NETC Project 21-1:
Quality Review and Assessment of Pavement Condition Survey Vehicle Data Across New England

Tasks 1 and 2 Report

July 20, 2022

NEW ENGLAND TRANSPORTATION CONSORTIUM

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Introduction

The New England Transportation Consortium (NETC) members consist of the Maine, Connecticut, Massachusetts, New Hampshire, Rhode Island, and Vermont transportation agencies. These member agencies spend a considerable amount of time and resources on pavement surface data collection. The data collected are used for a wide range of reporting and decision-making functions within these agencies, including (but not limited to):

- Evaluating the condition of the network;
- Reporting the pavement asset register, life-cycle planning, and investment strategies for the federally required Transportation Asset Management Plans (TAMP) and Performance Management Rule 2 (PM2);
- Selecting sections for preservation, maintenance and rehabilitation plans;
- Optimizing the expenditure of funds on the network through use of a Pavement Management System (PMS);
- Development and update of pavement performance models; and
- Utilizing the right-of-way (ROW) images for quantity take-offs for construction projects and to document site condition for asset inventories.

Roadway networks represent a large asset for DOTs, and the associated maintenance and rehabilitation budgets are significant. Data quality and data management are critical to ensure that the decisions being made based on the data are effective and reliable. Pavement Data Quality Management Plans (DQMPs)—mandated by Congress in 23 CFR 490.319(c) of the final rule for national performance management measure regulations published by the Federal Highway Administration (FHWA)—provide a means to assist in quality control (QC) and quality assurance (QA) over the entire data collection life cycle, including methods to check quality of data before, during, and after the pavement data collection cycle.

Figure 1 shows a timeline of typical DQMP activities carried out throughout the data collection cycle. However, the legislation does not specifically spell out the precise contents or the methods to be used for the DQMP. While FHWA has provided guidance, the specific steps a DOT must take are not clear. This has resulted in every DOT having plans which vary in the level and sophistication of QC/QA conducted. In addition, there are a few ongoing or recently completed studies related to important certification standards, such as the field evaluation of testing for the American Association of State Highway and Transportation Officials (AASHTO) certification of transverse pavement profiles and the revision of the AASHTO standard for the computation of rutting parameters, among others.

Taking into consideration the above challenges, the specific objectives of this project, as stated in the solicitation, are:

- Review northeast state Data Quality Management Plans for pavement condition data.
- Summarize control sites used in the northeast with potential for inter-agency sharing.
- Develop recommendations for regional efficiencies in collection and analysis of QC/QA data for each of the participating transportation agencies.

- Develop or adapt forms and macros as “best practices” recommendations to assist states with data reporting requirements for compliance with FHWA-approved DQMPs.

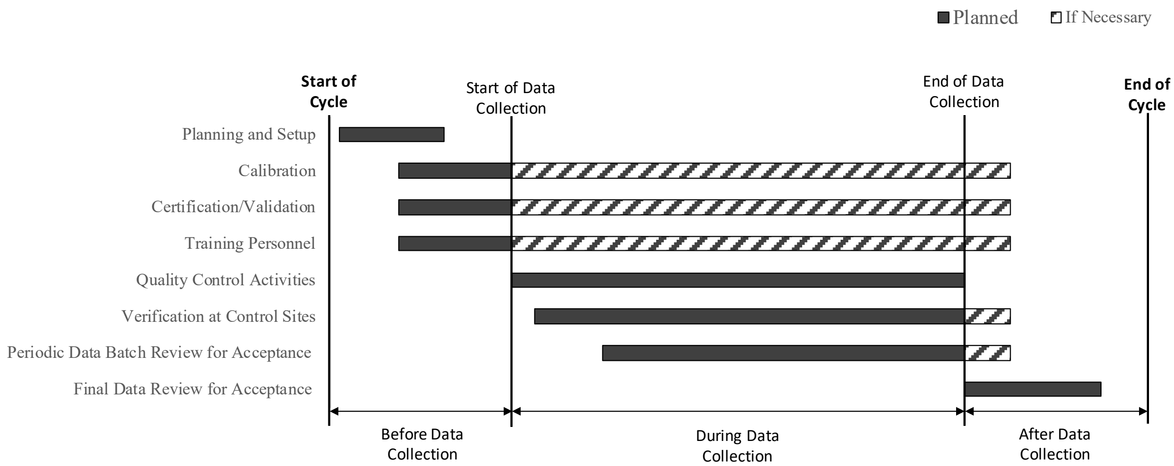

Figure 1. Timeline of typical DQMP activities throughout the data collection cycle.

To meet the stated objectives, the following five tasks are being carried out by the project team with support from the NETC agencies:

1. Review and analyze DQMPs for pavement condition data from the NETC agencies to:
    a. Identify regional efficiencies in collection and analysis of validation/control QC/QA data for each NETC agency.
    b. Identify how each NETC agency organizes its control sites, and any potential future changes to the setup of their control sites.
    c. Develop a set of standard terminology.
2. Identify test site characteristics needed to establish precision and bias values for the different pavement metrics and devices, which will be used to:
    a. Recommend existing or potential validation and control sites that optimizes inter-agency sharing.
    b. Determine if the same control sites can be used for each of the metrics or if different sites should be identified for each metric.
3. Based on results from Task 2, develop guidelines for validating that the data collection equipment is producing quality data.
4. Draft final report, technology transfer strategy, and toolbox.
5. Prepare final report.

Successful completion of these tasks is expected to produce the following outputs in support of the NETC DQMP practices:

- Improvement recommendations and draft language for each member State’s DQMP based on best practices.
- List of existing and potential control sites for inter-agency sharing that may be used by member States to calibrate their operators and equipment.
- Methods for each State to verify and calibrate their equipment to develop Highway Performance Monitoring System (HPMS) metrics and each State’s own PMS metrics.

- Forms and spreadsheets for each State to calculate conformance to their DQMPs and to document they have performed the checks included in said DQMPs.
- A list of potential efficiencies to be gained for the NETC agencies as a result of the project.

The remainder of this report focuses Tasks 1 and 2, including the approach, findings, conclusions, and recommendations associated with each of these tasks.

Task 1 – Review and Analysis of DQMPs

The objective of this initial task was to review and analyze DQMPs for pavement condition data from the NETC agencies. While every task was critical to the success of the project, this one was especially important as it provided the project foundation—the remaining tasks relied on the information resulting from this task. Accordingly, the project team carried out the following activities towards accomplishment of this task:

- Gathered, reviewed, and analyzed the latest DQMPs and any work-in-progress updates from the NETC agencies. Each of the following required DQMP components were considered:
    - Data collection equipment calibration and certification.
    - Certification process for persons performing manual data collection.
    - Data quality control measures to be conducted before data collection begins and periodically during the data collection program.
    - Data sampling, review, and checking processes.
    - Error resolution procedures and data acceptance criteria.
- Identified how NETC agencies organize their control sites and provided recommendations for potential future changes to the setup of their control sites.
- Identified regional efficiencies in collection and analysis of validation/control QC/QA data.
- Developed a recommended standard terminology that could be used by the NETC agencies.

Each of these activities are detailed next along with the associated findings, conclusions, and recommendations. Input on each of the activities was received from the NETC agencies via a virtual meeting held on March 29, 2022. Further input from the NETC agencies is anticipated after review of this report as well as from the virtual meeting scheduled for April 19, 2022.

Review of Data QMPs

To better understand the NETC's data quality procedures and practices, a detailed review of each of the six States' DQMPs was conducted. The review focused on comparing both the completeness of each DQMP as well as the specific practices used for data quality management across States. In this section, a summary of the key information used to conduct this comparison—including the latest DQMPs and DQMP scoresheets—and key findings of the review is provided.

NETC State DQMPs

The primary information used to compare data quality management practices used by the NETC States was each State's DQMP. For the most part, NETC States developed initial DQMPs for pavement data in 2018 to comply with the final rule for national performance management measure regulations published by FHWA. However, the project team asked that States provide their latest DQMPs in cases where the initial DQMP had been revised or updated. Of the six NETC States, only New Hampshire had updated and approved a new DQMP. The revision to New Hampshire's DQMP was primarily the result of the State beginning to outsource some of its pavement data collection and the acquisition of a new sensing vehicle for project-level pavement data collection. A summary of the DQMPs used for this task is provided in Table 1.

Table 1. Summary of DQMPs

State	Date of Most Recent DQMP	Additional Documentation Received/Comments
MA	2018	
ME	2018	
NH	2020	2020 DQMP discusses changes from in-house collection to outsourced data collection
RI	2018	
VT	2018	
CT	2018	Manual for Quality Control of Pavement Condition Data Collection Photolog Field Data Collection Standard Operation Procedures Control Sites QC Report

NETC Scoresheets

As part of FHWA-RC-20-0007, *Successful Practices for Quality Management of Pavement Surface Condition Data Collection and Analysis,* the project team evaluated State DQMPs for all 50 State DOTs, including the six NETC States. The project, which focused on developing national guidance for DQMPs, utilized a scoresheet to evaluate the completeness of each State's DQMP in five key areas:

- Data collection equipment calibration and certification.
- Certification process for persons performing manual data collection.
- Data quality control measures to be conducted before data collections begins and periodically during the data collection program.
- Data sampling, review, and checking processes.
- Error resolution procedures and data acceptance criteria.

Each of the five key areas and its individual components were scored on a scale of 0 to 2, where a score of a 2 represents a practice the DQMP completely and thoroughly explains. Table 2 provides a description of each score used within the scoresheets.

Table 2. Scoresheet Scores and Meanings

Score	Description
2	Complete and thorough explanation of process, missing no critical component. Reference "definitions" for critical component definition
1	Partial explanation of process, missing one critical component. If multiple critical components are missing, a score of unknown or 0 should be given. An explanation of what critical component is missing should be given in the notes section.
0	No explanation or inadequate explanation of process, missing multiple critical components, does not meet required protocol; this score shall be received if no information is present. For example, if there is no faulting information in the DQMP, and the state does not clarify whether there are concrete pavements in that state, a score of 0 shall be assigned to all faulting metrics.
N/A	No information is required for this DQMP; if this score is chosen, a description of why it does not apply must accompany the score in the notes section.
Unclear	Not clear whether the DQMP meets required protocol; the reviewer is unsure if there are critical components missing. Not scored, further information needed. Explanation on what is unclear is required in the notes section.

Based on the updates to the NETC States' DQMPs and supporting documents, the scoresheets developed as part of FHWA-RC-20-0007 were revisited and reassessed. However, as this project is focused on developing efficiencies between NETC States, the scoresheet updates focused on three of the five key areas of a DQMP. Table 3 provides a summary of the evaluated areas and its key subcomponents.

Table 3. DQMP Areas Assessed

Area Evaluated	Components Evaluated
Data collection equipment calibration and certification	• Certification testing performed at control sites. • Control sites meet the definition and are approved by the State DOT. To receive a score of 2, the referenced control sites must indicate ground reference conditions that cover a range of values and varying types of cracking. • Certification control site describes how ground reference and variability/range of expected values are established.

Area Evaluated	Components Evaluated
	• Includes comparison of data to minimum requirements for accuracy, repeatability, and precision. • Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision. • State DOT reviews, approves, and keeps record of certification documentation for all metrics.
Data quality control measures to be conducted before data collections begins and periodically during the data collection program	• Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection. • Identifies frequency of quality control measures before and throughout testing. • Outlines acceptance criteria and allowable tolerances. • Includes and describes training for data collection crews. • Includes verification of equipment and raters at control sites (same sites used for original calibration or certification); data compared to original calibration/certification data. • Includes real-time data checks (real-time data displays for out-of-range/malfunctioning data). • Includes cross-rater checks. • Includes QC checks during daily data reduction. • Includes corrective action for data not meeting allowable tolerances; may include returning to manufacturer for re-calibration. • Includes documentation and reporting requirements.

Error resolution procedures and data acceptance criteria	• Specifies the data acceptance criteria for each metric.
	• Includes statistical methods to compare and verify results for acceptance. The following are commonly used statistical methods for evaluating data quality control, verification, and independent assurance:
	  o F- and t-test.
	  o Paired t-test.
	  o Cohen’s kappa statistic.
	  o Percent within Limits (PWL).
	• When acceptance criteria are not met, describes corrective action process (examples may include re-collect, re-calibrate, re-analyze the raw data, or re-train staff).

Area Evaluated	Components Evaluated
	• Corrective action plan includes a method to troubleshoot why data was incorrect to avoid same error after re-collecting. • Data collector is notified of acceptance requirements and corrective action plan prior to data collection. • State DOT reports and keeps records of error resolution and data acceptance results.

The results of the scoresheets were utilized to better understand the strengths and weaknesses of existing data quality management practices used by NETC States. Appendix A provides a summary of the scoresheet comparison for the specified areas above.

Data QMP Findings

Using the DQMPs and updated scoresheets, an assessment of existing data quality management practices was conducted. At a high level, the DQMPs and practices implemented by NETC States compared well to the assessment of nationwide practices undertaken as a part of FHWA-RC-20-0007. Table 4 provides a summary of how the NETC State DQMPs compared to other geographic areas throughout the U.S. in terms of the five key areas a DQMP should address. As shown, the New England division, which is comprised of the six NETC States, had well-documented practices for all the key areas, as denoted by the yellow and green shading and the lack of red shading in the table below. In the three areas of particular interest to this project—equipment calibration and certification, QC before and during data collection, and error resolution procedures and data acceptance criteria—the average score for the States was above 50%.

