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

Final Report July 2023

NEW ENGLAND TRANSPORTATION CONSORTIUM

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7. Author(s) Gonzalo Rada, Ph.D., P.E., https://orcid.org/0000-0001-5409-0396, Amy Simpson, Ph.D., P.E., Connor Bruce		**8. Performing Organization Report No.** Report No. NETCR123
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16. Abstract

The New England Transportation Consortium (NETC) members spend significant time and resources on pavement surface condition data collection in support of a wide range of reporting and decision-making functions. Quality data are of critical importance to these functions—as the adage goes, "garbage in, garbage out." The data quality management plans (DQMPs) mandated by Congress in 23 CFR 490.319(c) provide a means to assist in achieving quality data, but the specific steps are not clear. This project was undertaken to provide data collection quality guidance. A review of the existing NETC member DQMPs was first undertaken to better understand their strengths and weaknesses. Interviews with NETC member agency staff were then conducted, with a focus on the identification and selection of control sites needed to establish the reference values for the certification, validation, and verification of pavement surface data collection equipment. The resulting information was used to develop common terminology to facilitate clear and concise communications between NETC members; guidelines and tool for the identification and selection of control sites, which consider site requirements and characteristics; recommendations for control site inter-agency sharing options; and other data quality-related guidelines, such as certification, validation, and verification frequency. Once implemented, the terminology and guidelines will yield important benefits to the NETC members.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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Introduction

The New England Transportation Consortium (NETC) members consist of the Maine (ME), Connecticut (CT), Massachusetts (MA), New Hampshire (NH), Rhode Island (RI), and Vermont (VT) 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).
- Developing and updating pavement performance models.
- 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 transportation agencies, and the associated maintenance and rehabilitation budgets are significant. Therefore, 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 transportation agency must take are not clear. This has resulted in every transportation agency 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, were:

- Review northeast state DQMPs 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 "successful practices" recommendations to assist states with data reporting requirements for compliance with FHWA-approved DQMPs.

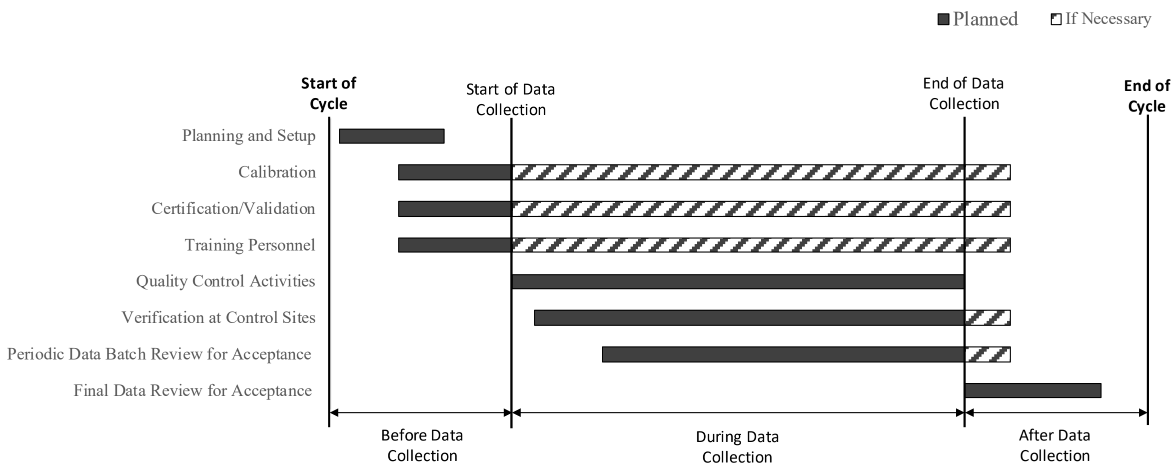

Figure 1. Chart. Timeline of typical DQMP activities throughout the data collection cycle.

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

1. Review and analyze DQMPs for pavement condition data from the NETC member agencies to:
   a. Identify regional efficiencies in collection and analysis of validation/control QC/QA data for each NETC member agency.
   b. Identify how each NETC member 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 was expected to produce the following outputs in support of the New England region DQMP practices:

- Improvement recommendations and draft language for each member's DQMP based on successful 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 member agencies as a result of the project.

This report details the work performed under Tasks 1 through 5 of NETC Project 21-1, including the approach, findings, conclusions, and recommendations associated with each task.

Task 1. Review and Analysis of NETC Members' DQMPs

The objective of this initial task was to review and analyze DQMPs for pavement condition data from the NETC member 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 member 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 member 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 member agencies.

These activities are detailed next along with the associated findings, conclusions, and recommendations. Input on these activities was received from the NETC members via draft report review comments and from virtual meetings held on March 29 and April 19, 2022.

Review of DQMPs

To better understand the NETC member agency 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 are provided.

NETC DQMPs

The research team compared the member agencies' DQMPs to assess data quality management practices. For the most part, the NETC member agencies 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 NETC member agencies provide their latest DQMPs in cases where the initial DQMP had been revised or updated. Of the six NETC member agencies, only New Hampshire had updated and approved a new DQMP. The revision to New Hampshire's DQMP was primarily the result of the agency 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[1]	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 the DQMPs for all 50 state DOTs, including the six NETC member agencies. The project, which focused on developing national guidance for DQMPs, utilized a scoresheet to evaluate the completeness of each agency'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. Based on the updates to the NETC member agency 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 member agencies, the scoresheet updates focused on

[1] A revised version of the CT DQMP was completed in the summer of 2022, after completion of Task 1. NETC Project 21-1 was not sufficiently complete to contribute to the revised DQMP, but it is anticipated that the project findings will be incorporated into future DQMP versions.

three of the five key areas of a DQMP. Table 3 provides a summary of the areas evaluated and the key components.

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.

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. • 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.

Area Evaluated	Components Evaluated
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, or re-analyze the raw data, or re-train staff).
	• 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 the NETC member agencies. Appendix A provides a summary of the scoresheet comparison for the specified areas above.

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.[2]

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%
Division 8: Mountain	56%	45%	26%	70%	71%	66%
Division 9: Pacific	34%	35%	28%	32%	54%	35%

[2] Scores of 65 points or higher (green) were considered good, between 30 and 65 (yellow) fair, and lower than 30 (red) poor.

The NETC member 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 member, the following were identified strengths of existing quality management practices in the three areas assessed:

- Equipment Calibration and Certification
  - Most NETC member agencies are already utilizing the required protocol, AASHTO R56-14, to certify their Inertial Profiling System.
  - Most NETC member agencies 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 NETC member agencies, 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 when data does not meet acceptance criteria, including reprocessing or recollecting, is well defined.

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

- 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 NETC members were conducted for the same ends (i.e., some members used verification and validation interchangeably while other members 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 successful practices, control sites should have varying levels of distress.

Based on this assessment of the key quality management practices implemented by each NETC member, the project team identified 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 NETC members' 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 successful 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 members carried out as part of Task 2. As an example, it became clear from the discussions that the NETC member agencies do 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 members 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—certification, validation, and verification—along with the requirements and additional information for each test is listed in Table 5. Certification refers to the procedure of evaluating data collected in accordance with a recognized standard or test procedure to check the accuracy and precision of data with respect to reference measurements. Calibration refers to the procedure of comparing data collected by equipment against a known standard to adjust equipment or applying a factor to collected data to reach an expected level of accuracy. And verification refers to the procedure performed to evaluate data by comparison with reference measurements under representative conditions. More detailed definitions of the test types are provided in Table 6 in the DQMP Terminology section.

