12665	6.34	35.76803	78.65948	422	Right	NO	
6.34 (Exhibit 18)	35.61590	78.75889	6.64	35.76803	78.65255	1584	Right	YES	Brownout/Bare

*** NOTE: Right side and Median turf condition should be collected, this table only shows Right side turf condition, but a similar table should be developed for Median turf condition and denoted in the "Roadside Location" column.**

Slopes (Linear)

Feature Description

Slopes act as a transition between the road and the natural grade or ditch. They provide lateral support to the roadbed and can also function as a clear recovery area for errant motorists. Slopes are not the same as ditches, but are instead made by cut or fill areas when constructing the roadway (see examples). Slopes should only be collected on interstate facilities and not arterials.

Data Collection Instructions

- Collect Slope inventory only along the interstate facilities as linear data.
- Only collect Slopes within 50 feet of the travelway.

Data Collection Fields

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of slope in **linear feet**.

Roadside Location: **Right** or **Median**

Field Inspection Required: Yes or No (i.e. no signs of erosion, ruts, wash-outs, or an unstable conditions.)

If Yes, one of the following notes should be added in the comments section:

- **Eroded/Rutted/Washed-out:** Washouts or ruts are greater than 6" deep and 2' wide.
- **Unstable:** No longer in a stable condition, creating an unsafe recovery area for vehicles leaving the roadway.
- **Other:** Any additional obstruction or distress that is not defined above that would result in an unstable slope.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 19: Unstable

Exhibit 20: Eroded

Slopes									
Starting Point			**Ending Point**			**Length (feet)**	**Field Inspection Required**	**Comments**
Course Milepost	**Latitude**	**Longitude**	**Course Milepost**	**Latitude**	**Longitude**			
0.0	35.76704	78.65841	2.01	35.76809	78.65912	10613	NO	
2.01	35.76809	78.65912	5.25	35.76748	78.65564	17107	NO	
5.25 (Exhibit 19)	35.76809	78.65948	5.75	35.85500	78.65948	2640	YES	Unstable - Riprap collapsed
5.34	35.76803	78.65948	6.26	35.76809	78.12665	4858	NO	
6.26	35.76809	78.12665	6.34	35.76803	78.65948	422	NO	
6.34 (Exhibit 20)	35.61590	78.75889	6.64	35.76803	78.65255	1584	YES	Eroded

Concrete Barriers (Linear)

Feature Description

Concrete Barriers are a safety device designed to protect errant motorists from hazards near the roadway. They shield roadside obstacles, protect drivers from steep drop-offs, and can even be used to separate opposing traffic.

Data Collection Instructions

- Collect Concrete Barrier inventory along the entire route as linear data.

Data Collection Fields

Location: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of the barrier in **linear feet**.

Offset: Distance measured from the **roadway edgeline to the barrier.**

Height: Distance measured from the **ground level to the top of the barrier**

Type: **Concrete** or **Other**

Roadside Location: **Right** or **Median**

Field Inspection Required: Yes or No (i.e. no signs of damages to the barrier.)

If Yes, one of the following notes should be added in the comments section:

- **Damaged:** Damages that would cause the barrier not to function properly; such as vegetation, obstruction greater than 2” for a length of 2’, or excessive runoff spreading into the travelway.
- **Other:** Any additional obstruction or distress that is not defined above.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 21: Damaged Concrete Barrier

Exhibit 22: Damaged Concrete Barrier

Concrete Barrier													
Starting Point			Ending Point										
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude	Length (feet)	Offset (ft)	Total Height (in)	Type	Roadside Location	Field Inspection Required?	Comments
0.0	35.76704	78.65841	2.01	35.76809	78.65912	10613	8	50	Concrete	RIGHT	NO	
5.25 (Exhibit 21)	35.76809	78.65948	5.75	35.85500	78.65948	2640	8	50	Concrete	RIGHT	YES	Damaged
5.34	35.76803	78.65948	6.26	35.76809	78.12665	4858	8	50	Concrete	RIGHT	NO	
6.26	35.76809	78.12665	6.34	35.76803	78.65948	422	12	50	Concrete	RIGHT	NO	
6.34 (Exhibit 22)	35.61590	78.75889	6.64	35.76803	78.65255	1584	12	50	Concrete	RIGHT	YES	Damaged

*** NOTE: Right side and Median concrete barriers should be collected, this table only shows Right side concrete barriers, but a similar table should be developed for Median concrete barriers and denoted in the "Roadside Location" column.**

Guardrail (Linear)

Feature Description

Guardrail is a safety device designed to protect errant motorists from hazards near the roadway.

Data Collection Instructions

- Collect Guardrail inventory along the entire route as linear data.
- While collecting a continuous length of Guardrail, be sure to end the Guardrail segment and begin a new segment after each access point or median opening.

Data Collection Fields

Location: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of the guardrail in **linear feet**.

Offset: Distance measured from the **roadway edgeline to the barrier.**

Roadside Location: **Right** or **Median**

Type: **Metal**, **Rusticated Steel**, **Wood**, **Cable Rail,** or **Unknown**

Field Inspection Required: Yes or No (i.e. no signs of damage as outlined below.)

If Yes, one of the following notes should be added in the comments section:

- **Damaged:** Guardrail that is **not functioning as designed** has been **damaged** as follows:
    - Metal/Rusticated Steel/Wood/other Guardrail: The rail beam is crushed more than **18 inches** out of line, if the rail has been severed, or if three or more posts have been broken
    - Cable rail: If any cable is broken, if the cable is sagging to the point that it would not function properly, or if four or more posts have been knocked down.
- **Unknown:** Any additional obstruction or distress that is not defined above.

Height: Distance measured from the **ground level to the top of the guardrail.**

Comments: Use this field to describe anything that may appear out of the ordinary.

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 23: Damaged W-Beam Guardrail

Exhibit 24: Damaged W-Beam Guardrail

Guardrail													
Starting Point			Ending Point				Offset (ft)	Total Height (in)	Type	Roadside Location	Field Inspection Required?	Comments
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude	Length (feet)						
0.0	35.76704	78.65841	2.01	35.76809	78.65912	10613	6	28	W-Beam	RIGHT	NO	
5.25 (Exhibit 23)	35.76809	78.65948	5.75	35.85500	78.65948	2640	6	28	W-Beam	RIGHT	YES	Damaged
5.34	35.76803	78.65948	6.26	35.76809	78.12665	4858	6	28	W-Beam	RIGHT	NO	
6.26	35.76809	78.12665	6.34	35.76803	78.65948	422	6	28	W-Beam	RIGHT	NO	
6.34 (Exhibit 24)	35.61590	78.75889	6.64	35.76803	78.65255	1584	6	28	W-Beam	RIGHT	YES	Damaged

*** NOTE: Right side and Median guardrail should be collected, this table only shows Right side guardrail, but a similar table should be developed for Median guardrail and denoted in the "Roadside Location" column.**

Pavement (Linear)

Feature Description

Pavements should provide a sound and reasonably smooth driving surface. Data under the PBMC is collected entirely using visual inspection since these are extreme pavement problems easily noted. Data is collected across the entire roadway width; however, the right-most through lane is typically the worst and may help indicate when other lanes should be investigated further.

Data Collection Instructions

- Collect Pavement inventory along the entire route as a linear feature.

Data Collection Fields

Starting/End Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.** Data is not a complete inventory, but only noted where problem areas exist.

Length: Note the total length of pavement in **linear feet**.

Material Type: **Concrete** or **Asphalt**

Field Inspection Required: Yes or No (i.e. pavement is reasonably smooth. patching is functional.)

If Yes, one of the following notes should be added in the comments section:

- **Rutted**: Rut depths > 0.75"
- **Potholes:** Pavement failures greater than 1 sq. ft. x 1.5 inches.
- **Unsealed Cracks:** Any cracks greater than 0.5" wide and more than 50' cumulative in section.
- **Other:** Any additional obstruction(s) or distress(es) that is not defined above.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 25: Rutting of Pavement

Exhibit 26: Cracked Asphalt Pavement

Exhibit 27: Typical Asphalt Pavement

Exhibit 28: Concrete Pavement Spall

Exhibit 29: Typical Concrete Pavement

Pavement									
Starting Point			**Ending Point**			**Length (Feet)**	**Material Type**	**Field Inspection Required**	**Comments**
Course Milepost	**Latitude**	**Longitude**	**Course Milepost**	**Latitude**	**Longitude**				
0.0	35.76704	78.65841	4.01	35.76809	78.65912	21120	Asphalt	No	
4.01 (Exhibit 25)	35.76809	78.65912	4.25	35.76802	78.65952	1320	Asphalt	Yes	Rutting
4.25	35.76802	78.65952	5.25	35.76841	78.65971	5280	Asphalt	No	
5.25 (Exhibit 26)	35.76841	78.65971	5.75	35.85500	78.65948	2640	Asphalt	Yes	Cracked
5.75 (Exhibit 27)	35.76803	78.65948	6.26	35.76809	78.12665	4858	Asphalt	No	
6.26 (Exhibit 28)	35.76809	78.12665	6.26	35.76803	78.65948	2	Concrete	Yes	Spall
6.26 (Exhibit 29)	35.76803	78.65948	6.64	35.76807	78.65257	1984	Concrete	No	

Retaining Walls (Linear)

Feature Description

A Retaining Wall is a structure that holds back soil or rock from a building, structure or area. Retaining walls prevent down slope movement or erosion and provide support for vertical or near-vertical grade changes.

Data Collection Instructions

- Collect Retaining Wall inventory along the entire route as a linear feature.

Data Collection Fields

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of the retaining wall in **linear feet**.

Field Inspection Required: Yes or No

No field inspection required, if the following criteria are met:

- 80% of wall length is free of vegetation.
- 75% of weep holes are functioning.
- No unsealed cracks or joints greater than 1/2" wide.
- Concrete elements have no spalls >= 1" deep and a surface area greater than 1 square foot and the cumulative area of 1" deep spalls cannot exceed an area of 5 square foot for the entire surface. Spalling occurs when the concrete sheds tiny particles off of the finished top surface layer.

If Yes, note which of the criteria were not met

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the "Field Inspection Required."

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 30: Retaining Wall – No Field Inspection Required

Exhibit 31: Retaining Wall– No Field Inspection Required

Retaining Walls								
Starting Point			Ending Point			Length (ft)	Field Inspection Required?	Comments
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude			
17.26 (Exhibit 30)	35.76809	78.61258	17.51	35.76258	78.65948	1320	No	
18.9 (Exhibit 31)	35.12568	78.65954	19.34	35.76803	78.62258	2323	No	

Median (Linear)

Feature Description

A median is situated in between opposing traffic lanes on a roadway. For width measurements, avoid transition areas such as tapers.

Data Collection Instructions

- Collect Median inventory along the entire route as linear data.
- Median should be noted as grassed or paved. Concrete Barrier located within or in place of a Median is collected as a different data collection element (see page 35, Concrete Barrier).

Data Collection Fields

Location: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of median in **linear feet**.

Type: Grass or Paved

Width: Measure the **width** of the **median** in feet.

Comments: Use this field to describe the reason a field inspection is needed.

Note: The following exhibit is referenced in the example data collection spreadsheet.

Exhibit 32: Grass Median with Guardrail.