Table 4. Overview of findings from the assessment of DQMPs

Groups	Overall	Equipment Calibration and Certification	Certification Process for Persons	QC Before and During Data Collection	Data Sampling, Review, and Checking	Error Resolution Procedures and Data Acceptance Criteria
Division 1: New England	63%	62%	38%	68%	71%	54%
Division 2: Middle Atlantic	62%	59%	21%	71%	75%	53%
Division 3: East North Central	34%	34%	13%	33%	53%	42%
Division 4: West North Central	50%	38%	26%	64%	54%	55%
Division 5: South Atlantic	53%	57%	21%	54%	61%	38%
Division 6: East South Central	34%	27%	00%	45%	46%	49%
Division 7: West South Central	59%	38%	47%	78%	81%	68%

Groups	Overall	Equipment Calibration and Certification	Certification Process for Persons	QC Before and During Data Collection	Data Sampling, Review, and Checking	Error Resolution Procedures and Data Acceptance Criteria
Division 8: Mountain	56%	45%	26%	70%	71%	66%
Division 9: Pacific	34%	35%	28%	32%	54%	35%

The NETC practices within the area of equipment calibration and certification, data quality control, and data acceptance criteria were also assessed on a State-by-State level. While Appendix A illustrates the differences in practices implemented for each State, the following were identified strengths of existing quality management practices in the three areas assessed.

- Equipment Calibration and Certification
    - Most States are already utilizing the required protocol, AASHTO R56-14, to certify their Inertial Profiling System.
    - Most States have clearly defined processes for validation rutting and faulting (when applicable).
- QC Before and During Data Collection
    - To varying extents, the procedures used to verify and/or check data before, during, and after data collection are well defined.
    - For most States, the resolution, accuracy, and repeatability of different distresses are well defined.
- Error Resolution Procedures and Data Acceptance Criteria
    - Specific acceptance criteria for each metric type are defined, although to varying extents.
    - Corrective actions taken, including reprocessing or recollecting, when data does not meet acceptance criteria is well defined.

In addition to examining the strengths of the NETC States' quality management practices, the project team also assessed areas for opportunity or improvement for the NETC States collectively. Areas of improvement include:

- Lack of clear and decisive terminology to describe processes used to assess the validity, precision, and accuracy of data collected. It was difficult to identify whether some of the processes used by the States were conducted for the same ends (i.e., some States used verification and validation interchangeably while other States used these terms to mean distinctly different processes).
- Lack of clear information on control sites and the purposes of the control sites. While almost every State utilized control sites to help verify or calibrate pavement data, the practices used to establish these sites varied greatly. Per best practices, control sites should have varying levels of distress.

Based on this assessment of the key quality management practices implemented by each State, the project team can identify existing efficiencies to recommend and further investigate in subsequent tasks.

NETC Control Sites and Regional Efficiencies

Control sites are to be defined for the different test types included as part of the States' DQMPs. At the same time, the test types to implement will depend on the available control sites, among other technical and practical aspects. The initial set of test types proposed by the project team in this report was defined based on recommended best practices. The final list of test types—and consequently, of control sites—to include as part of this project was defined from discussions with the NETC States carried out as part of Task 2. As an example, it became clear from the discussions that the NETC does not intend on adopting the AASHTO current provisional standards for the certification of transverse pavement profiling systems (AASHTO PP 106 to 111), which would require indoor and outdoor control sites. Instead, NETC will continue to use an ad-hoc field validation testing of rutting measurements, which only requires outdoor control sites.

The initial set of test types considered for establishing control sites, along with their control site requirements and additional information for each test, is listed in Table 5. The minimum number of control sites for the certification or validation tests is per location. If all States were to share the location at which their equipment are certified or validated—i.e., maximum regional efficiency—then these are the number of sites to define, whereas if not all States decide to share sites—e.g., if MA, NH, and VT were to share certification sites and CT, MA, and RI were to share other certification sites—then the number of control sites to determine would be higher. In addition, the last set of columns in the table shows the States to which each of the test types applies. Testing related to faulting data, or other distresses defined for rigid pavements, only apply to CT, as CT is the only State that has a significant number of rigid pavements in their highway network. In addition, all NETC States have processes to check State-defined cracking data.

The number of sites for field validation testing will be defined based on an experimental matrix (to be developed in Task 2) to achieve representativeness of the conditions encountered in the participating States' highway networks (e.g., surface types, distress levels, etc.). Another important aspect to consider for regional efficiency is the collection of reference data. Sharing control sites with unique reference data allows for cross-validation of NETC sensors and reduces data collection and processing efforts.

Verification testing will be performed at a regular interval—i.e., every certain number of miles collected, or every certain number of weeks—at either the same sites used for validation purposes or at different sites located in the area where the survey vehicle is located when the test is needed. Verification sites will be used for checking the equipment precision (repeatability for repeated passes) and accuracy (bias to reference data). Reference data can consist of collected measurements or recent values collected at the same location. Fixed verification sites would allow for better control of reference data, but they require the survey vehicle to travel back to the site locations.

Table 5. Initial set of test types and control site requirements.

Test Type	Metric/ Equipment	Protocol/ Field Testing	Control Sites Requirements		Applicable to					
			Sites	Reference Data	CT	MA	ME	NH	RI	VT
Certification	AC IRI	AASHTO R56	≥ 3 (Smooth, Medium, and Rough)	SurPRO profiler	✓	✓	✓	✓	✓	✓
	JCP/CRCP IRI	AASHTO R56	≥ 3 (Smooth, Medium, and Rough)	SurPRO profiler	✓					
	DMI	AASHTO R56	As part of IRI Certification	Surveyor	✓	✓	✓	✓	✓	✓
Validation	Rutting	Field Testing	≥ 3 (Experimental Matrix TBD)	Straightedge + Ruler/Gage	✓	✓	✓	✓	✓	✓
	AC Cracking	Field Testing	≥ 3 (Experimental Matrix TBD)	Consensus Survey of Raters	✓	✓	✓	✓	✓	✓
	JCP/CRCP Cracking	Field Testing	≥ 3 (Experimental Matrix TBD)	Consensus Survey of Raters	✓					
	Faulting	Field Testing	≥ 3 (Experimental Matrix TBD)	Manual Faultmeter	✓					
Verification	AC IRI	Field Testing	≥ 1 every X miles or X weeks	Consensus Survey of Raters Using Pavement Images	✓	✓	✓	✓	✓	✓
	JCP/CRCP IRI	Field Testing		Consensus Survey of Raters Using Pavement Images	✓					
	AC Cracking	Field Testing	≥ 1 every X miles or X weeks	Based on Control Site or Historical Data	✓	✓	✓	✓	✓	✓
	JCP/CRCP HPMS Distresses	Field Testing	≥ 1 every X miles or X weeks	Based on Control Site or Historical Data	✓					
	Rutting	Field Testing	≥ 1 every X miles or X weeks	Based on Control Site or Historical Data	✓	✓	✓	✓	✓	✓
	DMI	Field Testing	≥ 1 every X miles or X weeks	Surveyor	✓	✓	✓	✓	✓	✓

Availability of Control Sites

The following parts of this section contain the main pieces of information related to existing and projected control sites obtained from the States' DQMP documents, from information submitted by States to the project team, and from information gathered from individual meetings. This information will be used for the identification of control test site characteristics for each test and for identifying the potential test sites for each test as part of Task 2.

New Hampshire

The following list contains the main characteristics of each control site.

1. New Bedford Regional Airport
   - **Test**: IRI certification (AASHTO R56-14).
   - **Site location**: New Bedford Regional Airport.
   - **Number of sites and sections**: 1 location and 2 sections per site.
   - **Test frequency**: Annual.
   - **Reference data**: Collected by UMass.
   - **Number of repeated measurements**: 10 runs.
   - **Site characteristics**: Flexible pavement.
   - **Distress level**: Smooth and medium smooth test sections.
   - **Acceptance criteria**: IRI standard deviation < 5% for 10 replicate runs; repeatability >= 90% and accuracy >= 80%.
   - **Data processing**: ProVAL by UMass.
   - **Additional information**: This control site is only used for the NHDOT-owned sensing vehicle. The Agency also contracts a vendor with a sensing vehicle certified by Texas Transportation Institute (TTI).

2. IRI Sites for NHDOT and Contractor Verification
   - **Test**: IRI verification of NHDOT and contractor data collection vehicles.
   - **Site locations**: 2 locations next to the NHDOT office in Concord, NH (Figure 2 and Figure 4) and 1 in Hopkinton, NH (Figure 3); control sites were established in 2019.
   - **Number of sites and sections**: 3 locations with 1 section per site 0.1 miles long.
   - **Reference data**: Collected with a SurPro.
   - **Test frequency**: Weekly.
   - **Number of repeated measurements**: 5 runs on each of the control sites.
   - **Site characteristics**: Flexible pavement.
   - **Distress level**: Smooth, medium-smooth (Hopkinton), and medium-rough test sections.
   - **Acceptance criteria**: Repeatability >= 90% and accuracy >= 90.
   - **Additional information**: The control sites in Hopkinton and on Hazen Road are scheduled to be paved or are already paved and will need to be replaced. The site on Charles Doe Drive is still in use and requires traffic control.

Figure 2. Smooth IRI site at Hazen Drive, Concord, NH, next to NHDOT office.

Figure 3. Medium-smooth IRI site at Jewett Road, Hopkinton, NH.

Figure 4. Medium-rough IRI site at Hazen Drive, Concord, NH, next to NHDOT office.

3. Rutting sites for NHDOT and contractor verification
    - **Test**: rutting verification of NHDOT and contractor data collection vehicles.
    - **Site locations**: 1 next to NHDOT office in Concord, NH (Figure 5) and 1 in Dunbarton, NH (high rut) (Figure 6).
    - **Number of sites and sections**: 2 locations with 1 section per site.
    - **Test frequency**: Weekly.
    - **Reference data**: Collected using straightedge and wedge at 5ft increments.
    - **Number of repeated measurements**: 5 runs on each of the control sites.
    - **Site characteristics**: flexible pavement.
    - **Distress level**: Low and high rutting.
    - **Additional information**: Airport Road, Concord, NH (Figure 7) is being considered as a substitute control site for when existing sites are repaved.

Figure 5. Fair rut & crack site at Charles Doe Drive, Concord NH, next to NHDOT office.

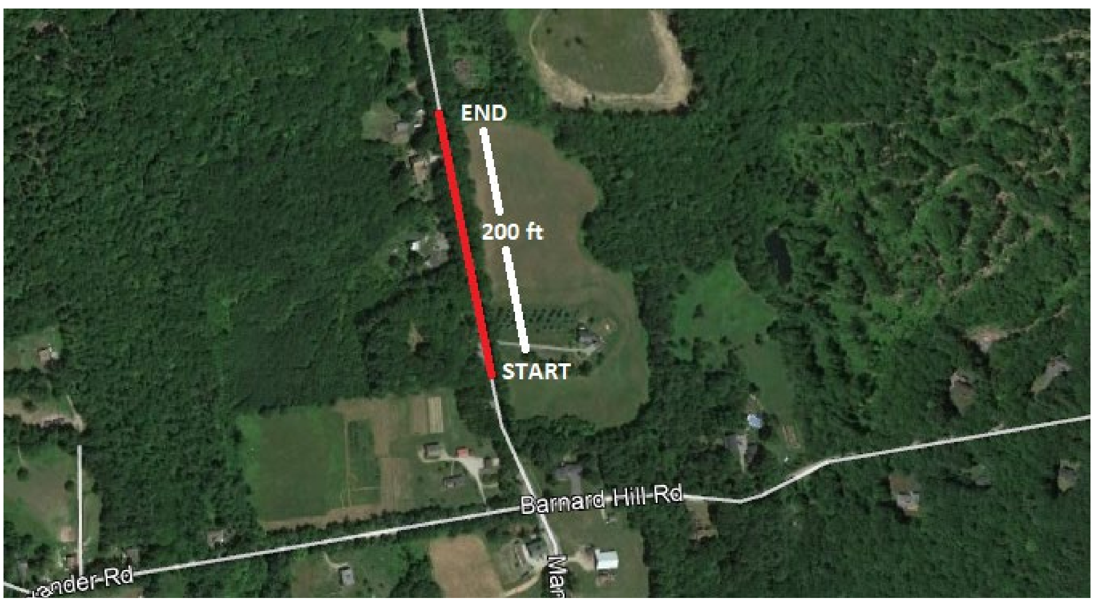

Figure 6. Poor rut site at Mansion Road, Dunbarton, NH.

4. Cracking site for NHDOT and contractor verification
    - **Test**: Cracking verification of NHDOT and contractor data collection vehicles.
    - **Site locations**: 1 next to NHDOT office in Concord, NH (Figure 5).
    - **Number of sites and sections**: 1 location with 1 section per site.
    - **Test frequency**: Annually.
    - **Reference data**: Measured by hand and verified with sensing van.