The minimum number of control sites for each certification or validation test 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 be determined 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 quantity of rigid pavements in their highway network. In addition, all NETC member 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 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 members' sensors and reduces data collection and processing efforts.

Verification testing is to be performed at a regular interval during routine data collection, as part of routine checks on equipment operation—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 are to be used for checking the equipment precision (repeatability for repeated passes) and potentially 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.

Availability of Control Sites

Appendix B contains the main pieces of information related to existing and projected control sites obtained from the states' DQMP documents, information submitted by the NETC members to the project team, and information gathered from individual agency meetings. This information was 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.

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

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

DQMP Terminology

In addition to identifying the efficiencies in pavement data quality management practices between NETC members, it was also important to develop standard terminology to assess the methodologies and processes used to assess pavement condition data throughout the NETC member agency networks. Specifically, the goal was to identify key terminology already being used by the NETC members and to provide a definition for which all NETC members could agree. To do so, the project team:

- Identified terminology and accepted definitions based on existing standards and literature.
- Compared these terms and definitions to the ones provided by the NETC members in their DQMPs.
- Reconciled the final terminology and definitions per input provided by NETC members.

A summary of this process is provided in the following subsection.

Proposed Terminology

As a first step, the project team identified and defined common terminology and definitions found within state DQMPs and AASHTO, ASTM, and ISO standards. This process resulted in the definition of the seven key terms summarized in Table 6, which include calibration, certification, validation, verification, quality control, quality assurance, and control sites.

Table 6. Proposed standard terminology.

Term	Definition
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.
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.
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.

Term	Definition
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.

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 at frequent or regular intervals throughout the data collection season.

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 member agencies’ DQMPs was conducted. To do so, the use of each term in the six NETC member DQMPs was evaluated and compared both against the proposed definitions and against definitions used by other members within the NETC. The comparison and summary of terminology used by each of the NETC members 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 members for review and comment.

During a virtual meeting held on March 29, 2022, the proposed terms and definitions were discussed in light of the difficulties in comparing terminology from the DQMPs. The NETC members agreed to the proposed terminology and definitions provided, and each was adopted and utilized throughout subsequent tasks of the project.

Task 2. Certification, Validation and Verification Control Sites

The objective of this task was twofold: (1) 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, based on the established characteristics, (2) 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 and Appendix C. 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 members based on each agency's willingness to travel. In addition to the NETC states' input, the performance metrics being considered (roughness, cracking, rutting, and distance) and the intended purpose of the control site (certification/validation versus verification) were used to establish a more 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 following sections.

Control Site Characteristics

As noted earlier, 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 members as well as the requirements and successful 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 member control site selection practices for varying performance tests. The review, which was primarily based on information available in the state DQMPs, was supplemented with individual interviews with NETC states. The interviews, which were conducted between May 4-12, 2022, focused on three key areas: (1) updates to information reported in Task 1, (2) current and preferred control site characteristics, and (3) willingness of the NETC members to travel for certification, validation, and verification testing. Information on existing control site selection practices were used to update the Task 1 write-up.

Through the interviews, the project team found that control site selection methods varied from agency to agency. While some members 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 NETC member used a SurPRO for IRI verification at defined control sites, another member 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, members 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 NETC members. Specifically, NH, ME, and MA discussed some of the challenges and opportunities in sharing the New Bedford Airport control site. For ME, which no longer uses the site, the New Bedford Airport illuminated the importance of making sure shared sites meet the needs of the different equipment members are using. Whereas for NH and MA, the airport was an example of how members could share resources to meet the same goals.

In terms of the desired site selection criteria, there was more of a consensus between the individual NETC members. For each agency, safety was the primary consideration or concern when selecting control sites. Specifically, NETC members 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 members in selecting control sites was pavement performance. Members 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 member, as well as successful 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 this task.

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 interviews also helped the project team to better understand each member's willingness to share control sites and travel. For the most part, NETC members agreed there was benefit in sharing control sites even if it meant traveling throughout New England. For one member, it was preferred to keep travel to a minimum. Therefore, one possible recommendation would be to have the northern three NETC members (NH, VT, and ME) and the southern three NETC members (MA, RI, and CT) establish separate control sites to reduce distance traveled. All NETC members 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 was to have one host agency manage locations, markings, and the collection of reference data, while the other NETC members participate in a "rodeo." The rodeo would rotate between the NETC members to distribute the work required to select and set-up control sites each year. The second option was to have each agency perform its own quality testing, independent of the other five agencies. The third and final option was a combination of options 1 and 2; some of the NETC members 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 members and the three southern NETC members 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 host agency establishes locations, marking and collection of reference data and 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 rodeo becomes more established) • May require higher amounts of travel

Option	Advantages	Disadvantages
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 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 virtual project meeting. States generally agreed that Option 1 or 3 would help maximize the benefits for certification and validation testing of pavement condition 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 the characteristics suggested by the NETC members, the project team also considered recommended site characteristics for certification, validation, and verification of different performance metrics. Specifically, AASHTO protocols and successful practices were used to develop a matrix of experimental factors recommended for control site selection. The matrix, shown in Appendix C, 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 discussed earlier, 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 successful 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[3], and faulting rely on field validation. As these tests occur infrequently and are conducted using similar methods from agency-to-agency, certification and validation testing provide an opportunity for NETC members to share efficiencies and resources by conducting a rodeo. Specifically, a rodeo enables NETC members 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 NETC member 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 successful practices summarized in Appendix C. Metrics covered include AC performance metrics—IRI, cracking, rutting—and DMI, as all six NETC members collect data on each. CT, which also maintains PCC pavements, can apply similar practices to those outlined in Appendix C to establish faulting control sites.

IRI

IRI certification testing should follow the 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 IRI certification control sites and the scheduling of traffic control would fall to the host agency. However, the collection of reference data could be a collaborative effort between rodeo participants. As it is recommended reference data for IRI certification be collected using a SurPRO profiler, NETC members would share resources to enable the host member to collect reference data with the recommended profiler. Once the reference data are collected, each rodeo participant would convene at the selected control site(s) of the host agency to conduct IRI certification.

Cracking

Unlike IRI, there are no national protocols for cracking data validation.[4] Instead, HPMS cracking percent and individual state cracking types are validated using successful practices or agency 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 agency to agency, 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 by the equipment and/or personnel being evaluated and the reference data; while the first option may provide a more "true" ground

[3] 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.

[4] There was discussion about standardizing the method used for collecting ground truth data for cracking between agencies that are sharing control sites—this way agencies sharing control sites are collecting ground truth data the same way. If the same cracking definition is used by the agencies, then this does make sense. The problem is that if different definitions are used, then using the same data does not demonstrate the ability to collect data in accordance with the definitions used by the agencies.

truth (assuming raters have good vision or eyeglasses, conduct the survey when the sun is not 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 members 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.[5] 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 C. 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 successful 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 agency.

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 an agency 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 members. Because verification testing occurs at a more frequent basis, it is recommended that the selection of controls sites be done by the individual agencies rather than through a rodeo.[6] In doing so, NETC members will have more flexibility in when and where verification testing is conducted. However, neighboring NETC members may also consider establishing shared verification sites near their borders.