Roadside: Median

Starting Point			Ending Point			Width (feet)	Type	Comments
Course Milepost	Latitude	Longitude	Course Milepost	Latitude	Longitude			
0.00 (Exhibit 32)	35.76812	78.65949	2.01	35.76809	78.65912	30	Grass	
5.25	35.76809	78.65948	5.75	35.85500	78.65948	32	Grass	
5.34	35.76803	78.65948	6.26	35.76809	78.12665	24	Grass	
6.26	35.76809	78.12665	6.34	35.76803	78.65948	12	Paved	
6.34	35.61590	78.75889	6.64	35.76803	78.65255	16	Paved	

Point Elements – Per Segment Length

The *Point Elements, 1/10th Mile Segments* include an inventoried element within a specified segment (1/10th mile or 100 feet). The data collected will be the total number of a specific element found along the 1/10th mile segment and then inventoried at a finite point at the beginning of every specified segment length along the test route. These elements include:

- Raised Pavement Markers
- Roadway Lanes
- Rumble Strips
- Pavement Markings & Striping
- Centerline

Raised Pavement Markers (Point, Per Segment)

Feature Description

Raised Pavement Markers (RPMs) may be used as positioning guides or to supplement pavement markings. These may be surface-mounted, recessed, or snow plowable.

Data Collection Instructions

- Travel along the far right through lane on each facility.
- Collect the number of visible RPMs found along a 1/10th of a mile segment of the left side of the far right through lane ONLY.
- Collected inventory along the entire route as point data every 1/10th of a mile.
- RPM data should be collected along each ramp listed in Data Collection Part II.
  - Collect the number of visible RPMs from the beginning of the gore to the stop bar or yield line at the end of the ramp.
  - Collect all RPMs along the ramp roadway; including RPMs to the left and right of all lanes (if more than one lane exists).

Data Collection Fields

Location Point: The location point of a segment should take place at the beginning of every 1/10th of a mile. Include the **course milepost**, **latitude**, and **longitude.**

Number of Markers: Note the number of visible RPMs along a given sample length of 1/10th mile segments. RPMs are found on all facility types along the test route as follows:

- Interstate Facilities: Collect data in the right-most through lane along the left side of that lane. Ramp junctions bare no weight on how to collect this attribute, continue collecting linearly in 1/10th mile segments (collect RPMs on the 5 ramps at the end of the course and ignore the major loop).
- Arterials: Collect data in the right-most through lane along the left side of that lane. Turn bays have no bearing on how to collect this data item, continue collecting linearly every in 1/10th mile segments.

Type: **Surface-mounted, Recessed,** or **Snow plowable.**

Transition: Note any transition zones during a 1/10th mile section such as an auxiliary through lane where a lane shift had to be made during that segment.

Comments: Use this field to describe the reason a field inspection is needed if necessary.

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 33: Pavement Markers

Exhibit 34: Pavement Markers

Exhibit 35: Example of transition zone, 4-lane facility drops two lanes. Vehicle must merge over 2 lanes to stay on loop (courtesy Google Earth).

Location			Type	Transition Zone	Visible RPMs	Comments
Course Milepost	Latitude	Longitude				
0.0 (Exhibit 33)	35.76809	78.65954	Raised	NO	8	
0.1 (Exhibit 34)	35.76809	78.65954	Raised	NO	5	
0.2 (Exhibit 35)	35.76811	78.65957	Raised	YES	2	
0.3	35.76813	78.65958	Raised	NO	7	
0.4	35.76816	78.65959	Raised	NO	5	

Note: *The example provided assumes an arbitrary total of RPMs in a 1/10th mile segment. This is only an example; vendors should not assume this data is accurate in any way!*

Roadway Lanes (Point, Per Segment)

Feature Description

A lane is defined a fully developed travel-way which a vehicle can clearly stay within and not overlap another adjacent lane. The lane should be fully developed and not include the transition zone.

Data Collection Instructions

- Collected Roadway Lanes inventory along the entire route.
- Collect the number of lanes in the direction of travel at the beginning of every 1/10th of a mile segment.

Data Collection Fields

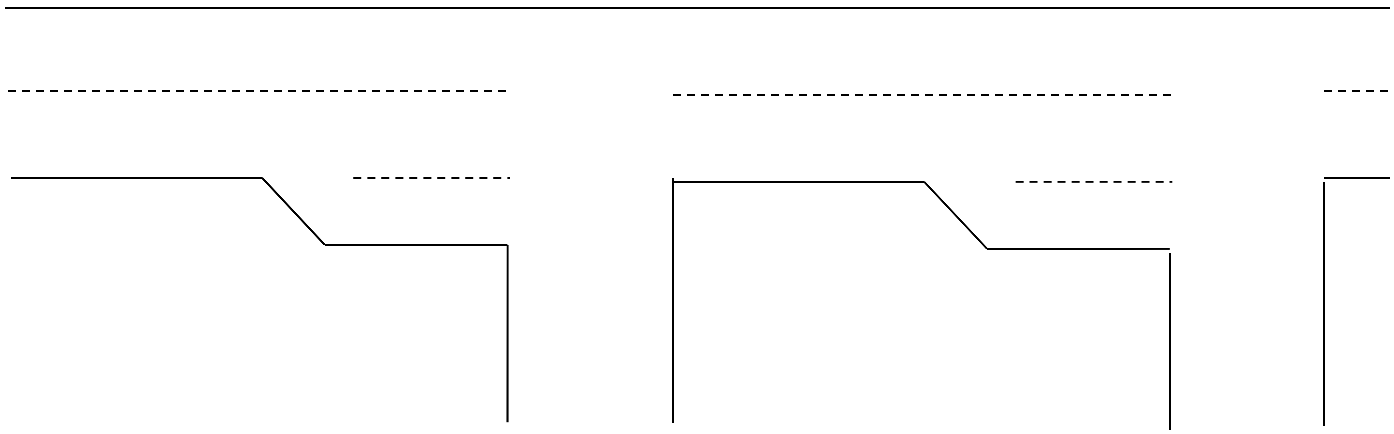
<u>Element Location:</u> Include the **course milepost**, **latitude**, and **longitude.**

<u>Number of Lanes:</u> Record the number of lanes is in your direction of travel (your side of the centerline) **only.** Include fully-developed auxiliary and turning lanes, but not the transition zone leading into the fully developed lane (ie. the starting point begins once the full lane width is available). Do not include any two-way-left-turn lanes (TWLTL's).

<u>Width:</u> Measure the width of the lanes in **linear feet.**

Note: The following exhibit is referenced in the example data collection spreadsheet.

Exhibit 36: Lane on a Multi-lane Facility



Roadway Lanes					
Starting Point			Number of Lanes	Width (feet)	Comments
Course Milepost	Latitude	Longitude			
0.00 (Exhibit 36)	35.76812	78.65949	2	12	
2.01	35.76809	78.65948	3	12	
5.34	35.76803	78.65948	2	11	
6.26	35.76809	78.12665	3	12	
6.34	35.61590	78.75889	2	12	

Rumble Strips (Point, Per Segment)

Feature Description

A shoulder rumble strip is a longitudinal design feature installed on a paved roadway shoulder near the travel lane. It is made of a series of indented or raised elements intended to alert inattentive drivers through vibration and sound that their vehicles have left the travel lane.

Data Collection Fields

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of the rumble strip in **linear feet**.

Roadside Location: **Right** or **Median**

Comments: Use this field to describe the reason a field inspection is needed.

Note: The following exhibit is referenced in the example data collection spreadsheet.

Exhibit 37: Rumble Strips on Right Side of Travel Lane

Exhibit 38: Gapped Rumble Strips along the travelway.

Starting Point			Length (ft)	Type	Roadside Location
Course Milepost	Latitude	Longitude			
17.26 (Exhibit 37)	35.76812	78.65949	10613	Continuous	Right
19.9 (	35.12568	78.65954	2323	Gapped	

Pavement Markings/Striping (Point, Per Segment)

Feature Description

Pavement Markings are applied to the road surface to convey warnings or information without diverting the driver's attention from the roadway.

Data Collection Instruction

- Collect data along the edge of the travel way only every 100 feet.

Data Collection Fields

Location: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Color: **White, Yellow,** or **Other**

Type: **Centerline, Edgeline, Skip Lines, Other.** Every lane is inventoried if it is fully developed (ie. don't count the lane until the transition zone is complete).

Retroreflectivity: Measure the retroreflectivity of the sign using a retroreflectometer. A sign with a retroreflective surface will direct all of the reflected light back towards the light source rather than disperse it in all directions. If a retroreflectivity measurement is not possible, just fill the table in as N/A.

Other Estimate of Retroreflectivity: Use a numerical value system to measure the retroreflectivity of the sign and please specify your value system.

Field Inspection Required: Yes or No (i.e. 50% or more of pavement striping (edgelines, centerlines, or skip lines) are present and visible in a given sample area.). The right-most lanes are concentrated on by inspectors for field inspection; however, problem areas should be noted across ALL lanes. The right-most lanes are very good indicators of when more thorough inspection of outer lanes should be done.

If Yes, field inspection required due to:

- 50% or more of pavement striping missing or obliterated.
- The pavement striping or marking is worn or showing other evidence of being non-retroreflective.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the "Field Inspection Required."

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 39: Faded Pavement Marking – Center Line

Exhibit 40: Pavement Marking – Skip Lines & Centerline

Pavement Striping/Markings																							
Course Milepost	**Latitude**	**Longitude**	**Line 1**						**Line 2**							**Line 3**							
			Line	**Color**	**Retroreflectivity**		**Field Insp. Req'd**	**Comment**	**Line**	**Color**	**Retroreflectivity**		**Field Insp. Req'd**	**Comment**		**Line**	**Color**	**Retroreflectivity**		**Field Insp. Req'd**	**Comment**		
					(mcd/m^2/ lux)	**Other Estimate**					**(mcd/m^2/ lux)**	**Other Estimate**						**(mcd/m^2/ lux)**	**Other Estimate**				
17.26 (**Error! Reference source not found.**)	35.76803	78.65999	Edge	Yellow	180		No		Center	Yellow	50		Yes	Fading									
17.28 (**Error! Reference source not found.**)	35.76806	78.65948	Edge	Yellow	110		No		Skip	Yellow	110		No			Center	Yellow	130		No			

Note: **Error! Reference source not found.** only shows a picture of the centerline which is fading. This is a single lane facility with an edgeline (and no skip line). For the table above, we recommend starting with the "edge line" as Line 1 and moving left to right (i.e. edge line, skip line, and center line." For a single lane facility, no skip lines will be collected (see example entry 1 above). Remember, only collect data in a single direction.

Centerline (Point, Per Segment)

Feature Description

The roadway centerline is located in the middle of the total lanes in one travel direction.

Data Collection Instructions

- Data should be collected along the entire test route at the beginning of each 100 foot segment..

Data Collection ***Fields***

Starting/Ending Point: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Azimuth: Measure the **azimuth** of the **centerline** in **decimal degrees**, which is the orientation of the centerline in relation to true north.

Grade: Collect the grade of the centerline at the beginning of each 100 feet segment..

Centerline				
Course Milepost	**Latitude**	**Longitude**	**Azimuth (decimal degrees)**	**Grade (%)**
17.26	35.76812	78.65949	105.35925	4.32%
17.28	35.76809	78.65954	105.35926	4.26%
17.30	35.76809	78.65954	105.35929	4.27%
17.32	35.76811	78.65957	105.35924	4.27%
17.34	35.76813	78.65958	105.35932	4.26%
17.36	35.76816	78.65959	105.35931	4.28%

Finite Point Elements

Finite point elements are elements whose locations can be defined by a finite point. These elements include:

- Landscape Areas (Ramps ONLY)
- Access Points
- Inlets
- Attenuators/End Treatments
- Bridges
- Median Openings
- Ground-Mounted Traffic Signs
- Overhead Traffic Signs
- Pavement Markings/Striping
- Pavement Words & Symbols
- Pavement Markers
- Centerline
- Vertical Curves
- Horizontal Curves

Landscape Areas (Point, Ramps Only)

Feature Description

Each Landscape Area is inventoried as a multi-sided aesthetic planting feature. Landscape areas are “man-made bedding areas” for plant growth, independent of whether plants are currently growing in that bed.