- **Number of repeated measurements**: 1 run on each of the control sites.
- **Site characteristics**: Flexible pavement.
- **Additional information**: Cracking is defined using State definitions (extent and severity) and converted in cracking percent.

5. DMI site for verification or calibration of NHDOT and contractor data collection vehicles
   - **Test**: DMI for weekly verification or calibration of NHDOT and contractor data collection vehicles.
   - **Site locations**: 1 at Airport Road, Concord, NH (Figure 7).
   - **Number of sites and sections**: 1 location with 1 section per site.
   - **Test frequency**: Weekly.
   - **Number of repeated measurements**: 1 run on each of the control sites.
   - **Site characteristics**: Flexible pavement.
   - **Acceptance criteria**: Plus or minus 3 feet of baseline (5,280 ft).

Figure 7. DMI site at Airport Road, Concord, NH.

Rhode Island

The following list contains the main characteristics of each control site.

1. IRI certification
    - **Test**: IRI certification (AASHTO R56-14).
    - **Site location**: Ocean Road, Town of Narragansett; also, proposed second site with smooth surface (IRI< 95in/mi).
    - **Number of sites and sections**: 1 location.
    - **Test frequency**: Annual.
    - **Reference data**: SurPRO profiler owned by RIDOT Materials section is used. ProVAL is used to determine reference IRI from raw profiles.
    - **Number of repeated measurements**: 3 runs.
    - **Site characteristics**: Flexible pavement; 528 ft-long section, straight and approximately level, with 100ft lead in and 100ft lead out for reference profile collection with lane closure; 300ft lead in and 200ft lead out in straight lane for profiler with unlimited road gently curving on both ends.
    - **Distress level**: Fair condition for IRI (95 in/mi < IRI < 170 in/mi) or medium-smooth according to R56; proposed second site: good condition for IRI (IRI < 95 in/mi) or smooth according to R56.
    - **Acceptance criteria**: IRI std. dev <= 5% (0.1-mile runs), symmetrical graphical appearance of 10 runs; repeatability and accuracy within 10%.
    - **Data processing**: Unfiltered profiles and with 300-ft high-pass filter applied.
    - **Additional Information**: Traffic volume varies based on time of year. Low AADTs present at the time of year testing typically occurs; lane closed for reference profile data collection, open to traffic for profiler testing (vehicle in lane of test section has right-of-way through site and assignment of a police detail may be used if desired to lead passage through site at a speed faster than traffic and speed limit permit, but there is sometimes a chance a test may be interrupted or aborted on account of unexpected traffic behavior.)

2. Cracking and rutting validation and verification
    - **Test**: Vendor certifies prior to pavement condition surveys start; used for verification every 500 miles; vendor can select any of the sites below for verification.
    - **Site location**: Throughout the State; presently: (1) RI-100 from RI-102 to RI-98, Town of Glocester, (2) RI-102 from Central Pike to 1 km north of Central Pike, Town of Scituate, and (3) Escoheag Hill Road from RI-165 to 1 km north of RI-165, Town of Exeter.
    - **Number of sites and sections**: 3 control sites for cracking and rutting used for validation with 2 sections per site; 100-m samples within control (used to check accuracy of DMI as well).
    - **Test frequency**: Annual or every 500 miles.

- **Reference data**: Rutting is measured every 10 m using a 6-ft straightedge on both the left and right wheelpath; cracking ground truth is based on survey of cracking.
- **Number of repeated measurements**: 3 runs minimum.
- **Site characteristics**: Flexible pavement. Faulting site was dropped because the last concrete surfaced state road was overlaid. On state roads, there is now only one intersection with whitetopping and concrete bridge decks.
- **Distress level**: Two of the sites have mostly low severity longitudinal and transverse cracking (RI-100 being one), one of which has noticeable rutting. The third site has more significant cracking (specifically alligator cracking) at higher severity levels, but there is little rutting.
- **Traffic control**: Two of the sites have low AADT, one of which has fairly heavy truck volumes. The third site has a moderate AADT with low to moderate truck volumes.
- **Acceptance criteria**: Runs to be within ± 3 mm of RIDOT measured values, and the cracking accuracy requirement is defined as all the runs being within ± 10 % of RIDOT measured values for each crack type 90 % of the time.
- **Additional information**: Use State defined cracking for validation and verification; severity is not used.

3. Cracking and rutting blind verification sites
    - **Test**: Blind sites for verification of RIDOT equipment and comparison with vendor equipment. Used for vendor validation prior to start of pavement condition surveys and for verification (and recalibration if needed) throughout data collection cycle (only in one direction).
    - **Site location**: Different blind sites are selected each year.
    - **Number of sites and sections**: 2 control sites for cracking and rutting.
    - **Test frequency**: Annual.
    - **Reference data**: Check imagery and measure cracking and rutting in the field.
    - **Site characteristics**: 0.1-mile segments in primary direction only.
    - **Additional Information**: Collection occurs at posted speed limit.

4. Frequent checks on data quality
    - **Test**: Daily verification of distresses by vendor as part of their quality management activities
    - **Frequency**: Frequent checks (daily) on data quality.

Maine

MaineDOT relies on its vendors to conduct its annual certification of IRI and therefore, does not have any control site information for certification. For validation and verification testing, the State attempted to establish control sites in 2018, 2019, and 2020. The first attempt was in 2018 at the Waterville airport and subsequently in a parking lot in which MaineDOT cut cracks;

however, both of locations had issues in that they did not represent road conditions, the speeds of collection were too low, and the cut cracks were not indicative of pavement distresses seen in the field. In 2019, MaineDOT selected a control site on Route 32 in China, Maine, which was quiet, near their office, had cracks of varying severity and wasn't scheduled to be resurfaced imminently. MaineDOT collected cracking and rutting reference data on the site and attempted to verify the measurements with the ARAN, but the manual measurements were not taken with the accuracy necessary for validation purposes. In 2020, MaineDOT selected a larger section of the same road with more cracks measured, and the ruts now measured with Vernier calipers instead of a ruler. However, this control site was recently paved over. A new control site with the following features has since been selected:

1. Validation of cracking, rutting, and IRI
    - **Test**: Validation of IRI, cracking, and rutting.
    - **Site location**: Leighton Road.
    - **Number of sites and sections**: 1 control site, sub-sectioned for different distresses.
    - **Test frequency**: Annual.
    - **Reference data:** Rutting data was collected using calipers.
    - **Number of repeated measurements**: 7 runs.
    - **Site characteristics**: Flexible pavement.
    - **Additional information**: This control site was also recently paved over.

Connecticut

A summary of this information is listed below.

1. Sites for validation of IRI, cracking, and rutting
    - **Test**: Validation of IRI, cracking, and transverse profiles for asphalt pavements. Used to check pre-production requirements for survey vehicle's accuracy, repeatability, and reproducibility.
    - **Site location**: Route 85 NB from milepost 2.112 to 2.524 (see Figure 8).
    - **Number of sites and sections**: One site divided into 0.10-mile-long sections.
    - **Test frequency**: Annual.
    - **Reference data**: CTDOT's CS8800 Walking Profiler is used to establish ground truth for IRI (Figure 9) and transverse profile (Figure 10) testing while manual raters produce the reference data for cracking testing.
    - **Site characteristics**: 0.40-mile-long sections of highway.
    - **Additional information**: (1) All validation sites should be free of railroad crossings, bridge joints, utility covers, catch basins, and other localized roughness spots; (2) One site can be used for multiple validation purposes (e.g., the same site for profile, rutting, and cracking measurement) if it meets multiple recommended parameters. A complete list of recommended site parameters is listed in CTDOT's "Manual for Quality Control of Pavement Condition Data Collection."

Figure 8. Location of CTDOT Validation Site

Figure 9. Marking of CTDOT Site for IRI Certification

Figure 10. Marking of CTDOT Site for Transverse Profile Validation

2. Sites for verification of IRI, cracking, rutting, and faulting
    - **Test**: Periodic verification of all distresses for repeatability, comparison against historical survey data, and reproducibility between survey vehicles.
    - **Site locations**: (1) Route 85 NB (i.e., validation site), (2) Brook Street and Elm Street in Rocky Hill, and (3) Willard Avenue in Newington.
    - **Number of sites and sections**: 3 sites.
    - **Test frequency**: Route 85 NB and Brook Street monthly; Willard Avenue site weekly.
    - **Number of repeated measurements**: 5 runs.
    - **Acceptance criteria**: Full acceptance criteria listed in Table 6.1 of CDOT's QMP document.

Massachusetts

A summary of this information is listed below. In addition to these control sites, MassDOT's inertial profilers were certified at the Texas A&M Transportation Institute (TTI) certification site by the equipment manufacturer before the delivery of the equipment.

1. Certification and verification at New Bedford Regional Airport—*same as NH site #1*
    - **Test**: IRI certification (AASHTO R56-14) and verification (and calibration, if needed) of DMI.

- **Site location**: New Bedford Regional Airport.
- **Number of sites and sections**: 1 location, 2 sections per site.
- **Test frequency**: Annual (IRI certification) or periodically for DMI verification.
- **Number of repeated measurements**: 10 runs on each of the control sites for both certification and verification testing.
- **Site characteristics**: Flexible pavement.
- **Distress level**: Cmooth and medium smooth test sections.
- **Acceptance criteria**: IRI standard deviation < 5% for 10 replicate runs; repeatability >= 90% and accuracy >= 80%.
- **Data processing**: ProVAL by UMass.

2. Verification sites for IRI, cracking, and rutting
   - **Test**: Periodic verification of IRI, cracking (several types), and rutting.
   - **Site locations**: (1) Macadam Road, Access Road, Hopkinton, NH; (2) SR 2 Westbound, MP 120.30 - MP 118.40, Concord, NH; and (3) Upton Road, MP 0.00 – MP 1.04, Hopkinton, NH (main control site).
   - **Number of sites and sections**: 3 locations.
   - **Test frequency**: Periodically (frequency not specified).
   - **Number of repeated measurements**: 10 runs on each of the control sites.
   - **Site characteristics**: Flexible pavement.
   - **Acceptance criteria**: IRI: std. dev <= 5% (0.1-mile runs), std. dev <= 10% (historical average), symmetrical graphical appearance of 10 runs; rutting: std. dev <= 0.4 inch (0.1-mile runs), std. dev <= 0.4 inch (historical average); distress: std. dev < 15% total length (0.1-mile runs and historical average). Full acceptable criteria listed in Table 5 of MassDOT DQMP document.

Vermont

The data collection contractor is responsible for performing VTrans' validation testing, and VTrans is responsible for reviewing the testing plan (including approval of control sites selected by contractor) and results. The contractor cannot initiate network-level data collection until the equipment and procedures are demonstrated to the satisfaction of VTrans staff. The following list summarizes the control section information from VTrans' DQMP document.

1. Validation Sites
   - **Test**: Validation of distresses and DMI.
   - **Site location**: Located within an hour drive from Montpelier. Actual locations vary each year. VTrans tried to keep some of these locations fixed.
   - **Number of sites and sections**: Minimum of 5 locations, sub-divided into 10 sections per site. One site is used for the validation of distresses and DMI, the remaining ones are used for validation of distresses only.
   - **Test frequency**: Annual.

- **Reference data**: Raters collect reference cracking data on site once a year before data collection starts. Reference IRI and rutting data are collected annually using VTrans' survey vehicle (DSP profiler).
- **Number of repeated measurements**: 5 runs.
- **Site characteristics**: Between 1,000 and 2,000-ft long sites, sub-divided into ten 0.05-mile sections. Marked miles for DMI calibration.

2. Verification Sites
   - **Test**: Verification of distresses and DMI.
   - **Test frequency**: Monthly.
   - **Reference data**: Comparison against values collected during validation testing for the same year, or on previous years for blind testing sites.
   - **Site location**: Validation sites (actual locations vary each year) and random selection of sites for blind checks.
   - **Number of sites and sections**: The contractor is required to collect on a minimum of 3 verification sites.

DQMP Terminology

In addition to identifying the efficiencies in pavement data quality management practices between NETC States, it was also important to develop standard terminology to assess methodologies and processes used to assess pavement data throughout the States. Specifically, the goal was to identify key terminology already being used by NETC States and to provide a definition for which all the NETC States could agree. To do so, the project team 1) identified terminology and accepted definitions based on existing standards and literature, 2) compared these terms and definitions to ones provided by the NETC States in their DQMPs, and 3) reconciled the final terminology and definitions per the input provided by NETC States. A summary of this process is provided in the subsections to follow.

Proposed Terminology

As a first step, the project team identified and defined common terminology and definitions found within DQMPs and AASHTO, ASTM, and ISO standards. This process resulted in the defining of seven key terms, summarized in Table 6, which include calibration, certification, validation, verification, quality control, quality assurance, and control sites. Each term represents important practices or concepts for data quality management. As summarized in Figure 1, many of these terms refer to processes that occur at specific times throughout data collection. For example, while certification and validation typically occur prior to annual data collection, verification occurs during frequent or at regular intervals throughout the season.