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

[5] If the NETC member agencies are using a different basis for measuring rut depth (6-ft straightedge vs 4-ft straightedge vs AASHTO algorithm), then the same issues as referenced for cracking apply to rutting (see previous footnote).

[6] NETC member agencies involved in a particular rodeo can discuss among themselves the possibility of using the host state's certification/validation sites for verification testing. However, verification testing does not necessarily require field work. If the agency requires a check on accuracy, it will be incumbent upon the NETC member agency to collect that information. However, that could be limited to once a year unless a significant difference is observed with the reference data.

- **Precision**.[7] Precision is a measure of whether data collection results can be reproduced or repeated when the same location is tested multiple times. Precision 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 NH, both vehicles will collect data on the same control site, and the results of the collection will be compared. It is recommended that NETC members keep track of the precision of data collection results through verification. However, this is not crucial if the data collection equipment has been certified and there has not been any changes to the equipment since certification/validation.
- **Accuracy**. Accuracy is a measure of how well the collected data compares to "ground truth" or reference data. Testing accuracy is key for verifying cracking data. NETC members 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 members 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 than in-field measurements.

Control site characteristics ideal for certification and validation testing should also be considered by the NETC members 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 member 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 members. An overview of how the algorithm developed as part of the Task 2 effort works, as well as a proof of concept on the implementation of this methodology for a subset of VT's pavement network data, is provided next.

Methodology for Selection of Control Sites

The methodology developed to identify control sites for certification, validation, and verification testing utilizes available agency 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 a National Highway System (NHS) roadway. However, as the types and reliability of inventory data may vary between NETC members, the methodology enables members to consider additional or fewer parameters than the ones described. For example, if a member 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, NETC members next consider the possible values each identified parameter can take on. For numeric

[7] There are two forms of precision. One of them is reproducibility, which is intended to refer to the variation between devices of the same type. The other is repeatability, which is the variability within a given device.

attributes, such as pavement distresses, members would consider the average type and severity of the distress throughout the agency's network. For example, when considering IRI, an agency will use 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, NETC members would define potential values or categories for the attribute based on agency data. In the case of whether the route is on the NHS, potential categories include "On the NHS" and "Not on the NHS."

Next, NETC members would 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 member may look at the distribution of AADT values across routes within the agency and categorize a route's AADT as low, medium, or high. The member would 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 may (but not always) be more advantageous to select a control site off the NHS. In this case, NETC members 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 as detailed in equation form in Figure 2:

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

Figure 2. Equation. Total control site score equation.

where n is the number of attributes considered by the NETC member based on available data.

States would repeat this process for all routes within their network and use the total score to identify potential control sites. Ideally, the NETC member 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 proposed methodology offers flexibility to meet NETC member needs and data deficiencies. Because the methodology only focuses on scoring attributes that are both available and important to the member, 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 agency. Attributes that the agency would like to emphasize in selecting a control site can be weighted so they proportionally affect the total score. For example, if an agency really wanted to focus on selecting a control site with a low AADT, the agency 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 illustrates how the proposed methodology for control site selection can be implemented using real data. For the purposes of this example, a subset of VT's pavement 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 the VT transportation agency. 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 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 VT—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.
2. 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 (across all sections from W to E) 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

3. **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 VT 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
4. **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.
5. **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 4 or more lanes were scored a 1, while sections with 3 or less lanes were scored a 0.5.
6. **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 3. Test sections with high total scores (shown in green), are considered good candidates for the VT agency's certification, validation, and verification testing control sites.

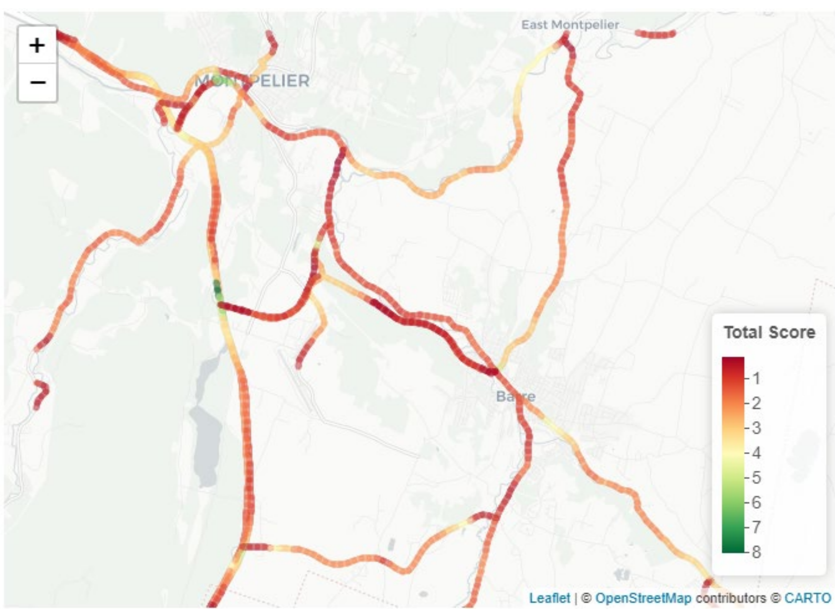

Figure 3. Map. Example map with scores.

Task 3. Development of Control Site Selection and Other Guidelines

The objective of Task 3 was to develop guidelines for certifying, validating or verifying that the data the pavement data collection equipment and operators are producing meets the quality needs and goals of the NETC members. Specific control site elements defined as part of the guidelines included:

- Site requirements.
- Site characteristics.
- Site sharing.
- Successful practices.

Guideline development initially focused on the control site requirements and characteristics due to the importance of control sites to improving quality review and assessment of pavement condition data. By having a means of verifying the accuracy and/or precision of the data, agencies can have more confidence in the data collected and its use in decision-making. Ultimately, NETC members can use the guidelines to identify the minimum number of control sites needed to meet the identified control site requirements and characteristics.

The sections that follow provide an overview of how the set of guidelines for control site requirements and characteristics were developed for incorporation into a tool. The actual control site guidelines—site terminology, site sharing, successful practices—and the tool developed to help implement those guidelines are contained in a standalone attachment to this report. As they evolved, NETC members reviewed and commented on the guidelines and tool. In addition, much input was provided by the NETC members via technical committee meetings held on August 12, 2022, October 14, 2022, January 25, 2023, and March 10, 2023.

Control Site Requirements

The first set of guidelines developed in support of the proposed tool focused on identifying specific control site requirements, including number of control sites and site and test section requirements based on the specific metric, test, and guidance type the agency is interested in. Using these guidelines, NETC members can define the type of control sites needed based on the following criteria:

- *Metric Type*: Agency can select the metrics for which the guidelines will apply—IRI, DMI, rutting, or cracking.
- *Test Type*: Based on the metric type selected, agencies can select the type of testing they would like to conduct. Testing types include certification (IRI and DMI only), validation, or verification.
- *Guidance Type*: Agencies can select the type of guidance for which the testing type will adhere to. This includes established standards (i.e., AASHTO R56) or other guidance developed based on NETC member practices.

In developing the requirement guidelines, the project team utilized information gathered during Tasks 1 and 2 as well as successful practices from the literature on the selection of experimental factors, control site locations, and reference measuring devices or procedures. More specifically, the guidelines development effort was informed by the experimental matrix for control sites (Appendix C) and the desired control site requirements described in Task 2.