Data Collection Instructions

- Collect Landscape Areas inventory only adjacent to each of the ramps as point data (see Data Collection Part II, page 5).

Data Collection Fields

Ramp #: Indicate the ramp number along the test route as indicated in Data Collection Part II (page 5).

Latitude/Longitude: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Roadside Location: **Right** or **Median**

Field Inspection Required: Yes or No (i.e. total score is 9 or higher.)

If Yes, due to total score being less than 9, scored by four specific elements (plant quality, mulching, undesirable vegetation, and pruning) within each Landscape Bed will be evaluated on a point scale of 1 to 3 for each element as follows:

	Points	Plant Quality	Mulching	Undesirable Vegetation	Pruning
Scoring	3	10% or less are dead or dying (or missing)	75% or more of mulchable area has a 3” mulch cover	0-10% of area is undesirable vegetation	10% or less of the area needs pruning to allow for maintenance activities
	2	20% or less are dead or dying (or missing)	50% - 74% of mulchable area has a 3” mulch cover	11% - 25% of area is undesirable vegetation	20% or less of the area needs pruning to allow for maintenance activities
	1	30% or less are dead or dying (or missing)	25% - 49% of mulchable area has a 3” mulch cover	26% - 50% of area is undesirable vegetation	30% or less of the area needs pruning to allow for maintenance activities
	0	Over 30% of plants are dead or dying (or missing)	Less than 25% of mulchable area has a 3” mulch cover	51% or more of area is undesirable vegetation	Over 30% of the area needs pruning to allow for maintenance activities

<u>Comments:</u> Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the "Field Inspection Required."

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 41: Typical Landscape Area at an Overpass

Landscape Areas										
Location			Condition				Total Score	Field Inspection Required	Comments
Ramp #	Latitude	Longitude	Plant Quality (points)	Mulch (points)	Undesirable Vegetation (points)	Pruning (points)			
1 (**Error! Reference source not found.**)	35.76803	78.65948	3	1	2	3	9	No	
2	35.76809	78.12665	2	1	2	1	8	Yes	

Access Points (Point, Arterials Only)

Feature Description

For this study, access points can be private or business driveways or public streets. Found on the right side of the roadway. An access point does not include medians; those should be recorded under "Median Openings." This data set should not be collected on interstate facilities.

Data Collection Instructions

- Look for Access Points to the right of the roadway only.
- Access Points should be collected along arterials only.

Data Collection Fields

Location: Mark the **course milepost**, **latitude**, and **longitude** of each access point in your direction of travel.

Roadway Type: **Residential Driveway, Business Driveway, Public Street (with street sign), Interchange Ramp Terminal, Channelized Turn Lane, or Other**

Intersection Type: **Signalized** or **Unsignalized.**

Comments: Use this field to describe the reason a field inspection is needed or to define type "Other."

Exhibit 42: At-Grade Intersection

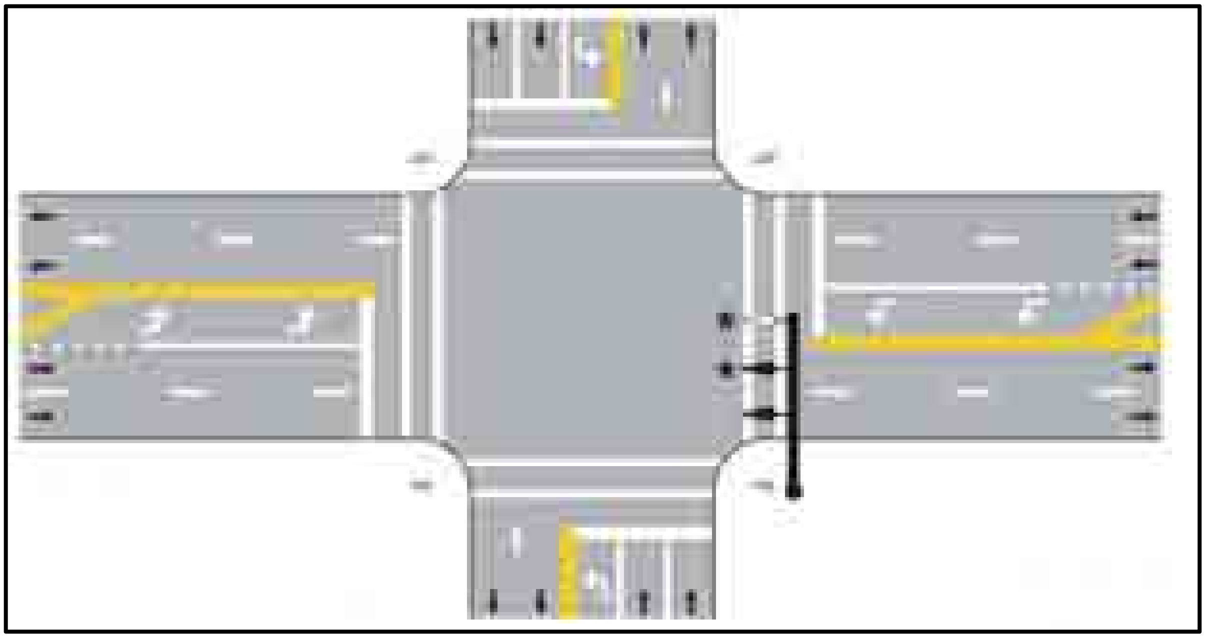


Exhibit 43: Business Driveway

Exhibit 44: Access Point data collection, aerial photography view.

Access Points					
Course Milepost	**Latitude**	**Longitude**	**Roadway Type**	**Intersection Type**	**Comments**
17.26 (Exhibit 42)	35.76812	78.65949	Public Street	Signalized	
18.34 (Exhibit 43)	35.76803	78.65948	Business Driveway	Unsignalized	
19.26	35.76809	78.12665	Residential Driveway	Unsignalized	
20.34	35.61590	78.75889	Public Street	Signalized	

Inlets (Point)

Feature Description

Inlets are the openings through which water enters an underground drainage network. Examples of inlets are catch basins, drop inlets, shoulder drains, and slope flumes.

Data Collection Fields

Element Location: The location includes the **course milepost, latitude,** and **longitude.**

Roadside Location: **Right** or **Median**

Field Inspection Required: Yes or No (i.e. no signs of blockage or damage. The drain is able to function as intended)

If Yes, one of the following notes should be added in the comments section:

- **Blocked:** Inlets that are **50% blocked** or more.
- **Eroded:** Erosion at the inlet or outlet that is wider or longer than 1.5 times the pipe diameter and greater than six inches deep within 1’ of the structure, or if pipe perched with more than 12’.
- **Damaged:** Inlets that are damaged, or have damaged/missing grates.
- **Other:** Any additional obstruction or distress that are not defined above.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the “Field Inspection Required.”

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 45: Inlet Blocked

Exhibit 46: Inlet Blocked

Exhibit 47: Inlet Damaged/Other: Missing

Inlet					
Element Location			Roadside Location	Field Inspection Required	Comments
Course Milepost	Latitude	Longitude			
17.26 (Exhibit 45)	35.72110	78.65949	RIGHT	YES	Blocked
17.33	35.76654	78.71235	MEDIAN	NO	
17.58	35.7715	78.65911	RIGHT	NO	
20.51 (Exhibit 46)	35.76812	78.21660	RIGHT	YES	Blocked
20.58	35.7665	78.71235	MEDIAN	NO	
20.96	35.7714	78.65932	RIGHT	NO	
21.21 (Exhibit 47)	35.76805	78.35220	RIGHT	YES	Damaged/Other: Missing

Attenuators/End Treatments (Point)

Feature Description

This element will either be a Curved W-Beam end treatment or a Type 350 attenuator as shown below.

Data Collection Fields

Location Point: The location points include the **course milepost**, **latitude**, and **longitude.**

Offset: Distance measured from the **roadway edgeline to the barrier.**

Height: Distance measured from the **ground level to the top of the guardrail.**

Roadside Location: **Right** or **Median**

Type: Curved W-Beam End Treatment, Type 350 Attenuator, or Other

Field Inspection Required: Yes or No (i.e. no signs of damage as outlined below.)

If Yes, one of the following notes should be added in the comments section:

- **Damaged:** The attenuator or end treatment is **not functioning as designed** has been **damaged**.
- **Unknown:** Any additional obstruction or distress.

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the "Field Inspection Required."

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 48: W-Beam End Treatment

Exhibit 49: Damaged End Treatment

Exhibit 50: Type 350 Attenuator

End Treatments/Attenuators										
Location Point			Length (ft)	Offset (ft)	Height (in)	Type	Roadside Location	Field Inspection Required?	Comments
Course Milepost	Latitude	Longitude							
11.25 (Exhibit 48)	35.72110	78.65949	200	8	18	W-Beam	MEDIAN	NO	
15.62 (Exhibit 49)	35.76812	78.21660	100	12	24	Attenuator	RIGHT	YES	Damage
17.26 (Exhibit 50)	35.76809	78.65948	100	12	30	Attenuator	RIGHT	NO	

Bridge Clearance & Inventory (Point)

Feature Description

This feature will collect the location of bridges along the test route, as well as the vertical and lateral clearances of the bridges crossing over the test route.

Data Collection Instructions

- Measure vertical clearance and lateral distance in feet.

Data Collection Fields

Element Location: The element location point includes the course milepost, latitude, and longitude directly at the bridge structure.

Right Side Lateral Clearance: Lateral distance in feet from edge of right side of travelway to nearest bridge pier or slope (measured at the driver's height in the vehicle).

Left Side Lateral Clearance: Lateral distance in feet from edge of left side of travelway to nearest bridge pier or slope (measured at the driver's height in the vehicle).

Vertical Clearance: Vertical distance from the roadway to the lowest point of the bridge structure over the travelway

Comments: Use this field to describe anything that may appear out of the ordinary (i.e. "Bridge appears to have been struck by trucks multiple times).

Exhibit 51: Bridge

Bridges						
Element Location			**Left Side Lateral Clearance (feet)**	**Right Side Lateral Clearance (feet)**	**Vertical Clearance (feet)**	**Comments**
Course Milepost	**Latitude**	**Longitude**				
17.26 (Exhibit 51)	35.76809	78.65954	16	18	55	
19.25	35.72110	78.65949	12	24	26	
20.62	35.76812	78.21660	18	23	24	

Median Openings (Point)

Feature Description

Median openings are found along a roadway where there is a gap in the continuous roadway median. The median opening allows for traffic to access cross streets or complete a U-Turn to continue in the opposite direction on the same roadway.

Data Collection instructions

- Median openings are found at the end of medians, including intersections and directed U-Turns, and cutouts.

Data Collection Fields

Location: The location points include the **course milepost**, **latitude**, and **longitude.**

Comments: Use this field to describe the reason a field inspection is needed.

Note: The following exhibit is referenced in the example data collection spreadsheet.

Exhibit 52: Median Opening

Median Opening			
Course Milepost	Latitude	Longitude	Comments
17.26 (Exhibit 52)	35.76812	78.65949	
19.25	35.72110	78.65949	
20.62	35.76812	78.21660	

Traffic Signs (Point)

Feature Description

Signs control traffic and convey information. To be effective, signs must be easily visible and legible to both vehicular and pedestrian traffic. If not, the result may be motorist confusion and error.

Data Collection Instructions

- Traffi signs intended for the direction of travel should be collected along the entire test route.

Data Collection Fields

Location: The location points include the **course milepost**, **latitude**, and **longitude.** Each individual sign on an assembly will have its own row and be located.

Assembly Type: The assembly will be described as **Overhead** or **Ground Mounted**. An overhead assembly will be a sign installed on any RIGID structure, such as a mast. This does not include span wires since they are not rigid. If a sign is mounted at ground level on a rigid structure, it is still considered an overhead assembly type. All other sign assemblies will be assumed to be ground mounted.