Table 6. Proposed Standard Terminology

Term	Definition
Calibration	A procedure to compare data collected by the equipment against a known standard that is used to adjust the equipment, or a factor applied to the collected data to reach an expected level of accuracy. Calibration of equipment is conducted prior to the start of the data collection effort, periodically during the data collection effort, and as required. Calibration is typically performed by the equipment manufacturer.
Certification	A procedure to evaluate the data collected by the equipment and operators in accordance with a nationally recognized standard or test procedure to check the accuracy and precision of the collected data with respect to reference measurements. Certification of the equipment and operators is conducted prior to the start of the data collection program.
Validation	A procedure performed to evaluate the data collected by the equipment or operators in comparison with reference measurements under representative conditions. Validation is conducted prior to the start of the data collection program.
Verification	A procedure performed at regular intervals throughout the data collection schedule to check that the equipment is functioning as expected.
Quality Control	Actions taken to measure the quality of the data to identify its compliance with the required quality standard. QC refers to the product and can be part of the calibration, validation, or verification review.
Quality Assurance	Actions taken to assure that the data collection processes are being followed as required, such that the resulting data will meet the specified quality standard. QA refers to the testing performed on the production processes and can be part of the calibration, validation, or verification review.
Control Site	Also known as "certification sites" or "verification sites," locations with known length and condition values used to calibrate, validate, or verify the equipment and operators.

DQMP Terminology Review

Once an initial list of proposed terminology and definitions was established, a review of how each term was defined in the NETC States' DQMPs was conducted. To do so, the use of each term in the six NETC State DQMPs was evaluated and compared both against the proposed definitions and against definitions used by other States within the NETC. The comparison and summary of terminology used by each of the NETC States proved to be difficult; some of the proposed terms were used interchangeably, making it difficult to define and differentiate between each. This was most evident in the way in which calibration, certification, validation, and verification were used in DQMPs. Specifically, because only IRI data collection has a nationally recognized standard for accuracy and precision, the definitions of these terms often coincided with each other, making it difficult to define each term per the DQMPs. As such, the comparison of the terminology was ultimately not used, and instead, the project team shared the proposed terminology with the NETC States for review and comment.

NETC Input

As noted, the proposed terminology was shared and reviewed by the NETC States. During a progress meeting on March 29, 2022, the proposed terms and definitions were discussed in light of the difficulties in comparing terminology from the DQMPs. The NETC States agreed to the proposed terminology and definitions provided, and each will be adopted and utilized throughout subsequent tasks within the project.

Summary, Conclusions, and Recommendations

The main findings of Task 1, including the review of DQMPs, available control sites, and terminology, are summarized below. A complete analysis of the available control sites, including an identification of gaps and list of potential sites as well as a discussion with NETC States regarding feasible aspects for selection and sharing of control sites, was conducted in Task 2.

Review of Data QMPs

- At a high level, the DQMPs and practices implemented by NETC States compared well to the assessment of nationwide practices undertaken as a part of FHWA-RC-20-0007. The six NETC States, had well-documented practices for all the required elements of a DQMP.
- NETC States had well-defined procedures for certifying Inertial Profiling systems (per AASHTO protocol); validation of rutting and faulting data collection; verification and QC of data before, during, and after data collection; ensuring resolution, accuracy, and repeatability of data collected; defining acceptance criteria; and identifying corrective actions.
- Through the assessment of individual DQMPs, it was also evident that NETC States would benefit from decisive terminology to the describe the processes used to assess pavement data and the selection of control sites that adhere to best practices.

Control Sites

- It is recommended to conduct the certification of inertial profiler equipment according to the AASHTO R56 standard. Some NETC already follow this practice. NH and MA share a control site for certification of inertial profilers.
- The implementation of AASHTO provisional standards for the certification of transverse pavement profiling systems (AASHTO PP 106 to 111) is recommended. These standards are not currently used by NETC and will replace some of the control sites currently used by agencies for the field validation of rutting measurement systems.
- Given the lack of a standard for validation of cracking and faulting, the project team will provide guidance for planning and implementation of field validation testing. All NETC States conduct field validation testing for these distress types—validation of faulting is needed only for CT and MA, and validation of State-defined cracking metrics is needed only for ME and VT, as indicated in Table 5. An experimental matrix will be developed based on the analysis of States' network-level data. Recommendations for potential sharing of control sites will be developed based on the location of each site and considering practical aspects,

such as travel distance and availability of raters and equipment for the collection of reference data.

DQMP Terminology

- The project team identified and defined common terminology and definitions found within DQMPs and AASHTO, ASTM, and ISO standards. The process resulted in the defining of seven key terms, which include calibration, certification, validation, verification, quality control, quality assurance, and control sites.
- An attempt was made to reconcile terminology used by the NETC States to create definitions that align with the existing understanding of States. However, there was a lack of consistency in terminology used between States.
- Ultimately, the NETC States agreed to the proposed terminology and definitions provided by the project team. Each will be adopted and utilized throughout subsequent tasks within the project.

Task 2 – Control Sites

The objective of this task was twofold: first, to identify those control site characteristics needed for the NETC performance metrics (i.e., longitudinal profile [pavement roughness], cracking, transverse profile [pavement rutting] and distance [DMI]) and secondly, based on the established characteristics, to recommend existing or potential control sites in New England that optimize inter-agency efficiencies.

To do so, the project team used the information on control sites gathered during Task 1 as well as findings from the individual virtual interviews with State DOTs on desired control site characteristics and existing practices. Information gathered through the individual virtual meetings was incorporated into the Task 1 write-up. Through these meetings, the project team was able to define the most important control site characteristics and an approach for sharing control sites between NETC States based on each agency's willingness to travel. In addition to the NETC States' input, the performance metrics being considered – i.e., roughness, cracking, rutting and distance—and the intended purpose of the control site – i.e., certification/validation versus verification—were used to establish a complete list of ideal control site characteristics.

Once the control site characteristics had been defined, the remainder of Task 2 focused on the control site selection process. The project team developed a methodology to select control sites based on available data and desired characteristics, which was then used to develop a proof-of-concept algorithm. Details on the process and results are provided in the subsections to follow.

Control Site Characteristics

As discussed in the previous section, the first objective of Task 2 was to identify control site characteristics for each performance metric test. The project team utilized information on specific control site selection criteria defined during the individual meetings with NETC States as well as the requirements and best practices of the different performance metric tests to establish control site characteristics. A summary of the process used to define these characteristics is provided below.

Agency Meetings

Through Task 1, the project team gathered information on existing NETC State control site selection practices for varying performance tests. The review, which was primarily based on information available in State DQMPs, was supplemented with individual interviews with NETC States. The interviews, which were conducted between May 4th and May 12th of 2022, focused on three key areas: updates to information reported in Task 1, current and preferred control site characteristics, and the willingness of the State to travel for certification, validation, and verification testing. Information on existing control site selection practices were used to update the Task 1 report.

Through these interviews, the project team found that control site selection methods varied greatly from State to State. While some States used recommended equipment and methods for certification, validation, and verification testing, others relied on historical data and average values to determine data quality. For example, while one State used a SurPro for IRI verification at defined control sites, another State relied on historical data and engineering judgement to determine whether the IRI values were acceptable. The number and types of control sites selected also varied. However, for the most part, States prioritized control sites which could be used for multiple performance metrics. In many cases, control sites for rutting or IRI were also used for cracking validation or verification. Finally, through these interviews, the project team also learned about existing shared control sites for States in the NETC. Specifically, New Hampshire, Maine, and Massachusetts discussed some of the challenges and opportunities in sharing the New Bedford Airport control site. For Maine, which no longer uses the site, the New Bedford Airport illuminated the importance of making sure shared sites meet the needs of different equipment State DOTs are using. Whereas for New Hampshire and Massachusetts, the airport was an example of how States could share resources to meet the same goals.

In terms of desired site selection criteria, there was more of a consensus between the individual NETC States. For each Agency, safety was the primary consideration or concern when selecting control sites. Specifically, NETC States were concerned with the AADT at the site, the number of lanes, and the extent to which traffic control was necessary. Another key characteristic important to all States in selecting control sites was pavement performance. States preferred control sites that contained a multitude of severity levels and distresses to help eliminate the need for individual control sites for each performance metric type and severity. Additional factors for the selection of control sites included geometry, access/collection efficiency, equipment requirements, and others. Based on the recommendations of each State, as well as best practices, the project team came up with a list of desired control site characteristics. The criteria, summarized in Table 7, was used to inform the control site selection methodology developed as part of Task 2.2.

Table 7. Desired Control Site Characteristics

Factor	Characteristics Considered
Pavement Performance	• Contains multiple severity levels—e.g., all low, medium, and high cracking severity on one section • Contains multiple distress types –e.g., not only high cracking but also high rutting

	• Variable distresses at sections before and after sections • Representative of network
Safety	• Low impact of traffic control • Rural area • Low AADT (e.g. <2,000) • Multilane preferred • Good sight distance
Geometry	• Not on a curve • Minimal grade changes • Not near an intersection • Not on a ramp, bridge, or tunnel • Consistent speed
Access/Collection Efficiency	• Limited turn-around time—i.e., the data collector does not need to travel significantly to turn around and recollect a site • Close to agency's garage where survey vehicle is stored
Equipment Requirements	• Not tree covered, open and clear of debris • Ability to reach speed required for test (low and high speed)
Other	• Will not be paved within the next few years/not on 3-year work plan list • State-owned and maintained

The meetings also helped the project team better understand each State's willingness to share control sites and travel. For the most part, NETC States agreed there was benefit in sharing control sites even if it meant traveling throughout New England. For one State, it was preferred to keep travel to a minimum. Therefore, one possible recommendation would be to have the northern three NETC States (New Hampshire, Vermont, and Maine) and the southern three NETC States (Massachusetts, Rhode Island, and Connecticut) establish separate control sites to reduce distance traveled. All States agreed that the shared control sites would be most beneficial for certification/validation testing rather than for verification testing.

Considering these findings, the project team proposed three options for control site selection moving forward. The first option would be where one host agency manages locations, markings, and the collection of reference data, while the other NETC member agencies participate in a "rodeo." The rodeo would rotate between all the agencies to distribute the work required to select and set-up control sites each year. The second option would be for each agency to perform all quality testing by itself, independent of the other five agencies. The third and final option was a combination of Option 1 and Option 2; some of the NETC States would work together to carry out a rodeo while other States would work independently. This option would also cover the scenario in which the three northern NETC States and the three southern NETC States would hold concurrent rodeos. A summary of the three proposed options is provided in Table 8.

Table 8. Control Site Sharing Options for NETC States

Option	Advantages	Disadvantages
Option 1: Annual rodeos where (1) host agency establishes locations, marking and collection of reference data (working or not with other NETC members) and (2) other NETC member agencies participate in rodeo	• Equally distributed workload between NETC States • Shared efficiency and lessons learned	• Requires a lot of upfront resources (until the rodeo becomes more established) • May require higher amounts of travel
Option 2: Each agency performs all activities by itself, independent from other five agencies.	• More control over timing and location of testing • Continuation of existing practices (no additional resources needed) • No travel involved for State agency	• No gained efficiencies in control site selection or setup • Requires control sites to be selected each year
Option 3: Combination of Options 1 and 2 – i.e., a group of agencies agree to work together and carry out rodeo, while remaining agencies may carry out work independently.	• Shared efficiency and lessons learned • More of an equally distributed workload between NETC States than Option 2	• Requires a lot of upfront resources (until the rodeo becomes more established) • May require higher amounts of travel but likely less overall than Option 1

Each of these options were discussed at the June 21, 2022 NETC Project 21-1 meeting. States generally agreed that Option 1 or Option 3 would help maximize benefit for certification and validation testing of pavement data. The project team proceeded to develop a methodology for control site selection that would accommodate all three options and therefore, meet changing needs.

Required Performance Metrics Tests

In addition to considering characteristics suggested by the NETC States, the project team also considered recommended site characteristics for certification, validation and verification of different performance metrics. Specifically, AASHTO protocols and best practices were used to develop a matrix of experimental factors recommended for control site selection. The matrix, shown in Appendix B, provides an overview of the equipment needed, test type, protocol/field testing that applies, site requirements (surface type, distress level, section length, section width, and macrotexture), test requirements (traffic control, whether it takes place in the field or a garage, number of passes/representative measures needed for collection, test speed, and reference data type), and the NETC States for which the different tests are applicable to. In total, if each of the recommended test types for certification/validation and verification of IRI, rutting, cracking, and faulting were conducted on separate control sites, more than 20 individual control sites would be needed. However, as was discussed previously, the number of control sites can be reduced by finding locations that cover varying types and severities of performance metrics.

The following provides a summary of key control site characteristics for certification/validation and verification testing based on AASHTO protocols and best practices.

Certification/Validation Testing

Certification and validation testing, or the comparison of data collected by equipment or raters with nationally recognized standards or reference measurements, typically occurs once a year, prior to data collection. Currently, only IRI testing follows a nationally recognized standard while cracking, rutting[1], and faulting rely on field validation. As these tests occur infrequently and are conducted using similar methods from State-to-State, certification and validation testing provide an opportunity for NETC States to share efficiencies and resources by conducting a rodeo. Specifically, a rodeo enables NETC States to share resources for reference data collection, testing set-up, and data analysis—which can be both expensive and time intensive. Additionally, as discussed in the previous section, by rotating which State hosts the certification and validation testing each year, the workload can be more equally distributed.