Based on the agency-defined inputs, the requirement guidelines recommend a set of control site characteristics and acceptance criteria for the specified inputs. Outputs are based on a series of decision trees such as the one illustrated in Figure 4.

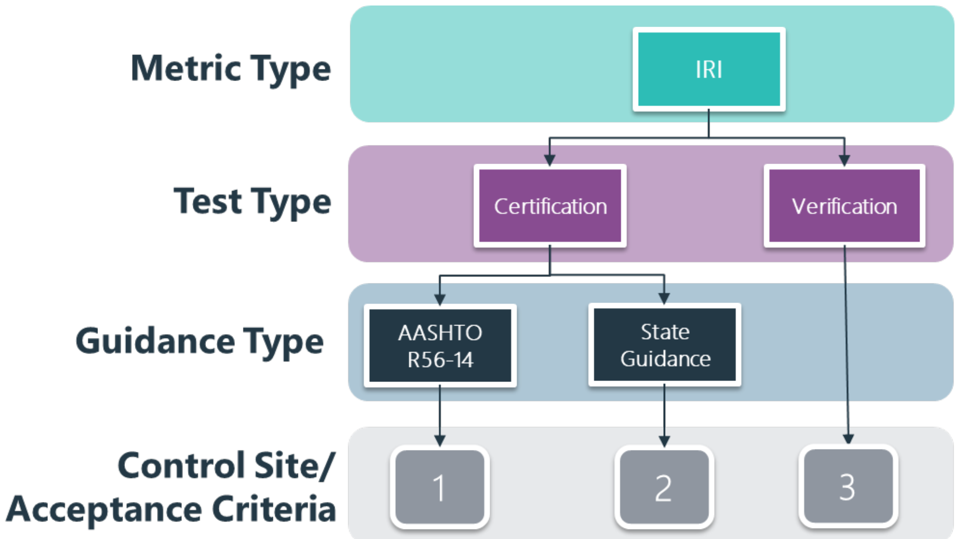

Figure 4. Flowchart. Decision tree for IRI control sites.

Control Site Characteristics

The second set of guidelines developed in support of the proposed tool were focused on control site characteristics. While the guidelines for control site requirements incorporated desired control site characteristics, the second set of guidelines developed focused on the way in which control site characteristics are used to select control sites based on available NETC member data. Guidelines development for control site characteristics standardized the control site selection proof-of-concept discussed in Task 2 (see Table 7); the guidelines provide a framework for states to import data and identify optimal control site locations based on control site requirements described in the previous section.

The development of control site characteristics guidelines included providing a standardized template for NETC members to format data on their pavement network to aid in the prioritization of potential control sites. The guidelines followed the methodology proposed during Task 2 and focused on:

- Identifying parameters in the available data,
- Assessing the possible range of values for each parameter,
- Scoring each parameter based on the value for each pavement section, and
- Calculating a total score by multiplying each individual parameter score together.

Based on a total score, NETC members are provided a list of prioritized locations to meet the specific control site characteristics discussed in the previous section.

As indicated earlier, the project team also developed a tool to assist in the implementation of the control site requirements and characteristics guidelines, i.e., to help with the control site selection process. The tool enables NETC members to identify and rank pavement sections for use as control sites based on agency data availability and needs. To do so, the tool imports available agency data and utilizes available attributes to determine the best potential locations for control sites; it helps agencies identify the number and characteristics of control sites based on agency-defined needs. Additionally, the tool provides recommended acceptance criteria for the metrics of interest. The resulting tool is included as a standalone attachment to this report.

Other Guidelines

The guidelines described in previous sections, to support NETC member agencies with the selection of control sites based on requirements and characteristics, are critical to quality pavement data collection. However, it was also recognized that additional guidelines were needed. For example, defining common terminology and definitions was considered a key element of the guidelines. Consequently, the information contained in the NETC member DQMPs as well as in AASHTO, ASTM, and ISO standards served as the basis for establishing definitions for seven key terms: calibration, certification, validation, verification, quality control, quality assurance, and control sites. These definitions were presented earlier in the report in Table 6.

In addition, three options for control site selection were suggested for consideration by the NETC. A summary of the three proposed options was provided earlier in the report in Table 8.

The project team also incorporated findings from the *FHWA Practical Guide for Quality Management of Pavement Condition Data Collection* into the guidelines. Specific practices that informed the guidelines are summarized in Table 10. The FHWA guide also provided recommendations on how to best categorize control sites based on the testing type and primary use of control sites. Specifically, the guide outlined three tiers of control site types, which were used to inform the reference data, environmental controls, and acceptance criteria. The three tiers described include:

- *Top Tier:* Control sites that are used for the highest level of data quality testing (i.e., certification). Control sites for the Top Tier adhere to strictest environmental controls, ground reference data (e.g., a walking profiler for IRI testing), and tolerances for acceptance criteria.
- *Middle Tier:* Control sites that follow some successful practices for data quality testing, but do not adhere to the strictest level of controls for environmental, ground reference data, and tolerances for acceptance criteria. Middle Tier control sites are most appropriate for validation testing.
- *Bottom Tier:* Control sites used to compare data quality but that do not adhere to specific controls for environmental conditions, reference data, or tolerances for acceptance criteria. Typically, control sites in this category reference historical or previous collection data and would therefore be most appropriate for verification testing.

The combined set of guidelines developed under the project should lead to improved control site selection, which in turn should lead to improved pavement condition data collection and better compliance with FHWA-approved DQMPs. The guidelines should also yield efficiencies in the collection and analysis of pavement condition data for each of the NETC agencies.

Table 10. Successful quality management practices.

Guidance Area	Successful Practices
Control Sites	• Reasonably represent pavement types in the network • Include a range and variety of ride quality and distresses that are typically encountered in the network • Include all data metrics that are collected and used during agency decision-making processes • Are of sufficient length to gather enough data for certification processes • Have adequate ground reference data established so that the accuracy of the data being collected can be checked
Ground reference data	• Are established during similar environmental conditions to certification of data collection equipment
Data collection procedures	• Allow for enough repeat runs • Performed at same speeds data are collected in the field • Verify calibrations of sensors and other associate systems
Acceptance criteria	• Have been established so that data collection equipment can be rated as pass or fail

Task 4. Draft Final Report, Technology Transfer Strategy, and Toolbox

The objective of Task 4 was to prepare a draft project report as well as to develop an implementation plan and technology transfer strategy for the outcomes and findings of the project. As required by the NETC, a technology transfer strategy and toolbox were also prepared, which go hand-in-hand with the referenced implementation plan. The specific tools considered and developed include a one-page fact sheet, a PPT presentation (for use with project webinar), and a poster.

Draft Final Report

The initial objective of this task was to prepare a draft final report documenting the entire research effort, from the kick-off meeting in February 2022 to the webinar presentation in July 2023. The preparation of this report was made easier, in large part, because of the NETC documentation requirements—i.e., a report at the end of each task. Moreover, this approach was consistent with the project team's preference of documenting the research effort as it progressed through the various tasks; this was considered more efficient, complete, and accurate as compared to waiting to prepare the report at the end of the project.