Number of Signs on Assembly: Note the number of signs on the entire assembly at this point location. If signs are on the same assembly, they are noted as being together (see examples).

Sign Description: Provide a description of the sign marking.

MUTCD Code: Refer to Appendix A: Excerpts from 2009 MUTCD for each sign's code.

Roadside Location: **Right, Median, or Overhead.** A sign assembly on a rigid structure from the right or median with a mast arm overhead is considered an Overhead location (see Exhibit 48).

Width: Measure the **width** of the **sign (inches)**.

Height: Measure the **height** of the **sign (inches)**.

Retroreflectivity: Measure the retroreflectivity of the sign using a retroreflectometer. A sign with a retroreflective surface will direct all of the reflected light back towards the light source rather than disperse it in all directions.

Other Estimate of Retroreflectivity: Use a numerical value system to measure the retroreflectivity of the sign and please specify your value system.

Comments: Use this field to describe anything that may appear out of the ordinary and to denote any damage to the sign.

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 53: Ground-Mounted Traffic Signs

Exhibit 54: Ground-Mounted Traffic Sign

Exhibit 55: Overhead Traffic Signs

Exhibit 56: Overhead Traffic Signs

Traffic Signs

Course Milepost	Latitude	Longitude	Ground Mounted	Overhead	Number of Signs on Assembly	Sign Description	MUTCD Code	Roadway Location	Size		Other Estimate of Retro-reflectivity	Retro-reflectivity (mcd/m^2/lux)	Comments
									Width (in)	Height (in)			
17.26 (Exhibit 53)	35.76803	78.65948	x		7	I-40	M1-1	Right	24	24		98	
17.26 (Exhibit 53)	35.76803	78.65948	x		7	To	M4-5	Right	24	12		112	
17.26 (Exhibit 53)	35.76803	78.65948	x		7	Forward Arrow	M6-3	Right	16	12		102	
17.26 (Exhibit 53)	35.76803	78.65948	x		7	Edwards Mill Rd.	D1-1	Right	72	12		114	
17.26 (Exhibit 53)	35.76803	78.65948	x		7	To	M4-5	Right	24	12		77	
17.26 (Exhibit 53)	35.76803	78.65948	x		7	US 70	M1-4	Right	24	24		84	
17.26 (Exhibit 53)	35.76803	78.65948	x		7	Right Arrow	M6-1	Right	16	12		97	
18.90 (Exhibit 54)	35.76808	78.65956	x		1	Speed Limit 45	R2-1	Right	30	30		154	Knocked Over
17.26 (Exhibit 55)	35.76803	78.65948		x	5	16 to 24 Exit Ahead	M2-2	Overhead	96	60		98	
17.26 (Exhibit 55)	35.76803	78.65948		x	5	Exit 36		Overhead	42	12		112	
17.26 (Exhibit 55)	35.76803	78.65948		x	5	Lane Ends 1000’		Overhead	42	48		102	
17.26 (Exhibit 55)	35.76803	78.65948		x	5	Exit 35		Overhead	42	12		114	

17.26 (Exhibit 55)	35.76803	78.65948		x	5	Glenwood Dr. Exit Only		Overhead	96	30		115	
17.46 (Exhibit 56)	35.76853	78.65962		x	2	Speedway Blvd - Concorde Mills Blvd.	M2-2	Overhead	96	42		84	
17.46 (Exhibit 56)	35.76853	78.65962		x	2	Exit 49		Overhead	42	12		97	

**** Note: Each sign is denoted as a single row. An assembly with 7 signs (see Table above) will have the same point location and number of signs on assembly for each signs designated row.***

Words & Symbols (Point)

Feature Description

Words and symbols on the pavement may be used for the purpose of guiding, warning, or regulating traffic. Some examples are Right Turn Arrows, Merge Arrows, Stop Bars, Lane Ends, etc. Data should be collected across all lanes (including turning bays).

Data Collection Instructions

- Words & Symbols data should be collected across all lanes (including turning bays) along the entire test route.

Data Collection Fields

Location: The Starting/Ending points include the **course milepost**, **latitude**, and **longitude.**

Description: Note what the symbol or words are indicating.

Field Inspection Required: Yes or No (i.e. the words or symbols are present and visible.)

If Yes, field inspection required due to:

- If portions of the word or symbol is missing or obliterated
- The Word/Symbol is non-retroreflective,

Comments: Use this field to describe the reason a field inspection is needed.

Note: The following exhibits are referenced in the example data collection spreadsheet.

Exhibit 57: School Zone Crossing

Exhibit 58: Right-Turn Symbol

Pavement Markings: Words & Symbols					
Course Milepost	Latitude	Longitude	Description	Field Inspection Required	Comments
17.26 (Exhibit 57)	35.76803	78.65948	School Crosswalk	Yes	Not visible
18.00 (Exhibit 58)	35.76714	78.65921	Right Turn Arrow	Yes	Non-retroreflective

Vertical Curves (Linear)

Feature Description

Vertical curves are crest or sag curves. Vertical curves are placed between two tangents of differing grades to have a smooth transition for motoring public.

Data Collection Instructions

- Data should be collected across all lanes (including turning bays) along the entire test route.

Data Collection Fields

Location Point: The location points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of the curve in **linear feet.** The length should be measured along the curve between the beginning and end points (2 tangents).

Comments: Use this field to describe the reason a field inspection is needed. Any comments will typically follow a response in the "Field Inspection Required."

Vertical Curves			
Location Point			Total Length (ft)
Course Milepost	Latitude	Longitude	
17.26	35.76809	78.65948	515
17.99	35.76812	78.65949	1545
18.45	35.76809	78.65954	689
20.36	35.76809	78.65954	2232
21.49	35.76811	78.65957	1589
22.36	35.76813	78.65958	4260
24.12	35.76816	78.65959	3695

Horizontal Curves (Linear)

Feature Description

Horizontal curves are placed between two tangents of differing azimuth's to have a smooth transition in direction for motoring public.

Data Collection Instructions

- Horizontal Curve data should be collected along the entire test route (including ramps).

Data Collection Fields

Location Point: The location points include the **course milepost**, **latitude**, and **longitude.**

Length: Note the total length of the curve in **linear feet.** The length should be measured along the curve between the beginning and end points (2 tangents).

Cross Slope: This is recorded as the maximum cross slope encountered on the curve.

Radius: Measure the radius of the horizontal curve in **feet.**

Horizontal Curves					
Location Point			Radius (ft)	Total Length (ft)	CrossSlope (%)
Course Milepost	Latitude	Longitude			
17.26	35.76809	78.65948	1200	547	5.80%
17.87	35.76812	78.65949	2460	849	6.10%
19.45	35.76809	78.65954	1843	1644	3.64%
20.36	35.76809	78.65954	6451	978	4.67%

Appendix A: Excerpts from 2009 MUTCD

Table 2B-1. Regulatory Sign and Plaque Sizes (Sheet 1 of 4)

Sign or Plaque	Sign Designation	Section	Conventional Road: Single Lane	Conventional Road: Multi-Lane	Expressway	Freeway	Minimum	Oversized
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2B-1. Regulatory Sign and Plaque Sizes (Sheet 2 of 4)

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—
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Table 2B-1. Regulatory Sign and Plaque Sizes (Sheet 3 of 4)

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—

Table 2B-1. Regulatory Sign and Plaque Sizes (Sheet 4 of 4)

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]

* [illegible]

Notes: 1. [illegible]
2. [illegible]

Table 2C-1. Categories of Warning Signs and Plaques

Category	Group	Section	Signs or Plaques	Sign Designations
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]

Table 2C-2. Warning Sign and Plaque Sizes (Sheet 1 of 3)

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2C-2. Warning Sign and Plaque Sizes (Sheet 2 of 3)

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
Pavement Ends	W8-3	2C.30	36 x 36	36 x 36	48 x 48	—	30 x 30*	—
Soft Shoulder	W8-4	2C.31	36 x 36	36 x 36	48 x 48	48 x 48	24 x 24*	48 x 48
Slippery When Wet	W8-5	2C.32	30 x 30*	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Road Condition (plaques)	W8-5P,5bP,5cP	2C.32	24 x 18	24 x 18	30 x 24	36 x 30	—	36 x 30
Ice	W8-5aP	2C.32	24 x 12	24 x 12	30 x 18	30 x 18	—	—
Truck Crossing	W8-6	2C.49	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Loose Gravel	W8-7	2C.32	36 x 36	36 x 36	36 x 36	—	24 x 24*	48 x 48
Rough Road	W8-8	2C.32	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Low Shoulder	W8-9	2C.31	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Uneven Lanes	W8-11	2C.32	36 x 36	36 x 36	36 x 36	48 x 48	—	48 x 48
No Center Line	W8-12	2C.34	36 x 36	36 x 36	36 x 36	48 x 48	—	—
Bridge Ices Before Road	W8-13	2C.32	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Fallen Rocks	W8-14	2C.32	30 x 30*	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Grooved Pavement	W8-15	2C.33	30 x 30*	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Motorcycle (plaque)	W8-15P	2C.33	24 x 18	24 x 18	30 x 24	36 x 30	—	36 x 30
Metal Bridge Deck	W8-16	2C.33	30 x 30*	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Shoulder Drop Off (symbol)	W8-17	2C.31	30 x 30*	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Shoulder Drop-Off (plaque)	W8-17P	2C.31	24 x 18	24 x 18	30 x 24	36 x 30	—	36 x 30
Road May Flood	W8-18	2C.35	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Flood Gauge	W8-19	2C.35	12 x 72	12 x 72	—	—	—	—
Gusty Winds Area	W8-21	2C.35	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Fog Area	W8-22	2C.35	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
No Shoulder	W8-23	2C.31	36 x 36	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Shoulder Ends	W8-25	2C.31	30 x 30*	36 x 36	36 x 36	48 x 48	24 x 24*	48 x 48
Left (Right) Lane Ends	W9-1	2C.42	36 x 36	36 x 36	36 x 36	48 x 48	30 x 30*	48 x 48
Lane Ends Merge Left (Right)	W9-2	2C.42	36 x 36	36 x 36	36 x 36	48 x 48	30 x 30*	48 x 48
Right (Left) Lane Exit Only Ahead	W9-7	2C.43	132 x 72	132 x 72	132 x 72	132 x 72	—	—
Bicycle	W11-1	2C.49	30 x 30	30 x 30	36 x 36	—	24 x 24*	48 x 48
Pedestrian	W11-2	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Large Animals	W11-3,4,16,17,18,19,20,21,22	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Farm Vehicle	W11-5,5a	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Snowmobile	W11-6	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Equestrian	W11-7	2C.50	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Emergency Vehicle	W11-8	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Handicapped	W11-9	2C.50	30 x 30*	36 x 36	36 x 36	—	—	48 x 48
Truck	W11-10	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Golf Cart	W11-11	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Emergency Signal Ahead (plaque)	W11-12P	2C.49	36 x 30	36 x 30	36 x 30	—	—	—
Horse-Drawn Vehicle	W11-14	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Bicycle / Pedestrian	W11-15	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Trail Crossing	W11-15a	2C.49	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48
Trail X-ing (plaque)	W11-15P	2C.49	24 x 18	24 x 18	30 x 24	—	—	36 x 30
Double Arrow	W12-1	2C.25	30 x 30*	36 x 36	36 x 36	—	—	—
Low Clearance (with arrows)	W12-2	2C.27	36 x 36	36 x 36	48 x 48	48 x 48	30 x 30*	—
Low Clearance	W12-2a	2C.27	78 x 24	78 x 24	—	—	—	—
Advisory Speed (plaque)	W13-1P	2C.08	18 x 18	18 x 18	24 x 24	30 x 30	—	30 x 30
Advisory Exit or Ramp Speed	W13-2,3	2C.14	24 x 30	24 x 30	36 x 48	36 x 48	—	48 x 60
Combination Horizontal Alignment/Advisory Exit or Ramp Speed	W13-6,7	2C.15	24 x 42	24 x 42	36 x 60	36 x 60	—	48 x 84
Dead End, No Outlet	W14-1,2	2C.26	30 x 30*	36 x 36	36 x 36	—	24 x 24*	48 x 48

Table 2C-2. Warning Sign and Plaque Sizes (Sheet 3 of 3)

Sign or Plaque	Sign Designation	Section	Conventional Road		Expressway	Freeway	Minimum	Oversized
			Single Lane	Multi-Lane				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	—	—	—	[illegible]	—	—
[illegible]	[illegible]	[illegible]	—	—	[illegible]	—	—	—
[illegible]	[illegible]	[illegible]	—	—	—	[illegible]	—	—
[illegible]	[illegible]	[illegible]	—	—	[illegible]	—	—	—
[illegible]	[illegible]	[illegible]	—	—	[illegible]	[illegible]	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—

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Notes: 1. Larger signs may be used when appropriate.
2. Dimensions in inches are shown as width x height.