The following sections provide an overview on what a rodeo for certification and validation testing, specifically control site selection and reference data collection, would look like based on the national standards and best practices summarized in Appendix B. Metrics covered include AC performance metrics—IRI, cracking, rutting—and DMI, as all six NETC States collect data on each. Connecticut DOT, which also maintains PCC pavements, can apply similar practices to those outlined in Appendix B to establish faulting control sites.

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[1] While still provisional, six standards for the certification of transverse profiles (i.e., rutting data) are currently being developed. However, as these standards are provisional and therefore, not required by State DOTs, they are not a focus of this report. Appendix B provides a summary of the requirements for each provisional standard if NETC States would like to consider these protocols later.

IRI

IRI certification testing should follow protocols established under AASHTO R56. This means control sites cover varying distress levels (smooth, medium-smooth, and medium-rough), are 528 feet in length, are on straight routes without significant grade or grade changes and are ideally open-graded or have high macrotexture. During a rodeo, the selection of an IRI certification control site and the scheduling of traffic control would fall to the host State. However, the collection of reference data would be a collaborative effort between rodeo participants. As it is recommended reference data for IRI certification be collected using a SurPRO profiler, States would share resources to enable the host State to collect reference data with the recommended profiler. Once the reference data is collected, each rodeo participant would convene at the selected control site(s) of the host State to conduct IRI certification.

Cracking

Unlike IRI, there are no national protocols for cracking data validation. Instead, HPMS cracking percent and individual State cracking types are validated using best practices or State developed methods. Preferred control site characteristics for cracking validation include varying distress levels (low, medium, and high), a section length of 528 feet, a straight section with limited grade or grade change, and macrotexture that is representative of the pavements on the network. As reference data collection methods for cracking vary from State to State, it is recommended, that during a rodeo, cracking reference data be established either 1) as a consensus distress survey of raters walking the control site or 2) as a consensus distress survey of raters using pavement images. The benefit of using pavement images to establish reference data is that it allows for a more direct comparison of the data collected; while option 1 may provide a more "true" ground truth (assuming raters have good vision or eyeglasses, conduct the survey when the sun isn't in their eyes, etc.), it is more logical to produce reference data that is consistent with the way cracking data is actually collected (using images). Additionally, because raters can identify cracking using pavement images, this option eliminates the need for traffic control and enables NETC States to identify additional control sites without the financial burden of scheduling traffic control.

Rutting

Currently, there is not a national protocol for rutting data validation. As noted previously, six provisional standards for transverse profilers are currently under review. The key site characteristics recommended by the provisional standards are provided in Appendix B. However, as the provisional standards have not been fully approved, the control site selection for rutting data validation, for the purposes of a NETC rodeo, would be focused on best practice. Preferred control site characteristics for rutting data validation include varying distress levels (low and high rutting), sections with a width of 12 feet and sections with a length of 0.25 miles. For the purposes of a rodeo, reference data would be collected with a straightedge and ruler by the host State.

DMI

The final metric is DMI. DMI is the "Distance Measuring Instrument" for measuring longitudinal position. Therefore, certification of DMI data is an important component of the overall certification of a State's longitudinal profiler. Currently, DMI certification follows AASHTO R56. Ideal site characteristics for DMI certification include the test section being greater than 1,000 feet and the site having little to no curvature, superelevation, or grade changes. Reference data would be collected using a steel tape measure.

Verification Testing

Verification testing is performed at regular (weekly, monthly, etc.) intervals throughout the data collection process to check that the data collection equipment is functioning properly. There are no nationally recognized protocols for verification testing, so the methods employed vary between NETC States. Because verification testing occurs at a more frequent basis, verification testing and the selection of controls sites for verification testing is recommended to be conducted by individual States rather than through a rodeo (Option 2). In doing so, NETC States will have more flexibility in when and where verification testing is conducted. However, neighboring NETC States may also consider establishing shared verification sites near their limits/borders.

While NETC States will conduct verification testing independently, it is recommended that States consider similar factors during verification testing. Key factors to consider include reproducibility and accuracy. A description of each factor is provided below:

- **Reproducibility**. Reproducibility is a measure of whether data collection results can be reproduced or repeated when the same location is tested multiple times. Reproducibility can be assessed by comparing the results of one collection vehicle to another. This means that if a State has two data collection vehicles, as is the case for New Hampshire DOT, both vehicles will collect data on the same control site, and the results of the collection will be compared. It is recommended that NETC States keep track of the reproducibility of data collection results through verification. However, this is not crucial if the data collection equipment has already been certified and there has not been any changes to the equipment since certification/validation.
- **Accuracy**. Accuracy is a measure of how well collected data compares to "ground truth" or reference data. Testing accuracy is key for verifying cracking data. NETC States can assess the accuracy of cracking data by comparing data collected at a control site with reference data from a manual assessment using pavement images, using data collected from previous years, or by using reference data from validation testing conducted at the beginning of the year. While States may also opt to check the accuracy of IRI, DMI, and rutting data, cracking is the metric type for which accuracy verification is most important as it relies on the rating of pavement images rather in-field measurements.

Control site characteristics ideal for certification and validation testing should also be considered by NETC States in selecting verification control sites.

Selection of Potential Control Sites

Based on the recommended control site characteristics described in the previous section, the project team next developed a methodology to select potential control sites for each metric given available pavement condition and inventory data provided by each individual NETC State. To accommodate all three control site selection options described previously (rodeo, individual State testing, and a combination of each), the project team developed an algorithm that can be applied by any of the NETC States. An overview of how the algorithm works as well as a proof of concept on the implementation of this methodology for a subset of Vermont DOT's pavement data is provided below.

Methodology for Selection of Control Sites

The methodology developed to identify control sites for certification, validation, and verification testing utilizes available State inventory and condition data to determine good candidates for each test type. The suggested data parameters used to identify potential control site locations include distress information (severity of IRI, rutting, and cracking), traffic information (AADT), section length, number of lanes, and whether the route is on an NHS roadway. However, as the types and reliability of inventory data may vary between NETC States, the methodology enables States to consider additional or less parameters than the ones described. For example, if a State has reliable information on roadway curvature, curvature could be added as a parameter used to define potential control sites.

Once the parameters available in the inventory and condition data have been defined, States next consider the possible values each identified parameter can take on. For numeric attributes, such as pavement distresses, States will consider the average type and severity of the distress throughout the State's network. For example, when considering IRI, a State will use all available IRI data reported in the previous year to establish thresholds for low, medium, and high IRI values based on the overall distribution of the IRI measurements. For categorical or qualitative attributes, States will define all potential values or categories for the attribute based on State data. In the case of whether the route is on the NHS, potential categories include "On the NHS" and "Not on the NHS."

Next, States will assign a score for each of the possible values of the identified parameter. For each identified parameter, a high score represents a value that is aligned with the recommended characteristics of a control site whereas a low score represents a value that is not ideal for a control site. For example, lower traffic or low AADT is preferred for ensuring safety on a control site. Therefore, a State may look at the distribution of AADT values across routes within the State and categorize a route's AADT as low, medium, or high. The State will then assign a score to each of the different categories of AADT—a score of 3 for low AADT, a score of 2 for medium AADT, and a score of 1 for high AADT. The same can be done for categorical attributes. For safety and cost purposes, it might be more advantageous to select a control site off the NHS. In this case, States could assign a score of 1 to routes on the NHS and a score of 2 for routes off the NHS. Once the scores of each individual attribute have been calculated, a total score is computed as the product of the score for each individual attribute or:

$$\text{Total Score} = \text{Score\_1} * \text{Score\_2} * \text{Score\_n}$$

Where n is the number of attributes considered by the Agency based on available data.

States will repeat this process for all routes within their network and use the total score to identify potential control sites. Ideally, the State would select sections with the highest total score as potential locations. However, additional evaluation by field personnel is recommended to ensure the highest-ranked control sites are viable for data collection. Viability may be affected by extreme changes in performance since the last data collection (i.e., sudden increase or decrease in performance), the ability to schedule traffic control on a particular section, or other concerns that are not captured by the available data.

The methodology proposed offers flexibility to meet State needs and data deficiencies. Because the methodology only focuses on scoring attributes that are both available and important to the State, the total score is adaptable and able to accommodate the addition or subtraction of attributes considered. However, as the control sites are focused on performance metric testing, distress or condition scores should always be considered. Additionally, the range of scores assigned to a particular attribute can be modified according to the priorities of the State. Attributes that the State would like to emphasize in selecting a control site can be weighted so they proportionally affect the total score. For example, if a State really wanted to focus on selecting a control site with a low AADT, the State could assign a score of 6 to low AADT, 4 for medium AADT, and 2 for high AADT routes.

Proof of Concept (POC) Example

The following is a proof-of-concept that exemplifies how the methodology proposed for control site selection can be implemented using real data. For the purposes of this example, a subset of Vermont DOT's inventory and condition data was used. An overview of the process and results of implementing the proposed methodology on this dataset is provided below.

Process

The first step in selecting potential control site locations was to assess the parameters available in the inventory and condition data provided by Vermont DOT. Key parameters available in the data included: the type and severity of distresses, traffic information, information on whether a section was on or off the NHS, whether the section lies on an intersection, and the number of lanes per section.

Based on these available parameters, the project team next defined the potential values and breakpoints for each parameter used to determine scores. In this proof-of-concept, five scores were defined:

1. **Distress score**: The distress score measures the type of distresses and their severities within a certain distance from a given section. As a control site ideally covers a variety of distress types and severities, the distress score was used to capture this characteristic. Each section was categorized as high, medium, or low severity for each of the key HPMS distresses in Vermont—IRI, rutting, and cracking—based on the distribution of the condition metrics for the entire State. Subsequently, a score was calculated based on the number of unique combinations of high, medium, and low severity distresses within 0.5 miles of a given section, including the section itself. Table 9 shows one possible scenario. Section A is the section being scored, and Sections W-Z and B-E represent sections that are within 0.5 miles of Section A. Unique combinations of high, medium, and low are highlighted in green, and duplicates are highlighted in red. The number of green rows determines the score, which in this case is 6.

Table 9. Possible Scenario of Distress Scoring

Section	IRI	Rutting	Cracking
W	H	M	L
X	H	M	M
Y	H	M	M
Z	M	M	M

A	M	M	L
B	H	L	L
C	M	H	M
D	M	H	M
E	H	M	M

2. **Traffic score**: Control sites are considered safer and less disruptive to the public when there is less traffic on a given section. The traffic score was based on the AADT of the section, with higher scores for lower AADT values. The breakpoints for traffic categorization in Vermont were AADT = 2000 and AADT = 9000. The following are the defined scores per category:
    a. AADT < 2000 – traffic score of 3
    b. 2000 < AADT < 9000 – traffic score of 2
    c. AADT > 9000 – traffic score of 1
3. **Endpoint score**: Control sites are typically busier and more difficult to analyze when they are located at an intersection or the end of a route. Additionally, profile collection requires lead-in and lead-out so that data collection may occur at a uniform speed within the control site. For the purposes of this proof-of-concept, sections within 0.7 miles of an intersection or route endpoint were designated as such. Sections determined to be at an endpoint or intersection were scored a 0.3 whereas sections that were not were scored a 1.
4. **Lane score**: Control sites with more lanes enable testing to be conducted more safely and with less of an impact on traffic. Therefore, sections with more lanes were scored higher than those with less lanes. Sections with more than 4 lanes were scored a 1, while sections with less than 3 lanes were scored a 0.5.
5. **NHS score**: Control sites that are not on the NHS are preferred over sites that are on the NHS due to higher consequences when altering traffic flow for traffic control on NHS routes. Therefore, sections not on the NHS were scored a 1, while sections on the NHS were scored a 0.5.

Finally, using the resulting Distress, Traffic, Endpoint, Lane, and NHS scores, a total score for each section was calculated as the product of these five scores. The results of this analysis are displayed in Figure 12. Test sections in green, with high total scores, are considered good candidates for Vermont DOT’s certification, validation, and verification testing control sites.