The draft final report was submitted to the NETC for review and comment at the end of April 2023. A revised version of the report was prepared based on the NETC input, and final report was submitted in July 2023. The final report as well as delivery of a webinar presentation were conducted as part of the Task 5 effort, which is not covered in this report beyond what has already been stated in this chapter. The remainder of this task focuses on the project's implementation plan and the technology transfer strategy.

Finally, in the next and last chapter, the major project findings, conclusions, and recommendations are presented. The report also contains three appendices: Appendix A provides a summary of NETC DQMP scoresheet comparisons, Appendix B presents a summary of existing availability of control sites, Appendix C presents the control site experimental matrix, and Appendix D contains the webinar presentation used at the end of the project . In addition, as indicated in the previous chapter, the control site selection guidelines and tool are being provided as a stand-alone attachment to this report.

Implementation Plan

The other objectives of the Task 4 effort were to develop an implementation plan and technology transfer strategy for the outcomes and findings of this project. As clearly stated in the project solicitation, the NETC fully recognizes that "research results are not automatically put into practice upon completion of the research and publication of the final report. Effective implementation is more likely when researchers and user agencies collaborate to plan for implementation." Like the NETC, the last thing the project team wants is for the research results to end up in the form of a report on a bookshelf where it is never looked at much less used.

In formulating the implementation plan, the project team first identified the three most important outcomes. They are:

- DQMP terminology,

- Control site selection guidelines and tool, and
- Control site sharing options.

Recognizing these three outcomes, the first implementation step (of three) is creating awareness of the importance of control sites to the quality of pavement surface data collection. Whether for certification, validation or verification, control sites provide the reference data needed to ascertain the quality—accuracy and precision—of those data, whether good or bad. Knowing good quality data are being collected is important, but perhaps more critical is knowing quality data are not being collected and that therefore steps are needed to correct the issues leading to those poor data. Together with this understanding is the establishment of common DQMP terminology, which will contribute to improved communications amongst the NETC members.

Achieving the referenced awareness will depend on the audience, but getting the message to all NETC member staff is important.[8] In the case of managers or staff not directly involved in pavement data collection, the best way to achieve this is via the one-page fact sheet and the webinar presentation, which are discussed later in this chapter. The one-page fact sheet and webinar presentation are also good for personnel directly involved in pavement data collection, but the information needs to be supplemented with the control site guidelines and tool, this report, and the poster discussed later in the chapter. For this latter group, consideration should also be given to carrying out one- to two-hour workshops to review in detail the control site selection guidelines and tool, including live demonstration and hands-on usage, followed by ample discussion time. The poster could easily be integrated into these workshops.

The second implementation step requires the NETC members to actively communicate and work together in establishing reference data for equipment certification and validation via rodeos. This will require acceptance of the sharing concept by the NETC members and a commitment to follow through with execution of the rodeos. Ideally, all six NETC member agencies would participate in the annual rodeos, but even a smaller subset of members would benefit from such rodeos. They will, no doubt, entail a significant level of effort, especially for the host agency, but it should only be required every few years and the benefits for the NETC members are important not just in terms of DQMPs, but also in that the rodeos present an ideal situation for technology transfer between agencies.

The third and last implementation step requires actual usage of the control site guidelines and tool at the earliest time possible, preferably as part of the upcoming selection of control sites. It is envisioned that the control site selection tool will be initially used as a stand-alone application to identify the highest potential control sites, whose adequacy would then be confirmed by follow-up in-person visits. Longer-term, it is recommended that the tool be incorporated into the NETC member pavement or asset management systems, to fully take advantage of the information contained in the associated databases as well as to implement the control site selection process more formally.

Both the second and third implementation steps are targeted for NETC member personnel involved in the day-to-day pavement data applications—data collection, pavement management, maintenance and rehabilitation planning, etc.

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[8] If the NETC member agency has consultant staff working on their pavement management-related activities, it is important that the agency (1) share the project deliverables with them so they to understand the results and (2) involve them with the actual implementation of those deliverables.

Technology Transfer Strategy and Toolbox

The NETC requires that each project include a technology transfer strategy and toolbox as a deliverable. This strategy and toolbox go hand-in-hand with the implementation plan discussed in the previous section. More specifically, the following tools are needed to support the implementation plan.

One-Page Fact Sheet

The project team developed a one-page fact sheet to succinctly provide the reader with a synopsis of the project and its results. This fact sheet was prepared following the NETC template and includes the following information:

- General project information, which includes project title, study timeline, and NETC contact.
- Introduction, which include problem statement and project objective.
- Methodology, which includes a summary of the activities completed during the project and the outcomes.
- Conclusion, which includes a summary of the major project findings.
- Implementation, which includes information on the impacts and benefits from implementation of the project findings and outcomes on the NETC members.

A copy of the one-page fact sheet is shown in Figure 5.

Presentation

Building off the previous work done in the project, the project team developed a PowerPoint slide deck with speaker notes. At the request of the NETC, the slide deck was developed for use during the first 30 minutes of a one-hour webinar. The next 15 minutes of the webinar would be spent delivering a live demonstration of the control site selection tool that resulted from the project, and the last 15 minutes would be dedicated to questions and answers. The resulting deck contains 22 slides, and it is contained (as six slides per page) in Appendix D. The contents of the presentation are adequate for all audiences—management and technical personnel—and its purpose is to inform the audience about the project and to teach them how to use the products to impact the work that they do.

Poster

The project team developed a 3 ft by 4 ft poster that can be used to, easily and clearly, disseminate the research results. The poster contains the following sections:

- Abstract, including general project information.
- Data, including NETC DQMPs, control sites information, interview findings, and literature review findings.
- Analysis of data, including major outcomes from the data analysis, such as terminology, guidelines, and tools.
- Conclusions, including impacts and benefits from implementation of the project findings.

The template provided by the NETC was used to prepare the poster. A copy of the resulting poster is contained in Figure 6.

FACT SHEET

Quality Review and Assessment of Pavement Condition Survey Vehicle Data Across New England

RESEARCH PROJECT TITLE

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

STUDY TIMELINE

February 2022 – July 2023

PRINCIPAL INVESTIGATOR

Gonzalo R. Rada, Ph.D., P.E.

Vice President, Pavement Consultancy Services

WSP USA Environment & Infrastructure Inc.

NETC CONTACT

Kirsten Seeber

NETC Coordinator

CTC & Associates LLC

608-620-5820

netc@ctcandassociates.com

MORE INFORMATION

Coordinator will add link to the final report on NETC website

The New England Transportation Consortium, a cooperative effort of the transportation agencies of the six New England States, funded this research. Through the Consortium, the states pool professional, academic and financial resources for transportation research leading to the development of improved methods for dealing with common problems associated with the administration, planning, design, construction, rehabilitation, reconstruction, operation and maintenance of the region's transportation system.

Introduction

The New England Transportation Consortium (NETC) members spend a considerable amount of time and resources on pavement surface condition data collection in support of a wide range of reporting and decision-making functions, including evaluating the condition of the network; selecting sections for preservation, maintenance, and rehabilitation plans; and optimizing expenditure of funds through use of a Pavement Management System (PMS).

Since pavement networks represent a large-scale asset and the associated maintenance and rehabilitation budget is significant, data quality is critical to the stated functions. The data quality management plans (DQMPs) mandated by Congress in 23 CFR 490.319(c) provide a means to assist in achieving high-quality data, but the specific steps are not clear, which has resulted in plans that vary in their level of sophistication amongst the New England states. Accordingly, this project was undertaken to provide guidance on collecting quality pavement surface condition data.