Table 2D-1. Conventional Road Guide Sign Sizes

Sign	Sign Designation	Section	Conventional Road	Minimum	Oversized
Interstate Route Sign (1 or 2 digits)	M1-1	2D.11	24 x 24	24 x 24	36 x 36
Interstate Route Sign (3 digits)	M1-1	2D.11	30 x 24	30 x 24	45 x 36
Off-Interstate Route Sign (1 or 2 digits)	M1-2,3	2D.11	24 x 24	24 x 24	36 x 36
Off-Interstate Route Sign (3 digits)	M1-2,3	2D.11	30 x 24	30 x 24	45 x 36
U.S. Route Sign (1 or 2 digits)	M1-4	2D.11	24 x 24	24 x 24	36 x 36
U.S. Route Sign (3 digits)	M1-4	2D.11	30 x 24	30 x 24	45 x 36
State Route Sign (1 or 2 digits)	M1-5	2D.11	24 x 24	24 x 24	36 x 36
State Route Sign (3 digits)	M1-5	2D.11	30 x 24	30 x 24	45 x 36
County Route Sign (1, 2, or 3 digits)	M1-6	2D.11	24 x 24	24 x 24	36 x 36
Forest Route (1, 2, or 3 digits)	M1-7	2D.11	24 x 24	18 x 18	36 x 36
Junction	M2-1	2D.13	21 x 15	21 x 15	30 x 21
Combination Junction (2 route signs)	M2-2	2D.14	60 x 48*	—	—
Cardinal Direction	M3-1,2,3,4	2D.15	24 x 12	24 x 12	36 x 18
Alternate	M4-1,1a	2D.17	24 x 12	24 x 12	36 x 18
By-Pass	M4-2	2D.18	24 x 12	24 x 12	36 x 18
Business	M4-3	2D.19	24 x 12	24 x 12	36 x 18
Truck	M4-4	2D.20	24 x 12	24 x 12	36 x 18
To	M4-5	2D.21	24 x 12	24 x 12	36 x 18
End	M4-6	2D.22	24 x 12	24 x 12	36 x 18
Temporary	M4-7,7a	2D.24	24 x 12	24 x 12	36 x 18
Begin	M4-14	2D.23	24 x 12	24 x 12	36 x 18
Advance Turn Arrow	M5-1,2,3	2D.28	21 x 15	21 x 15	—
Lane Designation	M5-4,5,6	2D.33	24 x 18	24 x 18	36 x 24
Directional Arrow	M6-1,2,2a,3,4, 5,6,7	2D.29	21 x 15	21 x 15	30 x 21
Destination (1 line)	D1-1	2D.39	Varies x 18	Varies x 18	—
Destination and Distance (1 line)	D1-1a	2D.39	Varies x 18	Varies x 18	—
Circular Intersection Destination (1 line)	D1-1d	2D.40	Varies x 18	Varies x 18	—
Circular Intersection Departure Guide	D1-1e	2D.40	Varies x 42*	—	—
Destination (2 lines)	D1-2	2D.39	Varies x 30	Varies x 30	—
Destination and Distance (2 lines)	D1-2a	2D.39	Varies x 30	Varies x 30	—
Circular Intersection Destination (2 lines)	D1-2d	2D.40	Varies x 30	Varies x 30	—
Destination (3 lines)	D1-3	2D.39	Varies x 42	Varies x 42	—
Destination and Distance (3 lines)	D1-3a	2D.39	Varies x 42	Varies x 42	—
Circular Intersection Destination (3 lines)	D1-3d	2D.40	Varies x 42	Varies x 42	—
Distance (1 line)	D2-1	2D.43	Varies x 18	Varies x 18	—
Distance (2 lines)	D2-2	2D.43	Varies x 30	Varies x 30	—
Distance (3 lines)	D2-3	2D.43	Varies x 42	Varies x 42	—
Street Name (1 line)	D3-1,1a	2D.45	Varies x 12	Varies x 8	Varies x 18
Advance Street Name (2 lines)	D3-2	2D.46	Varies x 30*	—	—
Advance Street Name (3 lines)	D3-2	2D.46	Varies x 42*	—	—
Advance Street Name (4 lines)	D3-2	2D.46	Varies x 60*	—	—
Parking Area	D4-1	2D.49	30 x 24	18 x 15	—
Park - Ride	D4-2	2D.50	30 x 36	24 x 30	36 x 48
National Scenic Byways	D6-4	2D.56	24 x 24	24 x 24	—
National Scenic Byways	D6-4a	2D.56	24 x 12	24 x 12	—
Weigh Station XX Miles	D8-1	2D.51	78 x 60	60 x 48	96 x 72
Weigh Station Next Right	D8-2	2D.51	84 x 72	66 x 54	108 x 90
Weigh Station (with arrow)	D8-3	2D.51	66 x 60	48 x 42	84 x 78
Crossover	D13-1,2	2D.55	60 x 30	60 x 30	78 x 42
Freeway Entrance	D13-3	2D.48	48 x 30	48 x 30	—
Freeway Entrance (with arrow)	D13-3a	2D.48	48 x 42	48 x 42	—
Combination Lane Use / Destination	D15-1	2D.35	Varies x 96	Varies x 96	—
Next Truck Lane XX Miles	D17-1	2D.53	42 x 48	42 x 48	60 x 66
Truck Lane XX Miles	D17-2	2D.53	42 x 42	42 x 42	60 x 54
Slow Vehicle Turn-Out XX Miles	D17-7	2D.54	72 x 42	72 x 42	96 x 54

*The size shown is for a typical sign. The size should be appropriately based on the amount of legend required for the sign.

Table 2E-1. Freeway or Expressway Guide Sign and Plaque Sizes (Sheet 1 of 2)

Sign or Plaque	Sign Designation	Section	Minimum Size
Exit Number (plaque)			
1-, 2-Digit Exit Number	E1-5P	2E.31	114 x 30
3-Digit Exit Number	E1-5P	2E.31	132 x 30
1-, 2-Digit Exit Number (with single letter suffix)	E1-5P	2E.31	138 x 30
3-Digit Exit Number (with single letter suffix)	E1-5P	2E.31	156 x 30
1-, 2-Digit Exit Number (with dual letter suffix)	E1-5P	2E.31	168 x 30
3-Digit Exit Number (with dual letter suffix)	E1-5P	2E.31	186 x 30
Left (plaque)	E1-5aP	2E.33	72 x 30
Left Exit Number (plaque)			
1-, 2-Digit Exit Number	E1-5bP	2E.31	114 x 54
3-Digit Exit Number	E1-5bP	2E.31	132 x 54
1-, 2-Digit Exit Number (with single letter suffix)	E1-5bP	2E.31	138 x 54
3-Digit Exit Number (with single letter suffix)	E1-5bP	2E.31	156 x 54
1-, 2-Digit Exit Number (with dual letter suffix)	E1-5bP	2E.31	168 x 54
3-Digit Exit Number (with dual letter suffix)	E1-5bP	2E.31	186 x 54
Next Exit XX Miles (1 line)	—	2E.34	Varies x 24
Next Exit XX Miles (2 lines)	—	2E.34	Varies x 36
Exit Gore (no exit number)	E5-1	2E.37	72 x 60
Exit Gore (with exit number)			
1-, 2-Digit Exit Number	E5-1a	2E.37	78 x 60
3-Digit Exit Number	E5-1a	2E.37	96 x 60
1-Digit Exit Number (with single letter suffix)	E5-1a	2E.37	90 x 60
2-Digit Exit Number (with single letter suffix)	E5-1a	2E.37	108 x 60
3-Digit Exit Number (with single letter suffix)	E5-1a	2E.37	126 x 60
1-Digit Exit Number (with dual letter suffix)	E5-1a	2E.37	120 x 60
2-Digit Exit Number (with dual letter suffix)	E5-1a	2E.37	138 x 60
3-Digit Exit Number (with dual letter suffix)	E5-1a	2E.37	156 x 60
Exit Number (plaque)			
1-, 2-Digit Exit Number	E5-1bP	2E.37	42 x 30
3-Digit Exit Number	E5-1bP	2E.37	60 x 30
1-Digit Exit Number (with single letter suffix)	E5-1bP	2E.37	48 x 30
1-Digit Exit Number (with dual letter suffix)	E5-1bP	2E.37	72 x 30
2-Digit Exit Number (with single or dual letter suffix)	E5-1bP	2E.37	72 x 30
3-Digit Exit Number (with single or dual letter suffix)	E5-1bP	2E.37	72 x 30
Narrow Exit Gore	E5-1c	2E.37	60 x 90*
Pull-Through	E6-2	2E.12	Varies x 120*
Pull-Through	E6-2a	2E.12	Varies x 90*
Exit Only (with arrow)	E11-1,1d	2E.24	174** x 36
Exit	E11-1a	2E.24	66 x 18
Only	E11-1b	2E.24	66 x 18
Exit Only	E11-1c	2E.24	120 x 18
Exit Only (with two arrows)	E11-1e,1f	2E.24	222** x 36
Left	E11-2	2E.40	60 x 18
Exit Gore Advisory Speed (plaque)	E13-1P	2E.37	72 x 24
Exit Direction Advisory Speed	E13-2	2E.36	162 x 24
Interstate Route Sign (1 or 2 digits)	M1-1	2E.27	36 x 36
Interstate Route Sign (3 digits)	M1-1	2E.27	45 x 36
Off-Interstate Route Sign (1 or 2 digits)	M1-2,3	2E.27	36 x 36
Off-Interstate Route Sign (3 digits)	M1-2,3	2E.27	45 x 36
U.S. Route Sign (1 or 2 digits)	M1-4	2E.27	36 x 36
U.S. Route Sign (3 digits)	M1-4	2E.27	45 x 36
State Route Sign (1 or 2 digits)	M1-5	2D.11	36 x 36

Table 2E-1. Freeway or Expressway Guide Sign and Plaque Sizes (Sheet 2 of 2)