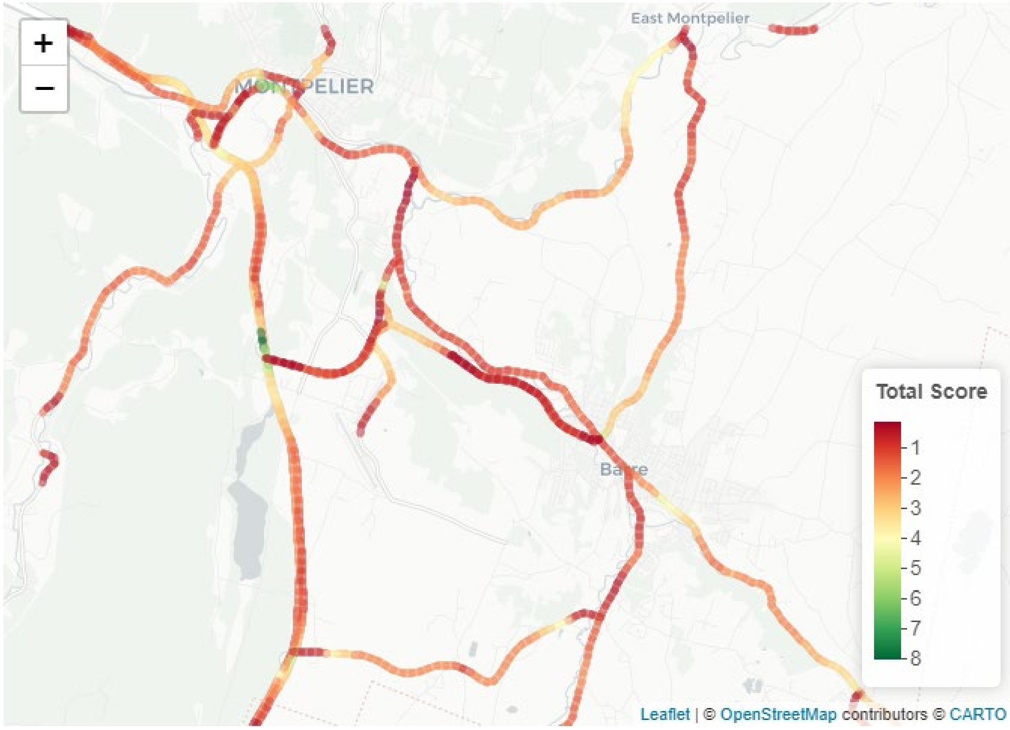

Figure 11. Example Map with Scores

Summary, Conclusions, and Recommendations

The main findings of Task 2, including the identification of control site characteristics and the selection of potential control sites, are summarized below.

Control Site Characteristics

- The project team conducted interviews with individual NETC States to identify ideal control site characteristics. NETC States were most concerned about safety and having a variety of distress types and severities on selected sites. Additional factors identified included geometry, access/collection efficiency, equipment requirements, and others.
- The meetings with the individual agencies helped the project team better understand each State's willingness to share control sites and travel. For the most part, NETC States agreed there was benefit in sharing control sites even if it meant traveling throughout New England.
- Considering these findings, the project team proposed three options for control site selection moving forward. The first option would be where one host agency manages locations, markings, and the collection of reference data, while the other NETC member agencies participate in a "rodeo." The second option would be for each agency to perform all quality testing by itself, independent of the other five agencies. The third and final option was a combination of Option 1 and Option 2; some of the NETC States would work together to carry out a rodeo while other States would work independently (i.e., the northern three NETC States and the southern three NETC States conduct separate rodeos).
- In addition to considering characteristics suggested by the NETC States, the project team also considered recommended site characteristics for certification/validation and verification of

different performance metrics. Specifically, AASHTO protocols and best practices were used to develop a matrix of experimental factors recommended for control site selection.

Selection of Potential Control Sites

- The project team developed a methodology focused on identifying potential control sites based on available inventory and condition data. The method focuses on 1) identifying parameters in the available data, 2) assessing the possible range of values for each parameter, 3) scoring each parameter based on the value for each pavement section, and 4) calculating a total score by multiplying each individual parameter score together. High total scores are considered good candidates for control sites.
- Because the methodology only focuses on scoring attributes that are both available and important to the State, the total score is adaptable and able to accommodate the addition or subtraction of attributes considered.
- A proof-of-concept, exemplifying how the proposed methodology could be used for control site selection, was conducted using a subset of Vermont DOT's data.

Appendix A. Summary of Scoresheet Comparison

Certification **Does DQMP include the following regarding equipment certification?**

Currently there are certification processes for Inertial Profiling Systems (used for gathering IRI) but not for other data collection devices. Therefore state DOTs should have there own methods for establishing and conducting equipment certification.

Metric	Does DQMP include the following regarding equipment certification?	Required Protocol	CT				ME				VT				MA				NH				RI			
			Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments
IRI	Certification of Inertial Profiling System in accordance with:	AASHTO R56-14	AASHTO R56-14	1	Agency	Uses R56-10 instead of R56-14, is conducted by photolog field staff	AASHTO R56-14	0		To be conducted starting Spring 2019	AASHTO R56-14	2	Vendor	Mentions AASHTO R56-10 as well	Other (explain)	0		Utilizes both AASHTO R 43-13 and AASHTO R 56-14	AASHTO R56-14	2	Agency	Uses appropriate AASHTO standard	AASHTO R56-14	2	Vendor	Utilizes AASHTO protocol
Cracking	Certification testing performed at control sites			0		No information provided on the certification/validation of cracking; proposed plans to implement validation sites		0		Three validation sites identified at the beginning of each year (starting in Spring 2019)		2	Vendor	Contractor collects on up to five validation sites		0		No certification for cracking; Relies on HPMS Field manual and MassDOT Distress Rating Manual for protocols		2	Agency	Control sites set up for routine runs; certification conducted by contractor doing data collection		2	Vendor	Selected 3 control sites throughout the State; separate site is selected for PCC
Cracking	Control sites meet the definition above and are approved by State DOT. In order to receive a score of 2, the referenced control sites must indicate ground reference conditions that cover a range of values and varying types of cracking			0		Proposed validation sites would have <300 ft of cracking per 0.1 lane-mile		0		Proposed sites to include varying IRI values as specified in AASHTO M 328-14 and at least 7 cracks of three levels of severity (less than 6 mm, 6 to 12 mm and over 12 mm)		1	Vendor	Does not mention a range of values covered		1	Unclear	No information is provided regarding the condition of location sites		2	Agency	Cover a range of smooth, medium-smooth, and medium rough surfaces		2	Agency	Control sites having varying pavement conditions; no additional specifics provided
Cracking	Certification control site describes how ground reference and variability/range of expected values are established			0		Proposed validation site data would be compared to manual distress surveys of the site		0		Calipers to be used to measure cracking at validation sites		2	Vendor	Manually rated		0		Not specified		2	Agency	Ground reference is created using a walking profiler and manual measurements		1	Agency	RIDOT measures distresses on control sites but does not explain how. Includes range of expected values for four metrics.
Cracking	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			0		None specified within DQMP; QC protocols suggest accuracy limits, reproducibility limits, and repeatability limits		0		*Minimum accuracy* : +/- 3mm, *Minimum Reproducibility* : N/A, *Required Repeatability* : Within +/- 3 mm standard deviation from the mean of five runs (95 % within limits)		2	Vendor	Conducted by contractor		1	Unclear	*Alligator Cracking Accuracy* : +/- 10% of total area, *Alligator Cracking Repeatability* : St. dev. <15%, *Longitudinal Cracking Accuracy* : +/- 15% length per severity, *Longitudinal Cracking Repeatability* : St. dev. <15%, *Transverse Cracking Accuracy* : +/- 2 count per severity, *Transverse Cracking Repeatability* : Std. dev. <15%		1	Agency	Precision/accuracy specified as 1-2mm cracking		1	Agency	Assesses repeatability and accuracy only
Cracking	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			0		No cracking test during certification process		0		Proposed methodology is prior to collection for the year		2	Vendor	Certification conducted by ARAN		0		Conducted before data collection and periodically during data collection		0	Agency	None specified		2	Vendor	Control sites are utilized to calibrate equipment; blind sites are utilized to assess vendor accuracy every 500 miles
Rutting	Certification testing performed at control sites			2	Agency	Validation sites are selected by CTDOT		0		Three validation sites identified at the beginning of each year (starting in Spring 2019)		2	Vendor	Contractor collects on up to five validation sites		0		No certification for rutting; Relies on AASHTO R 48 protocol		2	Agency	Control sites set up for routine runs; certification conducted by contractor doing data collection		2	Vendor	Selected 3 control sites throughout the State; separate site is selected for PCC
Rutting	Control sites meet the definition above and are approved by State DOT. In order to receive a score of 2, the referenced control sites must indicate ground reference conditions that cover a range of values and varying types of cracking			2	Agency	Validation sites have various levels of roughness and distress		0		Proposed sites to include varying IRI values as specified in AASHTO M 328-14 and at least 7 cracks of three levels of severity (less than 6 mm, 6 to 12 mm and over 12 mm)		1	Vendor	Does not mention a range of values covered		1	Unclear	No information is provided regarding the condition of location sites		2	Agency	Cover a range of smooth, medium-smooth, and medium rough surfaces		2	Agency	Control sites having varying pavement conditions; no additional specifics provided
Rutting	Certification control site describes how ground reference and variability/range of expected values are established			2		CTDOT's CS8800 Walking Profiler is used to establish ground truth		0		Rutting will be measured every 50 feet to meet requirements of AASHTO R 87-18 & R 88-18.		0	Vendor	Does not mention how ground reference is determined		0		Not specified		2		Ground reference is created using a walking profiler and manual measurements		2	Agency	RIDOT measures distresses on control sites but does not explain how. Includes range of expected values for four metrics.
Rutting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			2		*Resolution* : 0.04 in, *Accuracy* : +/- 0.08in, *Reproducibility* : Absolute difference in rut depth <0.06 in in (95% PWL), *Repeatability* : Each run with +/- 0.06 in standard deviation from mean of 5 runs		0		*Minimum accuracy* : +/- 0.12 inches, *Minimum Reproducibility* : N/A , *Required Repeatability* : Within +/-0.1 in from the mean of five runs (95 % within limits)		2	Vendor	*Accuracy* : +/- 0.06 in, *Repeatability* (three runs): +/- 0.06 in		1	Unclear	*Rut Depth Accuracy* : > 85% compared to reference profile, *Rut Depth Repeatability* : St. dev. < 0.04		2	Agency	Precision/accuracy specified as 1 mm or better		2	Agency	Assesses repeatability and accuracy only
Rutting	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			0	Agency	The equipment manufacturer provides proof of calibration but there is no mention of proof of certification		0		Proposed methodology is prior to collection for the year		2	Vendor	Certification conducted by ARAN		0		Conducted before data collection and periodically during data collection		0	Agency	None specified		2	Vendor	Control sites are utilized to calibrate equipment; blind sites are utilized to assess vendor accuracy every 500 miles
Faulting	Certification testing performed at control sites			2		Validation sites are selected by CTDOT		N/A		No PCC pavements		Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW		2	Unclear	Annual Certification of profiler (faulting data are collected using profiler)		N/A		No PCC pavements		2	Vendor	Selected 3 control sites throughout the State; separate site is selected for PCC
Faulting	Control sites meet the definition above and are approved by State DOT. In order to receive a score of 2, the referenced control sites must indicate ground reference conditions that cover a range of values and varying types of cracking			2		Validation sites have various levels of roughness and distress		N/A		No PCC pavements		Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW		1	Unclear	No information is provided regarding the condition of location sites		N/A		No PCC pavements		2	Agency	Control sites having varying pavement conditions; no additional specifics provided
Faulting	Certification control site describes how ground reference and variability/range of expected values are established			2	Agency	CTDOT's CS8800 Walking Profiler is used to establish ground truth		N/A		No PCC pavements		Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW		0		Not specified		N/A		No PCC pavements		1	Agency	RIDOT measures distresses on control sites but does not explain how. Includes range of expected values for four metrics.
Faulting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			2		*Resolution* : 0.04 in, *Accuracy* : +/- 0.08in, *Reproducibility* : Absolute difference in rut depth <0.06 in in (95% PWL), *Repeatability* : Each run with +/- 0.06 in standard deviation from mean of 5 runs		N/A		No PCC pavements		Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW		1	Unclear	*Faulting Accuracy* : +/- 0.5 inch, *Faulting Repeatability* : St. dev. <15%		N/A		No PCC pavements		2	Agency	Assesses repeatability and accuracy only
Faulting	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			0	Agency	The equipment manufacturer shall provide proof of calibration but there is no mention of proof of certification		N/A		No PCC pavements		Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW		0		Not specified		N/A		No PCC pavements		2	Vendor	Control sites are utilized to calibrate equipment; blind sites are utilized to assess vendor accuracy every 500 miles
All	State DOT reviews, approves, and keeps record of certification documentation for all metrics			2	Agency	All certification and validation reports are prepared for the Project Team		0		No documented practices in DQMP		1	Agency	Does not mention record keeping		0		No information in this regard		2				2	Agency	

Data Quality Control Measures to be Conducted Before Data Collection Begins and Periodically During the Data Collection Program

QC is used by data collector to monitor, assess, and adjust production processes. QC can be part of calibration, certification, validation, and verification. DQMP must show how the data collector will ensure the data collected meets quality standards.