Methodology

A review of existing DQMPs was undertaken to better understand the strengths and weaknesses of the New England transportation agencies data quality management practices. Numerous interviews were ~~also~~ held with transportation agency staff, with a focus on the identification and selection of control sites needed to establish the reference values for certification, validation, or verification of pavement surface data collection equipment. The resulting information was used to develop:

- Common terminology to facilitate clear and concise data quality-related communications between the NETC member states;
- Guidelines and supporting tool for the identification and selection of control sites, which consider site requirements and characteristics; and
- Recommendations for control site inter-agency sharing options to spread the certification, validation, and verification resource requirements amongst the New England states.

Conclusion

High-quality pavement surface condition data are of paramount importance to the NETC members; as the adage goes, "*garbage in, garbage out*." At the heart of establishing data quality—accuracy, precision, and repeatability—is the reference measurements obtained at certification, validation, and verification control sites. Consequently, much of the project effort focused on the identification, selection, and sharing of control sites within the New England region. However, other recommendations and guidelines were developed, such as certification, validation, and verification frequency; accuracy and repeatability acceptance limits; and error resolution.

Implementation

Adoption of the resulting recommendations and guidelines will lead to several benefits. A common terminology will improve data quality-related communications. An improved control site identification and selection process will lead to better reference data for data quality characterization, while inter-agency sharing of control sites will lead to improved regional efficiencies. Ultimately, these recommendations and guidelines will assist with compliance with the federal-mandated DQMPs data reporting requirements.

Figure 5. Screenshot. NETC Project 21-1 one-page fact sheet.

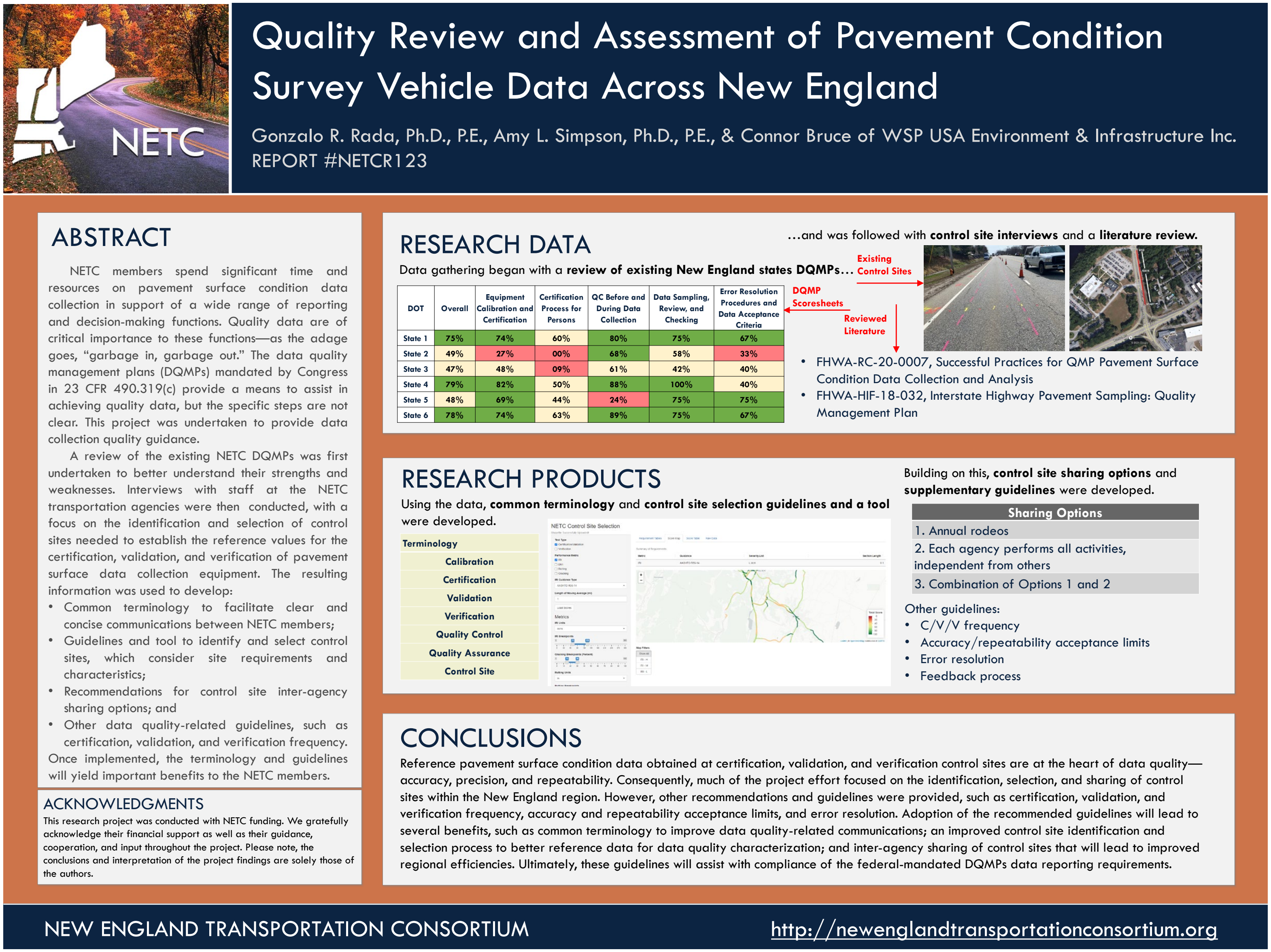

Figure 6. Screenshot. NETC Project 21-1 poster.

Summary and Conclusions

The objective of this chapter is to summarize the main project findings. For Task 1—which included the review of DQMPs, available control sites, and terminology—those findings were:

- The DQMPs and practices implemented by NETC members compared well to the assessment of nationwide practices undertaken as a part of FHWA-RC-20-0007. The six NETC member agencies had well-documented practices for all the required elements of a DQMP.
- NETC members had well-defined procedures for certifying inertial profiling systems; 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.
- In terms of control sites, it was recommended to conduct the certification of inertial profiler equipment according to the AASHTO R56 standard. Some NETC members already follow this practice. NH and MA share a control site for certification of inertial profilers.
- Given the lack of a standard for validation of cracking, the project team provided guidance for planning and implementation of field validation testing. NETC members conduct field validation testing for this distress type—validation of agency-defined cracking metrics is needed only for ME and VT. An experimental matrix was developed based on the analysis of agencies' network-level data. Recommendations for potential sharing of control sites were 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.
- The project team identified and reviewed common terminology and definitions found within DQMPs and AASHTO, ASTM, and ISO standards. The process resulted in the defining of seven key terms, which included calibration, certification, validation, verification, quality control, quality assurance, and control sites.
- An attempt was made to reconcile terminology used by the NETC members to create definitions that align with the existing understanding of the agencies. However, there was a lack of consistency in terminology used between agencies. Ultimately, the NETC members agreed to the proposed terminology and definitions provided by the project team. Each was adopted and utilized throughout subsequent project tasks.