Sign or Plaque	Sign Designation	Section	Minimum Size
State Route Sign (3 digits)	M1-5	2D.11	45 x 36
County Route Sign (1, 2, or 3 digits)	M1-6	2D.11	36 x 36
Forest Route (1, 2, or 3 digits)	M1-7	2D.11	36 x 36
Eisenhower Interstate System	M1-10,10a	2E.28	36 x 36
Junction	M2-1	2D.13	30 x 21
Combination Junction (2 route signs)	M2-2	2D.14	60 x 48*
Cardinal Direction	M3-1,2,3,4	2D.15	36 x 18
Alternate	M4-1,1a	2D.17	36 x 18
By-Pass	M4-2	2D.18	36 x 18
Business	M4-3	2D.19	36 x 18
Truck	M4-4	2D.20	36 x 18
To	M4-5	2D.21	36 x 18
End	M4-6	2D.22	36 x 18
Temporary	M4-7,7a	2D.24	36 x 18
Begin	M4-14	2D.23	36 x 18
Advance Turn Arrow	M5-1,2,3	2D.26	30 x 21
Lane Designation	M5-4,5,6	2D.27	36 x 24
Directional Arrow	M6-1,2,2a,3,4,5,6,7	2D.28	30 x 21
Destination (1 line)	D1-1	2D.37	Varies x 30
Destination and Distance (1 line)	D1-1a	2D.37	Varies x 30
Destination (2 lines)	D1-2	2D.37	Varies x 54
Destination and Distance (2 lines)	D1-2a	2D.37	Varies x 54
Destination (3 lines)	D1-3	2D.37	Varies x 72
Destination and Distance (3 lines)	D1-3a	2D.37	Varies x 72
Distance (1 line)	D2-1	2D.41	Varies x 30
Distance (2 lines)	D2-2	2D.41	Varies x 54
Distance (3 lines)	D2-3	2D.41	Varies x 72
Street Name	D3-1,1a	2D.43	Varies x 18
Advance Street Name (2 lines)	D3-2	2D.44	Varies x 42*
Advance Street Name (3 lines)	D3-2	2D.44	Varies x 66*
Advance Street Name (4 lines)	D3-2	2D.44	Varies x 84*
Park - Ride	D4-2	2D.48	36 x 48
National Scenic Byways	D6-4	2D.55	24 x 24
National Scenic Byways	D6-4a	2D.55	24 x 12
Weigh Station XX Miles	D8-1	2E.54	96 x 72 (F) 78 x 60 (E)
Weigh Station Next Right	D8-2	2E.54	108 x 90 (F) 84 x 72 (E)
Weigh Station (with arrow)	D8-3	2E.54	84 x 78 (F) 66 x 60 (E)
Crossover	D13-1,2	2D.54	78 x 42
Freeway Entrance	D13-3	2D.46	48 x 30
Freeway Entrance (with arrow)	D13-3a	2D.46	48 x 42
Combination Lane Use / Destination	D15-1	2D.33	Varies x 96
Next Truck Lane XX Miles	D17-1	2D.51	60 x 66
Truck Lane XX Miles	D17-2	2D.51	60 x 54
Slow Vehicle Turn-Out XX Miles	D17-7	2D.52	96 x 54

* The size shown is for a typical sign as illustrated in the figures in Chapters 2D and 2E. The size should be determined based on the amount of legend required for the sign.

** The width shown represents the minimum dimension. The width shall be increased as appropriate to match the width of the guide sign.

Notes: 1. Larger signs may be used when appropriate
2. Dimensions in inches are shown as width x height
3. Where two sizes are shown, the larger size is for freeways (F) and the smaller size is for expressways (E)

Appendix B: Acknowledgement of Data Ownership Form

Transfer of Data Ownership Form

I, ______________________________ **(Print Name)**, acknowledge that the data submitted as part of NCDOT 2011-02 research project "Comparison of Data Collection Vehicles to Human Collection Methods" are henceforth the property of the NCDOT and NCSU.

Signature: __________________________

Title: __________________________

Company: ______________________

Date: __________________________

1.3. Appendix C: Preliminary Submission Findings (Pathway Services, Inc.)

TO: Rudy Blanco, Pathways
.

FROM: Christopher M. Cunningham, Senior Research Associate
Institute for Transportation Research and Education (ITRE)
North Carolina State University
cmcunnin@ncsu.edu
(919) 515-8562

DATE: February 6, 2012

RE: Asset Data Collection Demo

Dear Rudy:

Thank you for your Fall 2011 submittal of collected data for the NCDOT research project 2011-02, "Comparison of Data Collection Vehicles to Human Collection Methods." We have reviewed a sample of the second half of the submission and are pleased with your work. This memo serves to evaluate the data collection effort by providing you with a summary of feedback on each of the elements you collected. The attached summary for each asset shows four different pieces of information as follows:

1. Sample size of analysis
2. A brief location analysis
    - *How many of the sample was located incorrectly.*
3. Attributes Analysis
    - *Any noteworthy errors in the collected features, such as accuracy of roadside location or inspection required.*
4. Possible sources of error.
    - *Examples include definition issue, no apparent reason for error, vendor bias, impossible to collect.*

The primary focus of this analysis is the comparison of locating elements, where a small sample of data was acquired from a full data set (where applicable). While some comments have been made with respect to condition and type, this comparison is not exhaustive.

Additionally, we will be updating the Catalog with any instructions that may have been unclear or confusing following our conference call scheduled for 2:30 PM EST on Tuesday, February 7, 2012. You will be provided sufficient time to recollect any data you feel necessary following this conference call. All recollected data needs to be submitted by **Friday, March 2, 2012.**

We appreciate your involvement in this effort and hope we can continue to proceed towards a successful data collection effort. If there are any questions or concerns, please let us know.

Respectfully,

Christopher M. Cunningham, PE

Vendor Data Collection Summary

Elements to be covered in our next conference call are denoted by an asterisk (*).

PAVED SHOULDER

1. Sample of 30
2. Location Analysis
   - *7 missed*
3. Attributes Analysis
   - *8 of the 30 segments sampled were identified as significantly shorter than the actual segment length.*
4. Possible Sources of Error
   - *Definition Issue. The missing paved shoulder lengths were identified as unpaved shoulder.*

UNPAVED SHOULDER

1. Sample of 30
2. Location Analysis
   - *0 missed*
3. Attributes Analysis
   - *Only 6% of the collected data was noted as "Inspection Required." Based on ITREs analysis, approximately 50% of the sample required inspection.*
4. Possible Sources of Error
   - *Definition Issue or Impossible to Collect. The low/high shoulder definition may need to be more clearly illustrated in the Catalog in order to accurately collect a failing segment. It is possible the vendor is unable to collect this type of assessment.*

*LATERAL DITCHES**

1. Sample of 131
2. Location Analysis
   - Missing segments and differences in start/ending points of the segments create differences in total lengths. The length differences below reflect total lengths found along the arterials of the route.
   - Visual examples of missing segments are provided in the attached PowerPoint.
     - *Total Length Collected along Hwy 16 (Pathways): 15,335 feet*
     - *Total Length Collected along Hwy 16 (Manual/ITRE): 33,659 feet*
     - *Total Length Collected along Hwy 24(Pathways): 27,011 feet*
     - *Total Length Collected along Hwy 24 (Manual/ITRE): 37,075 feet*
3. Attributes Analysis
   - Failures and roadside locations were accurately located.
4. Possible Sources of Error
   - *No Apparent Reasons for Error. Visual examples of missed segments are included in the attached PowerPoint.*

CURB & GUTTER

1. Sample of 30
2. Location Analysis
   - *7 missed*
3. Attributes Analysis
   - *3 – Arterial, Median*
   - *4 – Interstate, Right*
4. Possible Sources of Error

- *No Apparent Reasons for Error.*
    - *Note: 2 missing arterial segments were found at left turn cut outs.*

BRUSH & TREE

1. Sample not possible
    - Only 6 segments were identified by the vendor
2. Location Analysis
    - *Of the 6 identified by the vendor, only 4 segments were correctly located.*
3. Attributes Analysis
    - *All segments were identified as "requiring inspection."*
    - *Of the 4 segments correctly located, each was incorrectly identified as "requiring inspection."*
4. Possible Sources of Error
    - *Definition Issue. A full Inventory including all segments of Brush & Tree within 45' of the travelway is needed for this asset to be fully assessed.*

TURF

1. Sample of 20
2. Location Analysis
    - *3 missed*
3. Attributes Analysis
    - *N/A*
4. Possible Sources of Error
    - *No Apparent Reasons for Error.*
        - *1 missed within median*
        - *2 missed on the right side of the roadway*

*SLOPES**

1. Sample of 7 failures.
2. Location Analysis
    - *1 missed.*
3. Attributes Analysis
    - *4 slopes were accurately noted as "inspection required."*
    - *2 slopes were accurately located, but incorrectly noted as "inspection not needed."*
4. Possible Sources of Error
    - *Definition Issue. Catalog instructions may not be sufficient to identify slope segments requiring inspection. Visual example included in the attached PowerPoint.*

LANDSCAPE AREAS

1. Total Landscape Areas (Ramps): 7
2. Location Analysis
    - *0 missed*
3. Attributes Analysis
    - *Incorrectly identified 1 area as "no inspection needed."*
4. Possible Sources of Error
    - *Definition Issue. Should the definition of each rating be more clearly illustrated?*

*CONCRETE BARRIERS**

1. Sample of 55
2. Location Analysis
    - *2 missed (on either side of a bridge)*

3. Attributes Analysis
    - 1 sample mislabeled a retaining wall as a concrete barrier to the right of the roadway.
4. Possible Sources of Error
    - *No Apparent Reasons for Error.*

GUARDRAIL

1. Sample of 23
2. Location Analysis
    - *0 missed*
3. Attributes Analysis
    - *2 segments lengths were incorrect.*
4. Possible Sources of Error
    - *No Apparent Reasons for Error. The entire length of guardrail should be recorded, including failed segments.*

*PAVEMENT**

1. Sample of 4 failed pavement segments were selected.
2. Location Analysis
    - *Pavement along the entire route was appropriately collected.*
3. Attributes Analysis
    - *3 of the 4 located failed segments were correctly identified as requiring an inspection.*
    - *1 segment failed to be noted as "inspection required." Visual of missed failure is attached.*
4. Possible Sources of Error
    - *No Apparent Reasons for Error.*

RETAINING WALLS

1. Sample of 4
2. Location Analysis
    - *1 missed*
3. Attributes Analysis
    - *Missed lengths were found along I-85 bridge abutment.*
4. Possible Sources of Error
    - *Definition Issue. Segments found along bridges should also be included in the inventory.*

MEDIAN

1. Sample of 30
2. Location Analysis
    - *1 missed*
3. Attributes Analysis
    - *N/A*
4. Possible Sources of Error
    - *No Apparent Reasons for Error.*

ROADWAY LANES

1. Sample of 30
2. Location Analysis
    - *0 missed*
3. Attributes Analysis
    - *2 assets incorrectly identified the number of lanes.*
4. Possible Sources of Error

- *Definition Issue. Roadway Lane inventory and number of lanes present should be collected at the end of a transition, where the lane has become fully developed.*

RUMBLE STRIPS

1. Sample of 15
2. Location Analysis
    - *0 missed*
3. Attributes Analysis
    - *N/A*
4. Possible Sources of Error
    - *Sufficient inventory collected.*

ACCESS POINTS

1. Sample of 30
2. Location Analysis
    - *5 missed*
3. Attributes Analysis
    - *N/A*
4. Possible Sources of Error
    - *Definition Issue. 2 of 5 missed were located at ramps.*
    - *Include both on AND off ramps as 2 separate access points. Include every access point, i.e. if one business has two access points (such as a horseshoe driveway), count both separately.*

INLETS

1. Sample of 30
2. Location Analysis
    - *9 missed*
3. Attributes Analysis
    - *N/A*
4. Possible Sources of Error
    - *Medians difficult for vendor to collect. Missed inlets were located in wide medians with tall landscaping.*

ATTENUATORS/END TREATMENTS

1. Sample of 30
2. Location Analysis
    - *6 missed*
3. Attributes Analysis
    - *N/A*
4. Possible Sources of Error
    - *Definition Issue or Impossible to Collect. 4 missed attenuators/end treatments were facing away from the direction of travel. 1 missed was located on the right, curving away from the direction of travel.*