Metric	Does DQMP include the following regarding quality control measures?	CT				ME			
		Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments
IRI	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Agency	Validation checks (start of data collection season) include std dev <= 5% (five 0.1 mile runs) and symmetrical appearance of multiple runs; Daily checks include IRI >=30 in/mile and <=400 in/mi and left and right IRI values differ <= 50 in/mi		2	Agency	Diagnostic check is run each day; Random test area used to verify system output and appears reasonable based on the conditions operator sees on road; During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens; At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data
IRI	Identifies frequency of quality control measures before and throughout testing		2	Agency	Daily and weekly checks are conducted throughout the season		2	Agency	See above
IRI	Outlines acceptance criteria and allowable tolerances		2	Agency	See above		0		Does not specifically mention
IRI	Includes and describes training for data collection crews		2				2		
IRI	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Agency	Page 17, Table 2		1	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data; Only if there are concerns, not routine
IRI	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	Page 17, Table 2		2	Agency	During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens
IRI	Includes cross-rater checks		2	Agency	Collect same data with both ARAN vans on reference validation sites		0		Does not specifically mention
IRI	Includes QC checks during daily data reduction		0		None specified		2	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data
IRI	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0				2	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data
IRI	Includes documentation and reporting requirements		2	Agency	Page 25, section 8		0		Does not mention reporting requirements
Cracking	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Agency			2	Agency	Diagnostic check is run each day; Random test area used to verify system output and appears reasonable based on the conditions operator sees on road; During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens; At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data
Cracking	Identifies frequency of quality control measures before and throughout testing		2	Agency			2	Agency	See above
Cracking	Outlines acceptance criteria and allowable tolerances		2	Agency			0		Does not specifically mention
Cracking	Includes and describes training for data collection crews		2				2		
Cracking	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Agency			0		At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data; Only if there are concerns, not routine
Cracking	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency			2	Agency	During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens
Cracking	Includes cross-rater checks		2	Agency			0		Does not specifically mention
Cracking	Includes QC checks during daily data reduction		0		None specified		2	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data
Cracking	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0		Page 25, section 8		2	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data
Cracking	Includes documentation and reporting requirements		2	Agency			0		Does not mention reporting requirements
Rutting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Agency			2	Agency	Diagnostic check is run each day; Random test area used to verify system output and appears reasonable based on the conditions operator sees on road; During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens; At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data
Rutting	Identifies frequency of quality control measures before and throughout testing		2	Agency			2	Agency	See above
Rutting	Outlines acceptance criteria and allowable tolerances		2	Agency			0		Does not specifically mention
Rutting	Includes and describes training for data collection crews		2				2		
Rutting	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Agency			1	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data; Only if there are concerns, not routine
Rutting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency			2	Agency	During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens
Rutting	Includes cross-rater checks		2	Agency			0		Does not specifically mention

Metric	Does DQMP include the following regarding quality control measures?	VT				MA			
		Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments
IRI	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Vendor	QC report is submitted by the contractor on a monthly basis		1	Agency	Visually inspect lasers, camera, and 3-D systems are functioning properly prior to start; Monitor errors during data collection; Verifies data has been collected based on time and number of records; Conducts office checks on the data at the end of the week
IRI	Identifies frequency of quality control measures before and throughout testing		2	Vendor	See above		2	Agency	See above; IRI QC is primarily conducted pre-data collection and monthly
IRI	Outlines acceptance criteria and allowable tolerances		2	Vendor	Quality acceptance to be within 95% of the limits		2	Agency	Specifies resolution, accuracy, and repeatability; *IRI Resolution*: 1 in/mi; *IRI Accuracy*: >= 80% compared to reference profiler; *IRI Repeatability:* >= 90% (10 replicate runs)
IRI	Includes and describes training for data collection crews		2	Vendor			2	Agency	
IRI	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Vendor	Discusses how contractor to utilize up to 5 additional sites to verify different distresses		2	Agency	Identified one control site for certification and three sites for verification
IRI	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Vendor	Contractor manages real-time alerts due to equipment malfunction		2	Agency	Checks roadway cameras, 3D system, and profiler are working correctly throughout collection
IRI	Includes cross-rater checks		0		Not specified		0		Not specified
IRI	Includes QC checks during daily data reduction		2	Vendor	Daily verification checks are conducted by the contractor		0		Daily data reduction conducted on a weekly basis
IRI	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		2	Vendor	Corrective action includes rejection of deliverable where contractor must recollect		1	Agency	Specifies whether to identify and fix, identify and test, or re-collect data
IRI	Includes documentation and reporting requirements		2	Vendor	Contractor to provide documentation and reporting requirements		2	Agency	As part of the responsibilities of data collection team is to document all field data quality activities
Cracking	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Vendor	QC report is submitted by the contractor on a monthly basis		1	Agency	Visually inspect lasers, camera, and 3-D systems are functioning properly prior to start; Monitor errors during data collection; Verify data has been collected based on time and number of records; Conduct office checks on the data at the end of the week
Cracking	Identifies frequency of quality control measures before and throughout testing		2	Vendor	See above		2	Agency	See above; Distress QC is primarily conducted pre-data collection and monthly
Cracking	Outlines acceptance criteria and allowable tolerances		2	Vendor	Quality acceptance to be within 95% of the limits		2	Agency	Specifies resolution, accuracy, and repeatability; *Alligator Cracking Resolution*: N/A; *Alligator Cracking Accuracy*: +/- 10% total area; *Alligator Cracking Repeatability:* <15% (10 replicate runs and historical runs); Longitudinal Cracking Resolution: N/A; *Longitudinal Cracking Accuracy*: +/- 15% length per severity; *Longitudinal Cracking Repeatability*: <15% (10 replicate runs and historical runs); *Transverse Cracking Resolution*: N/A; *Transverse Cracking Accuracy:* +/- 2 count per severity; *Transverse Cracking Repeatability*: <15% (10 replicate runs and historical runs);
Cracking	Includes and describes training for data collection crews		2	Vendor			2	Agency	
Cracking	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Vendor	Discusses how contractor to utilize up to 5 additional sites to verify different distresses		2	Agency	Identified one control site for certification and three sites for verification
Cracking	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		0	Vendor	Contractor manages real-time alerts due to equipment malfunction		2	Agency	Checks roadway cameras, 3D system, and profiler are working correctly throughout collection
Cracking	Includes cross-rater checks		2	Vendor	Not specified		0		Not specified
Cracking	Includes QC checks during daily data reduction		2	Vendor	Daily verification checks are conducted by the contractor		0		Daily data reduction conducted on a weekly basis
Cracking	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		2	Vendor	Corrective action includes rejection of deliverable where contractor must recollect		1	Agency	Specifies whether to identify and fix, identify and test, or re-collect data
Cracking	Includes documentation and reporting requirements		2	Vendor	Contractor to provide documentation and reporting requirements		2	Agency	As part of the responsibilities of data collection team is to document all field data quality activities
Rutting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Vendor	QC report is submitted by the contractor on a monthly basis		1	Agency	Visually inspect lasers, camera, and 3-D systems are functioning properly prior to start; Monitor errors during data collection; Verify data has been collected based on time and number of records; Conduct office checks on the data at the end of the week
Rutting	Identifies frequency of quality control measures before and throughout testing		2	Vendor	See above		2	Agency	See above; Rutting QC is primarily conducted pre-data collection and monthly
Rutting	Outlines acceptance criteria and allowable tolerances		2	Vendor	Quality acceptance to be within 95% of the limits		2	Agency	Specifies resolution, accuracy, and repeatability; *Rut Depth Resolution*: 1 in/mi; *Rut Accuracy*: >= 80% compared to reference profiler; *Rut Repeatability:* >= 90% (10 replicate runs)
Rutting	Includes and describes training for data collection crews		2	Vendor			2	Agency	
Rutting	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Vendor	Discusses how contractor to utilize up to 5 additional sites to verify different distresses		2	Agency	
Rutting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Vendor	Contractor manages real-time alerts due to equipment malfunction		2	Agency	
Rutting	Includes cross-rater checks		0		Not specified		0		Checks roadway cameras, 3D system, and profiler are working correctly throughout collection

Metric	Does DQMP include the following regarding quality control measures?	NH				RI			
		Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments
IRI	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Agency	Conducts multiple checks including vehicle, sensor, cracking, and numeric checks throughout collection process	Practical Guide for Quality Management of Pavement Condition Data Collection	1	Vendor	Partial explanation is provided regarding the verification of the equipment during data collection and repeatability test which vendor has to do on the control sites.
IRI	Identifies frequency of quality control measures before and throughout testing		2	Agency	Process controls are specified for prior to collection or during collection	Practical Guide for Quality Management of Pavement Condition Data Collection	0	Vendor	None specified
IRI	Outlines acceptance criteria and allowable tolerances		2	Agency	Identifies thresholds for difference distress metrics	Practical Guide for Quality Management of Pavement Condition Data Collection	0		None specified
IRI	Includes and describes training for data collection crews		2	Agency		Practical Guide for Quality Management of Pavement Condition Data Collection	0		None specified
IRI	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Agency	DCU establishes at least three control sites to check contractor certification	Practical Guide for Quality Management of Pavement Condition Data Collection	1	Vendor	Verification of the equipment and raters at two blind sites selected by the RIDOT
IRI	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	Real time checks on GPS and Pathways 3D system		0		None specified
IRI	Includes cross-rater checks		2	Agency	Conduct repeat runs to confirm repeatability		0		None specified
IRI	Includes QC checks during daily data reduction		0	Agency	None specified (except bounce testing)		0		None specified
IRI	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		2	Agency	Corrective actions handled by contractor		1	Vendor	Includes corrective action if the vendor's results do not meet the required accuracy on the blind sites.
IRI	Includes documentation and reporting requirements		2	Agency			2	Vendor	The vendor is required to report and document all QC activities
Cracking	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Agency	Conducts multiple checks including vehicle, sensor, cracking, and numeric checks throughout collection process		1	Vendor	Partial explanation is provided regarding the verification of the equipment during data collection and repeatability test which vendor has to e done on the control sites
Cracking	Identifies frequency of quality control measures before and throughout testing		Unclear	Agency	Process controls are specified for prior to collection or during collection		0		None specified
Cracking	Outlines acceptance criteria and allowable tolerances		2	Agency	Identifies thresholds for difference distress metrics		0		None specified
Cracking	Includes and describes training for data collection crews		2	Agency			0		None specified
Cracking	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Agency	DCU establishes at least three control sites to check contractor certification		1	Vendor	Verification of the equipment and raters at two blind sites selected by the RIDOT
Cracking	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		1	Agency	Real time checks on GPS and Pathways 3D system		0		None specified
Cracking	Includes cross-rater checks		2	Agency	Conduct repeat runs to confirm repeatability		0		None specified
Cracking	Includes QC checks during daily data reduction		0	Agency	None specified (except bounce testing)		0		None specified
Cracking	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		2	Agency	Corrective actions handled by contractor		1	Vendor	Includes corrective action if the vendor's results do not meet the required accuracy on the blind sites.
Cracking	Includes documentation and reporting requirements		2	Agency			2	Vendor	The vendor is required to report and document all QC activities
Rutting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Agency	Conducts multiple checks including vehicle, sensor, cracking, and numeric checks throughout collection process		1	Vendor	Partial explanation is provided regarding the verification of the equipment during data collection and repeatability test which vendor has to e done on the control sites.
Rutting	Identifies frequency of quality control measures before and throughout testing		2	Agency	Process controls are specified for prior to collection or during collection		0		None specified
Rutting	Outlines acceptance criteria and allowable tolerances		2	Agency	Identifies thresholds for difference distress metrics		0		None specified
Rutting	Includes and describes training for data collection crews		2	Agency			0		None specified
Rutting	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Agency	DCU establishes at least three control sites to check contractor certification		1	Vendor	Verification of the equipment and raters at two blind sites selected by the RIDOT
Rutting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	Real time checks on GPS and Pathways 3D system		0		No specified; daily checks are proposed
Rutting	Includes cross-rater checks		2	Agency	Conduct repeat runs to confirm repeatability		0		None specified