The main findings of Task 2—which included the identification of control site characteristics and the selection of potential control sites—are summarized below:

- The project team conducted interviews with individual NETC members to identify ideal control site characteristics. NETC members 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 to better understand each agency's willingness to share control sites and travel. For the most part, NETC members agreed there was benefit in sharing control sites even if it meant traveling.

- In light of the above 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 Options 1 and 2; some of the NETC members would work together to carry out a rodeo while other members would work independently (i.e., the northern three NETC members and the southern three NETC members conduct separate rodeos).
- In addition to considering characteristics suggested by the NETC members, the project team also considered recommended site characteristics for certification, validation, and verification of different performance metrics. Specifically, AASHTO protocols and successful practices were used to develop a matrix of experimental factors recommended for control site selection.
- 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 proposed methodology only focuses on scoring attributes that are both available and important to the agency, 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 the VT transportation agency data.

The main findings from Task 3—which included the guideline development process and guideline implementation—are summarized below:

- The first set of guidelines focused on identifying specific control site requirements. This includes the number of control sites and site and test section requirements based on the specific metric, test, and guidance type the agency is interested in.
- The project team utilized information gathered during Tasks 1 and 2 as well as successful practices from the literature to develop guidelines on the selection of experimental factors, control site locations, and reference measuring devices or procedures.
- The second set of guidelines focused on control site characteristics; the guidelines standardized the control site selection proof-of-concept discussed in Task 2. The guidelines provide a framework for agencies to import data and identify optimal control site locations based on control site requirements described in the previous section.
- The project team also developed a tool to assist in the implementation of the control site characteristics guidelines. The tool enables NETC members to identify and rank pavement sections for use as control sites based on agency data availability and needs.
- The project team incorporated findings from the FHWA Practical Guide for Quality Management of Pavement Condition Data Collection into the guidelines.

The resulting guidelines should lead to improved control site selection, which in turn should lead to improved pavement condition data collection and better compliance with FHWA-approved DQMPs. The guidelines should also yield efficiencies in the collection and analysis of pavement condition data.

Finally, the main outcomes from Task 4 were:

- Draft final report.
- Plan for implementation of the project findings—terminology, guidelines, and tool.
- Technology transfer strategy, along with a set of tools—one-page fact sheet, poster, and presentation—to help with adoption and implementation of the project findings.

As indicated earlier, the draft final report was submitted to the NETC for review and comment at the end of April 2023. A revised version of the report was prepared based on the NETC input, and final report was submitted in July 2023. The final report as well as delivery of a webinar presentation were conducted as part of the Task 5 effort, which is not covered further in this report.

Appendix A. Summary of Scoresheet Comparisons

Certification: Does DQMP include the following regarding equipment certification?

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

Connecticut

Metric	Does DQMP include the following regarding equipment certification?	Required Protocol	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
Cracking	Certification testing performed at control sites			0		No information provided on the certification/validation of cracking; proposed plans to implement validation sites
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
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
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
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
Rutting	Certification testing performed at control sites			2	Agency	Validation sites are selected by CTDOT
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
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
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
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
Faulting	Certification testing performed at control sites			2		Validation sites are selected by CTDOT
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
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
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
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
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

Maine

Metric	Does DQMP include the following regarding equipment certification?	Required Protocol	Referenced Protocol	Score	Responsibility	Comments
IRI	Certification of Inertial Profiling System in accordance with:	AASHTO R56-14	AASHTO R56-14	0		To be conducted starting Spring 2019
Cracking	Certification testing performed at control sites			0		Three validation sites identified at the beginning of each year (starting in Spring 2019)
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 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)
Cracking	Certification control site describes how ground reference and variability/range of expected values are established			0		Calipers to be used to measure cracking at validation sites
Cracking	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			0		Minimum accuracy: +/- 3mm, Minimum Reproducibility: N/A, Required Repeatability: Within +/- 3 mm standard deviation from the mean of five runs (95 % within limits)
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		Proposed methodology is prior to collection for the year
Rutting	Certification testing performed at control sites			0		Three validation sites identified at the beginning of each year (starting in Spring 2019)
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			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)
Rutting	Certification control site describes how ground reference and variability/range of expected values are established			0		Rutting will be measured every 50 feet to meet requirements of AASHTO R 87-18 & R 88-18.
Rutting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			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)
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		Proposed methodology is prior to collection for the year
Faulting	Certification testing performed at control sites			N/A		No PCC pavements
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			N/A		No PCC pavements
Faulting	Certification control site describes how ground reference and variability/range of expected values are established			N/A		No PCC pavements
Faulting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			N/A		No PCC pavements
Faulting	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			N/A		No PCC pavements
All	State DOT reviews, approves, and keeps record of certification documentation for all metrics			0		No documented practices in DQMP

Vermont

Metric	Does DQMP include the following regarding equipment certification?	Required Protocol	Referenced Protocol	Score	Responsibility	Comments
IRI	Certification of Inertial Profiling System in accordance with:	AASHTO R56-14	AASHTO R56-14	2	Vendor	Mentions AASHTO R56-10 as well
Cracking	Certification testing performed at control sites			2	Vendor	Contractor collects on up to five validation sites
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			1	Vendor	Does not mention a range of values covered
Cracking	Certification control site describes how ground reference and variability/range of expected values are established			2	Vendor	Manually rated
Cracking	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			2	Vendor	Conducted by contractor
Cracking	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			2	Vendor	Certification conducted by ARAN
Rutting	Certification testing performed at control sites			2	Vendor	Contractor collects on up to five validation sites
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			1	Vendor	Does not mention a range of values covered
Rutting	Certification control site describes how ground reference and variability/range of expected values are established			0	Vendor	Does not mention how ground reference is determined
Rutting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			2	Vendor	Accuracy: +/- 0.06 in, Repeatability (three runs): +/- 0.06 in
Rutting	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			2	Vendor	Certification conducted by ARAN
Faulting	Certification testing performed at control sites			Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW
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			Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW
Faulting	Certification control site describes how ground reference and variability/range of expected values are established			Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW
Faulting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW
Faulting	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			Unclear	Vendor	Has QC procedures but there is no required data collection for faulting in the SOW
All	State DOT reviews, approves, and keeps record of certification documentation for all metrics			1	Agency	Does not mention record keeping

Massachusetts

Metric	Does DQMP include the following regarding equipment certification?	Required Protocol	Referenced Protocol	Score	Responsibility	Comments
IRI	Certification of Inertial Profiling System in accordance with:	AASHTO R56-14	Other (explain)	0		Utilizes both AASHTO R 43-13 and AASHTO R 56-14
Cracking	Certification testing performed at control sites			0		No certification for cracking; Relies on HPMS Field manual and MassDOT Distress Rating Manual for protocols
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			1	Unclear	No information is provided regarding the condition of location sites
Cracking	Certification control site describes how ground reference and variability/range of expected values are established			0		Not specified
Cracking	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			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%
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		Conducted before data collection and periodically during data collection
Rutting	Certification testing performed at control sites			0		No certification for rutting; Relies on AASHTO R 48 protocol
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			1	Unclear	No information is provided regarding the condition of location sites
Rutting	Certification control site describes how ground reference and variability/range of expected values are established			0		Not specified
Rutting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			1	Unclear	Rut Depth Accuracy: > 85% compared to reference profile, Rut Depth Repeatability: St. dev. < 0.04
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		Conducted before data collection and periodically during data collection
Faulting	Certification testing performed at control sites			2	Unclear	Annual Certification of profiler (faulting data are collected using profiler)
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			1	Unclear	No information is provided regarding the condition of location sites
Faulting	Certification control site describes how ground reference and variability/range of expected values are established			0		Not specified
Faulting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			1	Unclear	Faulting Accuracy: +/- 0.5 inch, Faulting Repeatability: St. dev. <15%
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		Not specified
All	State DOT reviews, approves, and keeps record of certification documentation for all metrics			0		No information in this regard