BRIDGES

1. Sample of 17
2. Location Analysis
    - *3 missed*
3. Attributes Analysis
    - *N/A*
4. Possible Sources of Error
    - *Definition Issue. Each bridge structure should be identified as a single asset.*

MEDIAN OPENINGS

1. Sample of 30
2. Location Analysis
   - *3 missed*
3. Attributes Analysis
   - *N/A*
4. Possible Sources of Error
   - *No Apparent Reasons for Error. 2 of the missed assets were at left turn cut outs.*

TRAFFIC SIGNS (GROUND)

1. Sample of 30
2. Location Analysis
   - *8 missed*
3. Attributes Analysis
   - N/A
4. Possible Sources of Error
   - *No Apparent Reasons for Error.*

TRAFFIC SIGNS (OVERHEAD)

1. Sample of 30
2. Location Analysis
   - *5 missed*
3. Attributes Analysis
   - *N/A*
4. Possible Sources of Error
   - *No Apparent Reasons for Error.*

*WORDS & SYMBOLS**

1. Sample of 29
2. Location Analysis
   - *All Words & Symbols sampled were accurately located within 20 feet*
3. Attributes Analysis
   - *26 samples were correctly noted as "inspection required."*
   - *3 samples were incorrectly noted as "inspection required."*
4. Possible Sources of Error
   - *No Apparent Reasons for Error. Visual examples of incorrectly labeled elements included in the attached PowerPoint.*

*CENTERLINE**

1. Sample of 30
2. Location Analysis
   - *Accurately located centerline data at all sampled locations.*
3. Attributes Analysis
   - *In progress.*
4. Possible Sources of Error
   - *No errors noted.*

*HORIZONTAL CURVES**

1. Sample of 19 Curves
2. Location Analysis

- *Successful location match.*

3. Attributes Analysis
    - *Total Curve Length Identified: 34,837 feet*
        - *Expected Total Length: 27,102 feet*
        - *Average Curve Length Difference per Curve: 807 feet*
    - *Total Radius: 65,764 feet*
        - *Expected Total Radius: 73,717 feet*
        - *Average Radius Difference per Curve: 1,158 feet*
4. Possible Sources of Error
    - *No Apparent Reasons for Error. Difference in collection methods may lead to difference in attributes.*

ADDITIONAL COMMENTS

Pavement Marking & Striping

- Vendor data set is collected at various segments lengths. Data should be collected every 100 feet.
- Centerline information seems to be missing. (Only 1 entry labeled “centerline” is present, found in the Pavement Markings & Striping data set.)

Raised Pavement Markers (RPM)

- Though the vendor correctly identified RPM throughout the entire course, the number of RPM in each 1/10th mile segment was not included.

1.4. Appendix D: Preliminary Submission Findings (Fugro Roadware)

TO: Geoff Dew, Fugro Roadware, Inc.

FROM: Christopher M. Cunningham, Senior Research Associate
Institute for Transportation Research and Education (ITRE)
North Carolina State University
cmcunnin@ncsu.edu
(919) 515-8562

DATE: February 15, 2012

RE: Asset Data Collection Demo

Dear Geoff:

Thank you for your Fall 2011 submittal of collected data for the NCDOT research project 2011-02, “Comparison of Data Collection Vehicles to Human Collection Methods.” We have reviewed a sample of the second half of the submission and are pleased with your work. This memo serves to evaluate the data collection effort by providing you with a summary of feedback on each of the elements you collected. The attached summary for each asset shows four different pieces of information as follows:

1. Sample size of analysis
2. A brief location analysis
   - *How many of the sample was located incorrectly.*
3. Attributes Analysis
   - *Any noteworthy errors in the collected features, such as accuracy of roadside location or inspection required.*
4. Possible sources of error.
   - *Examples include definition issue, no apparent reason for error, vendor bias, Impossible to collect.*

The primary focus of this analysis is the comparison of locating elements, where a small sample of data was acquired from a full data set (where applicable). While some comments have been made with respect to condition and type, this comparison is not exhaustive.

Additionally, we will be updating the Catalog with any instructions that may have been unclear or confusing following our conference call scheduled for **1:00 PM EST on Friday, February 17.** You will be provided sufficient time to recollect any data you feel necessary following this conference call. All recollected data needs to be submitted by **Thursday, March 2, 2012.**

We appreciate your involvement in this effort and hope we can continue to proceed towards a successful data collection effort. If there are any questions or concerns, please let us know.

Respectfully,

Christopher M. Cunningham, PE

Vendor Data Collection Summary

PAVED SHOULDER

1. Sample of 32
2. Location Analysis
   - 2 missed
3. Attributes Analysis
   - None noted.
4. Possible sources of error
   - *No apparent reason for errors*

UNPAVED SHOULDER

1. Sample of 30
2. Location Analysis
   - 0 missed
3. Attributes Analysis
   - None noted.
4. Possible sources of error
   - *Errors were primarily found in the length category*

*LATERAL DITCHES**

1. Sample of 131
2. Location Analysis
   - Missing segments and differences in start/ending points of the segments create differences in total lengths. The length differences below reflect total lengths found along a particular segment of roadway. Visual street views of missing segments are provided in the attached PowerPoint.
3. Attributes Analysis
   - Differences may be due to missing segments or differences in start/ending points.
4. Possible Sources of Error
   - ▪ *Visual examples of missed lengths and possible errors in additional lengths are included in the attached PowerPoint.*

CURB & GUTTER

1. Sample of 30
2. Location Analysis
   - 1 missed
3. Attributes Analysis
   - The1 missed sample was found in the median.
4. Possible sources of error
   - *No apparent reason for errors*
   - *Didn't include access point breaks in your linear segments. We will note this in the manual for future reference.*

BRUSH & TREE

1. Sample of 50
2. Location Analysis
    - 17 missed
3. Attributes Analysis
    - Of the 17 missed, 8- Right, 9 – Median.
4. Possible sources of error
    - *We believe there is a definition issue here. We need an entire inventory within a certain defined distance. Would it better to say within the ROW?*

TURF

1. Sample of 20
2. Location Analysis
    - 10 missed (5 – Median, 5 – Right)
3. Attributes Analysis
    - Of the 10 missed, 5 – Median, 5 – Right.
4. Possible sources of error
    - *No apparent reason for errors*

*SLOPES**

1. Sample of 7 failures.
2. Location Analysis
    - *Slope was located accurately at each sample.*
3. Attributes Analysis
    - *All collected data noted slopes as "Field Inspection Not Needed."*
    - *All 7 samples were noted as instances of failed or eroded slope along the route.*
4. Possible Sources of Error
    - *Definition Issue. Catalog instructions may not be sufficient to identify slope segments requiring inspection.*

*LANDSCAPE AREAS**

The vendor did not collect all ramp landscape areas as required.

CONCRETE BARRIERS

1. Sample of 18
2. Location Analysis
    - 2 missed
3. Attributes Analysis
4. Possible sources of error
    - *No apparent reason for errors*

GUARDRAIL

1. Sample of 23
2. Location Analysis
    - 0 missed
3. Attributes Analysis
    - *7 of the 23 were categorized incorrectly as "Field Inspection Not Needed."*
4. Possible sources of error
    - *Located guardrail correctly; however, some issues with categorizing damages.*

*PAVEMENT**

1. Sample of 4 failed pavement segments were selected.
2. Location Analysis
   - *3 of the 4 pavement failures were accurately located.*
   - *Pavement along the entire route was appropriately collected.*
3. Attributes Analysis
   - *3 of the 4 located failed segments were correctly identified as requiring an inspection.*
   - *1 segment failed to be noted as "inspection required." Visual of missed failure is attached.*
4. Possible Sources of Error
   - *No Apparent Reasons for Error.*

*RETAINING WALLS**

1. Sample of 4
2. Location Analysis
   - *1 missed: At bridge abutment along I-85.*
3. Attributes Analysis
   - *All segments identified were correctly noted as not requiring inspection.*
   - *Difference in total lengths found was approximately 160 feet.*
     - *Manual/ITRE: 1858 feet*
     - *Fugro: 1698 feet*
     - *Difference: 160 feet*
4. Possible Sources of Error
   - *No Apparent Reasons for Error.*

MEDIANS

1. Sample of 50
2. Location Analysis
   - 0 Missed
3. Attributes Analysis
4. Possible sources of error
   - *No apparent reason for errors*

*RAISED PAVEMENT MARKERS (RPMs)**

1. Sampled 64 segments, each 1/10th mile (528 feet) in length.
   - *Expected RPMs per 1/10th mile segment: 7; Entire Route: 448*
2. Location Analysis
   - *Total Visible RPMs (Manual/ITRE): 256*
   - *Total Visible RPMs (Fugro): 596*
3. Attributes Analysis
   - *Transition Zone Notation.*
     - *42 segments were identified as in a transition zone.*
4. Possible Sources of Error
   - *Definition Issue. Only RPMs to the left of the far right thru lane should be collected; transition zone lanes should not be included (see Catalog instructions).*

ROADWAY LANES

1. Sample of 30
2. 1 incorrectly identified the number of lanes
3. Attributes Analysis
4. Possible sources of error

- *Transitions from one number of lanes to another are not defined well.*

*RUMBLE STRIPS**

1. Sample of 15 segments
2. Location Analysis
    - *Segments missed along I-485*
    - *Segments missed along the median of I-85.*
3. Attributes Analysis
    - *Rumble Strips collected along I-85 excluded any median rumble strips found along that route.*
4. Possible Sources of Error
    - *No Apparent Reason for Errors. Rumble Strips should be collected along to the right and along the median of the roadway.*
    - *Definition Issue. Although the rumble strips along I-485 were not continuous (i.e., at 80' spacing), this type of rumble strip should be collected. The rumble strip feature description will be updated to clearly describe spaced rumble strips.*

ACCESS POINTS

1. Sample Size: 50
2. 7 of sample were missing (6 - Right, 1 - Ramp)
3. Possible sources of error
    - *Include both on AND off ramps as 2 separate access points*
    - *Include every access point, i.e. if one business has two access points, count both separately*

INLETS

1. Sample of 50
2. Location Analysis
    - 14 missed (5 – Right, 9 – Median)
3. Attributes Analysis
4. Possible sources of error
    - *Missed inlets were recessed inlets located in wide medians with tall landscaping*

ATTENUATORS

1. Sample Size: 50
2. Location Analysis
    - 4 of sample were missing (3 - Right, 1 - Median)
3. Attributes Analysis
4. Possible sources of error
    - *Seem to be missing them on the far end of the guardrail*

BRIDGES

1. *Sample Size: 17*
2. Location Analysis
    - *0 Missing*
3. Attributes Analysis
4. Possible sources of error
    - *No Apparent Reasons for Error.*

*MEDIAN OPENINGS**

1. Sample of 10
2. Location Analysis
    - *0 missed*
3. Attributes Analysis
    - *Not applicable.*
4. Possible Sources of Error
    - *No errors noted.*
    - *Note: The vendor's current data set includes only a portion of Highway 16. Median Openings along the entire route will need to be collected.*

GROUND SIGNS

1. Sample of 19
2. Missed 8 (7 – Right, 1-Median)
3. Attributes Analysis
4. Possible sources of error
    - *Some of the types were identified incorrectly. Be sure to indicate a MUTCD code and description that is accurate for each sign type, including subcategory notations (i.e., "Wrong Way" [MUTCD Code: **R5-1a**] vs. "Do Not Enter" [MUTCD Code: **R5-1**].)*

OVERHEAD SIGNS

1. Sample of 30
2. Location Analysis
    - *0 missed in sample*
3. Attributes Analysis
4. Possible sources of error
    - *No Apparent Reasons for Error.*