Rutting	Includes QC checks during daily data reduction		0		None specified		2	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data		2	Vendor	Daily verification checks are conducted by the contractor		0		None specified		0	Agency	None specified (except bounce testing)		0		None specified
Rutting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0		None specified		2	Agency	At the end of each collection day, operator will review a small number of random sections to ensure data collected is as expected without any errors or missing data		2	Vendor	Corrective action includes rejection of deliverable where contractor must recollect		1	Agency	Page 17, for control site tests		2	Agency	Corrective actions handled by contractor		1	Vendor	Includes corrective action if the vendor's results do not meet the required accuracy on the blind sites.
Rutting	Includes documentation and reporting requirements			Agency			0		Does not mention reporting requirements		2	Vendor	Contractor to provide documentation and reporting requirements		2	Agency	As part of data collection team's responsibility		2	Agency			2	Vendor	The vendor is required to report and document all QC activities
Faulting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		2	Agency			N/A		No PCC pavements		Unclear	Vendor	QC report is submitted by the contractor on a monthly basis		1		Visually inspect lasers, camera, and 3-D systems are functioning properly prior to start; Monitor errors during data collection; Verify data has been collected based on time and number of records; Conduct office checks on the data at the end of the week		N/A	Agency	No PCC pavements		1	Vendor	Partial explanation is provided regarding the verification of the equipment during data collection and repeatability test which vendor has to e done on the control sites.
Faulting	Identifies frequency of quality control measures before and throughout testing		2	Agency			N/A		No PCC pavements		Unclear	Vendor	See above		2	Agency	See above; Profiler QC is primarily conducted pre-data collection (annually)		N/A	Agency	No PCC pavements		0		None specified
Faulting	Outlines acceptance criteria and allowable tolerances		2	Agency			N/A		No PCC pavements		Unclear	Vendor	Quality acceptance to be within 95% of the limits		1	Agency	No allowable tolerance		N/A	Agency	No PCC pavements		0		None specified
Faulting	Includes and describes training for data collection crews		2				N/A		No PCC pavements		Unclear	Vendor			2	Agency			N/A	Agency	No PCC pavements		0		None specified
Faulting	Includes verification of equipment and raters at control sites (same sites used for original calibration or certification) data compared to original calibration/certification data		2	Agency			N/A		No PCC pavements		Unclear	Vendor	Discusses how contractor to utilize up to 5 additional sites to verify different distresses		2	Agency			N/A	Agency	No PCC pavements		1	Vendor	Verification of the equipment and raters at two blind sites selected by the RIDOT
Faulting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency			N/A		No PCC pavements		Unclear	Vendor	Contractor manages real-time alerts due to equipment malfunction		2	Agency	Checks roadway cameras, 3D system, and profiler are working correctly throughout collection		N/A	Agency	No PCC pavements		0		None specified
Faulting	Includes cross-rater checks		2	Agency			N/A		No PCC pavements		Unclear		Not specified		0		None specified		N/A	Agency	No PCC pavements		0		Not specified
Faulting	Includes QC checks during daily data reduction		0		None specified		N/A		No PCC pavements		Unclear	Vendor	Daily verification checks are conducted by the contractor		0				N/A	Agency	No PCC pavements		0		Not specified
Faulting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0		None specified		N/A		No PCC pavements		Unclear	Vendor	Corrective action includes rejection of deliverable where contractor must recollect		1	Agency	Page 17, for control site tests		N/A	Agency	No PCC pavements		1	Vendor	Includes corrective action if the vendor's results do not meet the required accuracy on the blind sites.
Faulting	Includes documentation and reporting requirements		2	Agency	The Data Collection Quality Control Supervisor monitors the QC activities.		N/A		No PCC pavements		Unclear	Vendor	Contractor to provide documentation and reporting requirements		2	Agency	Page 9, as part of the responsibilities of data collection team is to document all field data quality activities		N/A	Agency	No PCC pavements		2	Vendor	The vendor is required to report and document all QC activities
All	State DOT reviews and keeps record of QC results for all metrics		2	Agency	The Data Collection Quality Control Supervisor monitors the QC activities.		0		Does not specifically mention		1	Agency	Corrective actions and quality control are documented by the contractor but the extent is not clear		1	Agency	Data Collection and Data Reduction Team keep daily logs of data quality checks; However, the length for which these logs are kept was not specified		2	Agency			0		No explanation

Error Resolution Procedures and Data Acceptance Criteria

This section addresses procedural errors (typically during data processing to summarize test results), data quality and omission errors (poor image quality, poor accuracy, lack of complete data), and data correctness errors.

Metric	Does DQMP include the following regarding Error Resolution Procedures and Data Acceptance ?	CT				ME				VT				MA				NH				RI			
		Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments	Referenced Protocol	Score	Responsibility	Comments
All	Specifies the data acceptance criteria for each metric		2	Agency	*IRI:* 40-450 in/mile for CTDOT network sections, 30 in/mi-400 in/mi for HPMS sections); *Rut Depth*: <=0.5 in for CTDOT network sections, Max 1 in for HPMS sections; *Asphalt Pavement Cracking*:		2	Agency	*IRI:* Values expected between 20 and 900 in/mile; *Percent Cracking*: 0-60%; *Rutting*: 0 to 1.5 inches; *Vehicle Speed*: 25- 60 mph; *PSR*: 1 to 5 with 0.1 precision		2	Agency	Specifies acceptance criteria based on stats on each distress metric		2	Agency	*IRI*: St. dev. <=5% (ten 0.1 mile runs), Std. dev. <= 10% (historical average), symmetrical graphical appearance of 10 runs; *Distress:* Std. dev. <=15% total length (ten 0.1 mile runs), Std. dev <=15% total length (historical average); *Rutting*: Std. dev <=0.4 inch (ten 0.1 mile runs), Std. dev. <=0.4 inch (historical average)		Unclear	Agency	Specified types of errors, but not specifics with regards to metrics		1	Agency	Set for each metric; not super detailed
All	Includes statistical methods to compare and verify results for acceptance. The following are commonly used statistical methods for evaluating data quality control, verification, and independent assurance: • F- and t-test. • Paired t-test. • Cohen's kappa statistic. * Percent within Limits (PWL)		0		None specified		0		Does not specifically mention		0		Does not specifically mention		0		Does not specifically mention		0	Agency	None specified		2	Agency	F test and t test
All	When acceptance criteria is not met, describes corrective action process (examples may include: re-collect, re-calibrate, re-analyze the raw data, or re-train staff)		2	Agency	Corrective actions include re-collection, re-calibration of equipment, re-analyzing raw data, or even re-training staff responsible for data collection or analysis		2	Agency	Data is flagged and discussed; depending on the error, there may be recalculating/reprocessing or recollection		2	Agency	Corrective actions are taken throughout entire collection process; Includes recollection by contractor		2	Agency	Specifies whether to identify and fix, identify and test, or re-collect data		2	Agency	Corrective actions include reprocessing and recollecting		2		RIDOT will check to see if the unreasonable data is related to field conditions; if not, vendor will check their processing; if not a processing issue, data will be recollected
All	Corrective action plan includes a method to troubleshoot why data was incorrect to avoid same error after re-collecting		2	Agency	Corrective actions are specified for each deliverable type including IRI, rutting, faulting, and cracking		0		Does not specifically mention		2	Vendor	Corrective actions are taken throughout entire collection process; Includes recollection by contractor		0		Does not specifically mention		2	Agency	Common error types are described		2		See above; no specific actions other than process listed
All	Data collector is notified of acceptance requirements and corrective action plan prior to data collection		0		Data collected in-house		N/A		Data collected in-house		2	Agency	Corrective actions and requirements are assessed yearly; contractor is notified		0		Data collected in-house		0	Agency	None specified		0		Not stated in DQMP
All	State DOT reports and keeps records of error resolution and data acceptance results		2	Agency	Error logs, QC logs, and acceptance logs are maintained throughout entire data collection process; Acceptance logs are used to itemize, document, and track to closure items reported throughout the process		0		Does not specifically mention		0		Does not specifically mention		0		Utilizes a QC log, but not an error resolution log		0	Agency	None specified		2	Agency	Yes, provided through vendor

Appendix B. Control Site Experimental Matrix

Metric	Equipment	Test Type	Protocol/ Field Testing	Section #	Site/Section Requirements								Test Requirements			Applicable to					
					Surface Type	Distress Level	Section Length	Section Width	Geometry	Surface Macrotexture	Traffic Control	Field/ Garage	Nr Passes/ Rep Meas	Test Speeds	Reference Data	CT	MA	ME	NH	RI	VT
IRI	Inertial Profiler	Certification	AASHTO R56	1	AC/Composite	Smooth (30-75 in/mile)	≥ 528' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network. Coarse preferred	Yes	Field	5 per speed	2 speeds: maximum operation speed and minimum operation speed	SurPRO profiler	✓	✓	✓	✓	✓	✓
IRI	Inertial Profiler	Certification	AASHTO R56	2	AC/Composite	Medium-Smooth (95-135 in/mile)	≥ 528' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network. Coarse preferred	Yes	Field	5 per speed	2 speeds: maximum operation speed and minimum operation speed	SurPRO profiler	✓	✓	✓	✓	✓	✓
IRI	Inertial Profiler	Certification	AASHTO R56	3	AC/Composite	Medium-Rough (<200 in/mile)	≥ 528' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network. Coarse preferred	Yes	Field	5 per speed	2 speeds: maximum operation speed and minimum operation speed	SurPRO profiler	✓	✓	✓	✓	✓	✓
Section Length (part of IRI test)	DMI	Certification	AASHTO R56	1	AC/Composite	NA	≥ 1,000' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	NA	No	Field	at least 3 per speed	2 speeds: maximum operation speed and minimum operation speed	Measuring Tape	✓	✓	✓	✓	✓	✓
IRI	Inertial Profiler	Certification	AASHTO R56	1	JCP/CRCP	Smooth (30-75 in/mile)	≥ 528' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	5 per speed	2 speeds: maximum operation speed and minimum operation speed	SurPRO profiler	✓	✓				
IRI	Inertial Profiler	Certification	AASHTO R56	2	JCP/CRCP	Medium-Smooth (95-135 in/mile)	≥ 528' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	5 per speed	2 speeds: maximum operation speed and minimum operation speed	SurPRO profiler	✓	✓				
IRI	Inertial Profiler	Certification	AASHTO R56	3	JCP/CRCP	Medium-Rough (<200 in/mile)	≥ 528' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	5 per speed	2 speeds: maximum operation speed and minimum operation speed	SurPRO profiler	✓	✓				
Section Length (part of IRI test)	DMI	Certification	AASHTO R56	1	JCP/CRCP	NA	≥ 1,000' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	NA	No	Field	at least 3 per speed	2 speeds: maximum operation speed and minimum operation speed	Measuring Tape	✓	✓	✓	✓	✓	✓
Rutting	Transverse Profiler	Certification	AASHTO PP106 - Static	1	NA	NA	NA	≥ 13.5 ft	mini ramps and jack stands	NA	NA	Garage?	10 scans	NA	13' Straightedge & block	✓	✓	✓	✓	✓	✓
Rutting	Transverse Profiler	Certification	AASHTO PP107 - Body Motion	1	AC	NA	8' section 0.25 mile lead-in + stopping distance	≥ 14 ft	?	?	Yes	Field	2 per speed	3 speeds 5, 8, 12 mph	Flate Plates & Excitation Boards	✓	✓	✓	✓	✓	✓

Metric	Equipment	Test Type	Protocol/ Field Testing	Section #	Site/Section Requirements								Test Requirements			Applicable to					
					Surface Type	Distress Level	Section Length	Section Width	Geometry	Surface Macrotexture	Traffic Control	Field/ Garage	Nr Passes/ Rep Meas	Test Speeds	Reference Data	CT	MA	ME	NH	RI	VT
Rutting	Transverse Profiler	Certification	AASHTO PP108 - Navigation Drift	1	AC	NA	178'	79'	?	?	Yes	Field	5	8 mph	Global position survey	✓	✓	✓	✓	✓	✓
Rutting	Transverse Profiler	Certification	AASHTO PP109- Highway Performance AASHTO PP110- GRE	1	AC	Low Rutting	12' section 0.25 mile lead-in + stopping distance	≥ 13.5 ft	?	?	Yes	Field	3 per speed	7 speeds 15 to 105, every 15 mph	Hand-held Scanner	✓	✓	✓	✓	✓	✓
Rutting	Transverse Profiler	Certification	AASHTO PP109- Highway Performance & AASHTO PP110- GRE	2	AC	High Rutting	12' section 0.25 mile lead-in + stopping distance	≥ 13.5 ft	?	?	Yes	Field	3 per speed	7 speeds 15 to 105, every 15	Hand-held Scanner	✓	✓	✓	✓	✓	✓
HPMS Cracking	Distress Measuring System	Validation	Field Testing	1	AC/Composite	Low Cracking	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓	✓	✓	✓	✓
HPMS Cracking	Distress Measuring System	Validation	Field Testing	2	AC/Composite	Medium Cracking	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓	✓	✓	✓	✓
HPMS Cracking	Distress Measuring System	Validation	Field Testing	3	AC/Composite	High Cracking	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓	✓	✓	✓	✓
HPMS Cracking & Faulting	Distress Measuring System	Validation	Field Testing	1	JCP	Low Cracking, Low Faulting	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓				
HPMS Cracking & Faulting	Distress Measuring System	Validation	Field Testing	2	JCP	High Cracking, Low Faulting	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓				
HPMS Cracking & Faulting	Distress Measuring System	Validation	Field Testing	3	JCP	Low Cracking, High Faulting	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓				
HPMS Cracking & Faulting	Distress Measuring System	Validation	Field Testing	4	JCP	High Cracking, High Faulting	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓				
HPMS Cracking	Distress Measuring System	Validation	Field Testing	1	CRCP	Low Cracking	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓				

Metric	Equipment	Test Type	Protocol/ Field Testing	Section #	Site/Section Requirements								Test Requirements			Applicable to					
					Surface Type	**Distress Level**	**Section Length**	**Section Width**	**Geometry**	**Surface Macrotexture**	**Traffic Control**	**Field/ Garage**	**Nr Passes/ Rep Meas**	**Test Speeds**	**Reference Data**	**CT**	**MA**	**ME**	**NH**	**RI**	**VT**
HPMS Cracking	Distress Measuring System	Validation	Field Testing	2	CRCP	High Cracking	≥ 528' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative of pavements in States' highways network	Yes	Field	10 per speed	2 speeds 30, 55 mph	Consensus Survey of Raters	✓	✓				
AC HPMS Distresses		Verification	Field Testing		AC, open-graded surface preferred	Medium levels of roughness and distress	≥ 1,000' with lead-in & stopping distance	9'-13'	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	Representative but coarse preferred	No	Field	5 per speed	≥ 1 every X miles or 2 weeks during peak data collection	Based on historical data	✓	✓	✓	✓	✓	✓
JCP/CRCP HPMS Distresses		Verification	Field Testing											≥ 1 every X miles or X weeks	Based on historical data	✓	✓				
DMI		Verification	Field Testing											≥ 1 every X miles or X weeks	Based on historical data	✓	✓	✓	✓	✓	✓