*PAVEMENT MARKINGS/STRIPINGS**

1. Sample of 104
2. Location Analysis
    - *Accurately located pavement markings & striping in the sampled area.*
3. Attributes Analysis
    - *Attributes along the samples were accurately collected. Failures were generally identified correctly.*
4. Possible Sources of Error
    - *No errors noted.*

*WORDS & SYMBOLS**

1. Sample of 32.
2. Location Analysis
    - *All Words & Symbols sampled were accurately located.*
3. Attributes Analysis
    - *All Words & Symbols sampled attributes were accurately identified.*
4. Possible Sources of Error
    - *No errors noted.*

*CENTERLINE**

1. Sample of 30
2. Location Analysis
   - *Accurately located centerline data at all sampled locations.*
3. Attributes Analysis
   - *In progress.*
4. Possible Sources of Error
   - *No errors noted.*

*HORIZONTAL CURVES**

1. Sample of 21 Curves
2. Location Analysis
   - *Successful location match.*
3. Attributes Analysis
   - *Total Curve Length Identified: 33,709 feet*
     - *Expected Total Length: 29,193 feet*
     - *Average Difference per Curve: 684 feet*
   - *Total Radius: 61,382 feet*
     - *Expected Total Radius: 76,446 feet*
     - *Average Difference: 928 feet*
4. Possible Sources of Error
   - *Difference in collection methods may lead to errors.*

1.5. Appendix E: Power Point Presentation – Discussion of Preliminary Findings (Pathway Services, Inc.)

Institute for Transportation Research and Education – N.C. State University

Preliminary Data Analysis Update

Comparison of Human Data Collection Methods
to Data Collection Vehicles
February 1, 2011

Outline

- Background Refresher
- Process for analyzing data
- Where we are in the process
- Overview of missing data
- Summary

Background

- Two vendors collect data on 27 various roadway features
- Vendors drive course
- Vendors post-process a sample of data that will be analyzed.
- Feedback given to the vendor
- Vendor performs final data collection effort
- Final analysis completed by ITRE.
- Results provided to NCDOT

Analyzing Data

- Sample data received from vendors and compared to manually collected data.
- GIS is the primary tool for analysis
- Conservative thresholds used to “match” data
- Linear elements are more challenging.
- For today’s discussion, missing elements are shown from the sample data that was provided.

Where are we as of today?

- This is the completed sample analysis.
- We want to provide be sure problem areas are addressed before the final data collection effort.
- Feel free to move forward with the final data collection effort, due to ITRE by March 1, 2012.

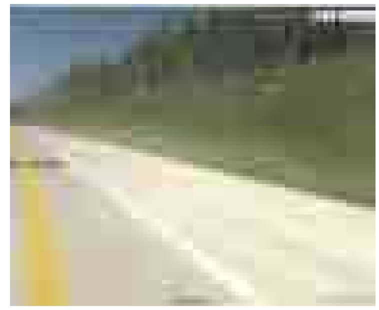
Institute for Transportation Research and Education – N.C. State University

Overview of Missing Data

Lateral Ditches – Aerial View

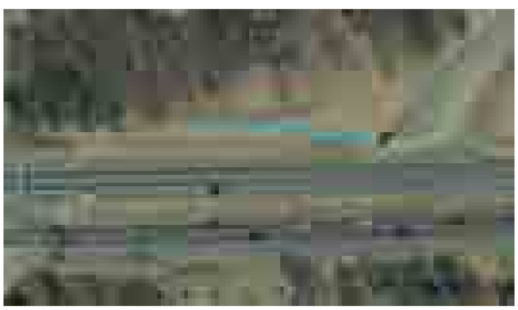
http://www.itre.ncsu.edu

Lateral Ditches – Street View



http://www.itre.ncsu.edu

Slopes – Aerial View

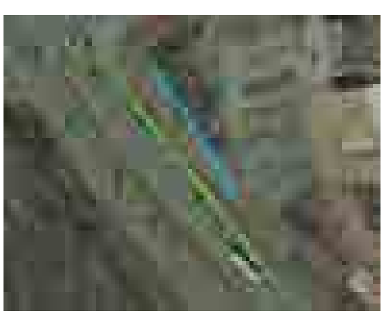


http://www.itre.ncsu.edu

Slopes – Street View

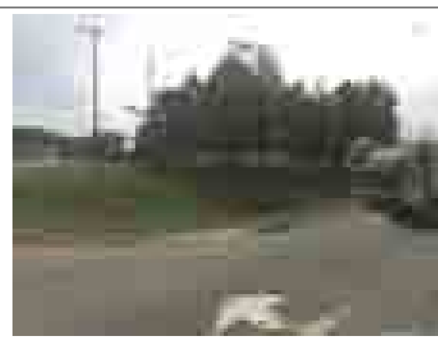
http://www.itre.ncsu.edu

Slopes – Aerial View



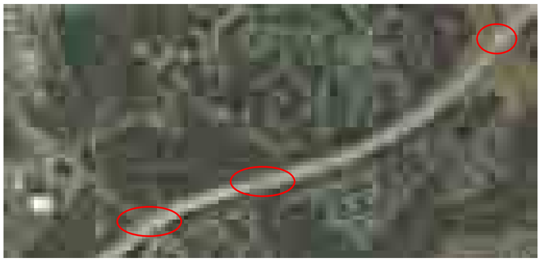
http://www.itre.ncsu.edu

Slopes – Street View



http://www.itre.ncsu.edu

Concrete Barriers



http://www.itre.ncsu.edu

Concrete Barriers – Aerial View

http://www.itre.ncsu.edu

Concrete Barriers – Street View

http://www.itre.ncsu.edu

Concrete Barriers

http://www.itre.ncsu.edu

Words & Symbols – Aerial View

http://www.itre.ncsu.edu

Words & Symbols – Street View

http://www.itre.ncsu.edu

Words & Symbols – Aerial View

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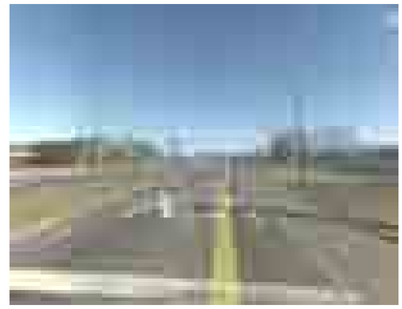

http://www.itre.ncsu.edu

Centerline

- 30 segments were sampled
- Centerline data was found at all sampled locations
- No errors are noted at this time.

http://www.itre.ncsu.edu

Horizontal Curves

	Curve Length (ft)	Average Δ	Radius (ft)	Average Δ	Average Degree of Curvature	Average Δ
ITRE/Manual	27,102	807	73,717	1,157	2.0	0.5
Pathways	34,837		65,764		2.1	

http://www.itre.ncsu.edu

Summary

- Data is very promising
- What are the problem areas?
  - Be thinking about where problem areas exist that may not be resolved.
  - Recollect data where improvements can be made based on our discussions.
    - Improvements to catalog that can be made
    - Misunderstanding of data collection needs
    - Other issues that arise

http://www.itre.ncsu.edu

1.6. Appendix F: Power Point Presentation – Discussion of Preliminary Findings (Fugro Roadware)

Institute for Transportation Research and Education – N.C. State University

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ITRE 2012

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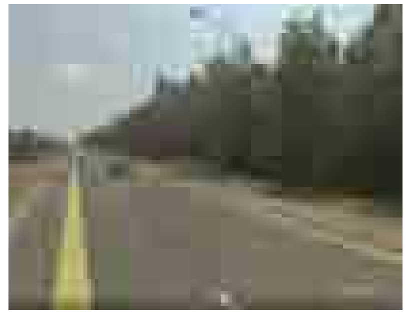
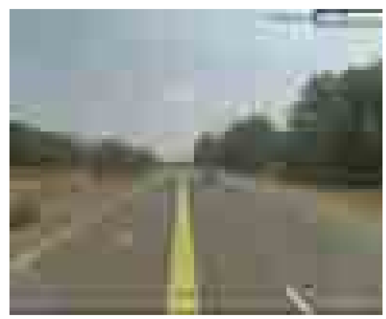


http://www.itre.ncsu.edu

Lateral Ditches – Aerial View

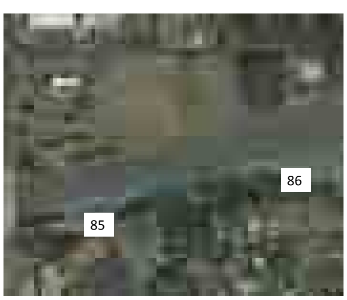
http://www.itre.ncsu.edu

Lateral Ditches – Street View



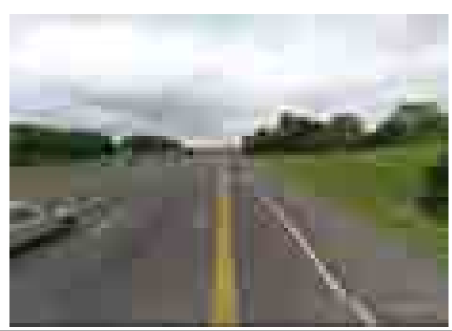
http://www.itre.ncsu.edu

Lateral Ditches – Aerial View



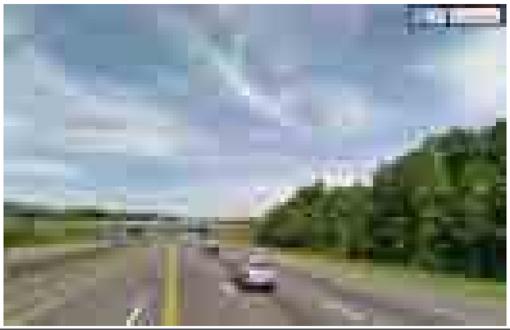
http://www.itre.ncsu.edu

Lateral Ditches – Street View



http://www.itre.ncsu.edu

Lateral Ditches – Street View



http://www.itre.ncsu.edu

Slopes – No Inspection Required?

http://www.itre.ncsu.edu

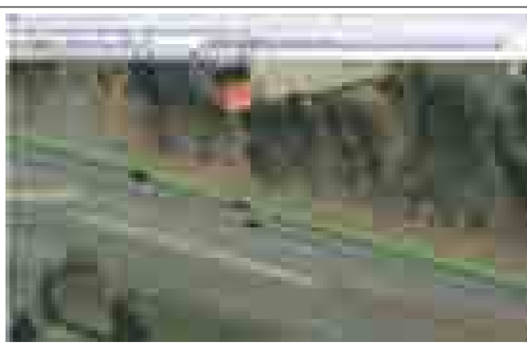
Slopes – Aerial View

http://www.itre.ncsu.edu

Landscape Areas

http://www.itre.ncsu.edu

Pavement

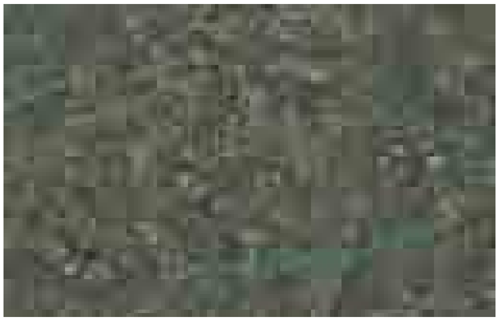


http://www.itre.ncsu.edu

Raised Pavement Markers (RPMs)

http://www.itre.ncsu.edu

Rumble Strips



http://www.itre.ncsu.edu

Rumble Strips

http://www.itre.ncsu.edu

Additional Elements

- *HORIZONTAL CURVES*
- *CENTERLINE*
- *PAVEMENT MARKINGS/STRIPINGS*
- *MEDIAN OPENINGS*
- *RETAINING WALLS*

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