New Hampshire

Metric	Does DQMP include the following regarding equipment certification?	Required Protocol	Referenced Protocol	Score	Responsibility	Comments
IRI	Certification of Inertial Profiling System in accordance with:	AASHTO R56-14	AASHTO R56-14	2	Agency	Uses appropriate AASHTO standard
Cracking	Certification testing performed at control sites			2	Agency	Control sites set up for routine runs; certification conducted by contractor doing data collection
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			2	Agency	Cover a range of smooth, medium-smooth, and medium rough surfaces
Cracking	Certification control site describes how ground reference and variability/range of expected values are established			2	Agency	Ground reference is created using a walking profiler and manual measurements
Cracking	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			1	Agency	Precision/accuracy specified as 1-2mm cracking
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	Agency	None specified
Rutting	Certification testing performed at control sites			2	Agency	Control sites set up for routine runs; certification conducted by contractor doing data collection
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	Cover a range of smooth, medium-smooth, and medium rough surfaces
Rutting	Certification control site describes how ground reference and variability/range of expected values are established			2		Ground reference is created using a walking profiler and manual measurements
Rutting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			2	Agency	Precision/accuracy specified as 1 mm or better
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	None specified
Faulting	Certification testing performed at control sites			N/A		No PCC pavements
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			N/A		No PCC pavements
Faulting	Certification control site describes how ground reference and variability/range of expected values are established			N/A		No PCC pavements
Faulting	Includes comparison of data to minimum requirements for accuracy, repeatability, and precision			N/A		No PCC pavements
Faulting	Proof of certification prior to data collection demonstrating that equipment successfully performs tests and meets established minimum requirements for accuracy, repeatability, and precision			N/A		No PCC pavements
All	State DOT reviews, approves, and keeps record of certification documentation for all metrics			2		

Rhode Island

Metric	Does DQMP include the following regarding equipment certification?	Required Protocol	Referenced Protocol	Score	Responsibility	Comments
IRI	Certification of Inertial Profiling System in accordance with:	AASHTO R56-14	AASHTO R56-14	2	Vendor	Utilizes AASHTO protocol
Cracking	Certification testing performed at control sites			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			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			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			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			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	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	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	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	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			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	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	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			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	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			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	

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.

Connecticut

Metric	Does DQMP include the following regarding quality control measures?	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
IRI	Identifies frequency of quality control measures before and throughout testing		2	Agency	Daily and weekly checks are conducted throughout the season
IRI	Outlines acceptance criteria and allowable tolerances		2	Agency	See above
IRI	Includes and describes training for data collection crews		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
IRI	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	Page 17, Table 2
IRI	Includes cross-rater checks		2	Agency	Collect same data with both ARAN vans on reference validation sites
IRI	Includes QC checks during daily data reduction		0		None specified
IRI	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0		
IRI	Includes documentation and reporting requirements		2	Agency	Page 25, section 8
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	
Cracking	Identifies frequency of quality control measures before and throughout testing		2	Agency	
Cracking	Outlines acceptance criteria and allowable tolerances		2	Agency	
Cracking	Includes and describes training for data collection crews		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	
Cracking	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	
Cracking	Includes cross-rater checks		2	Agency	
Cracking	Includes QC checks during daily data reduction		0		None specified
Cracking	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0		Page 25, section 8
Cracking	Includes documentation and reporting requirements		2	Agency	
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	
Rutting	Identifies frequency of quality control measures before and throughout testing		2	Agency	
Rutting	Outlines acceptance criteria and allowable tolerances		2	Agency	
Rutting	Includes and describes training for data collection crews		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	

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
Rutting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	
Rutting	Includes cross-rater checks		2	Agency	
Rutting	Includes QC checks during daily data reduction		0		None specified
Rutting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0		None specified
Rutting	Includes documentation and reporting requirements			Agency	
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	
Faulting	Identifies frequency of quality control measures before and throughout testing		2	Agency	
Faulting	Outlines acceptance criteria and allowable tolerances		2	Agency	
Faulting	Includes and describes training for data collection crews		2		
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	
Faulting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	
Faulting	Includes cross-rater checks		2	Agency	
Faulting	Includes QC checks during daily data reduction		0		None specified
Faulting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		0		None specified
Faulting	Includes documentation and reporting requirements		2	Agency	The Data Collection Quality Control Supervisor monitors the 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.

Maine

Metric	Does DQMP include the following regarding quality control measures?	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	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	See above
IRI	Outlines acceptance criteria and allowable tolerances		0		Does not specifically mention
IRI	Includes and describes training for data collection crews		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		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	During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens
IRI	Includes cross-rater checks		0		Does not specifically mention
IRI	Includes QC checks during daily data reduction		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

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
IRI	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		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		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	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	See above
Cracking	Outlines acceptance criteria and allowable tolerances		0		Does not specifically mention
Cracking	Includes and describes training for data collection crews		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		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	During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens
Cracking	Includes cross-rater checks		0		Does not specifically mention
Cracking	Includes QC checks during daily data reduction		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		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		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	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	See above
Rutting	Outlines acceptance criteria and allowable tolerances		0		Does not specifically mention
Rutting	Includes and describes training for data collection crews		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		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	During collection, operator monitors that the data looks accurate, cameras are clear, and there are no error screens
Rutting	Includes cross-rater checks		0		Does not specifically mention
Rutting	Includes QC checks during daily data reduction		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
Rutting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		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

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
Rutting	Includes documentation and reporting requirements		0		Does not mention reporting requirements
Faulting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		N/A		No PCC pavements
Faulting	Identifies frequency of quality control measures before and throughout testing		N/A		No PCC pavements
Faulting	Outlines acceptance criteria and allowable tolerances		N/A		No PCC pavements
Faulting	Includes and describes training for data collection crews		N/A		No PCC pavements
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		N/A		No PCC pavements
Faulting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		N/A		No PCC pavements
Faulting	Includes cross-rater checks		N/A		No PCC pavements
Faulting	Includes QC checks during daily data reduction		N/A		No PCC pavements
Faulting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		N/A		No PCC pavements
Faulting	Includes documentation and reporting requirements		N/A		No PCC pavements
All	State DOT reviews and keeps record of QC results for all metrics		0		Does not specifically mention

Vermont

Metric	Does DQMP include the following regarding quality control measures?	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
IRI	Identifies frequency of quality control measures before and throughout testing		2	Vendor	See above
IRI	Outlines acceptance criteria and allowable tolerances		2	Vendor	Quality acceptance to be within 95% of the limits
IRI	Includes and describes training for data collection crews		2	Vendor	
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
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
IRI	Includes cross-rater checks		0		Not specified
IRI	Includes QC checks during daily data reduction		2	Vendor	Daily verification checks are conducted by the contractor
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
IRI	Includes documentation and reporting requirements		2	Vendor	Contractor to provide documentation and 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	Vendor	QC report is submitted by the contractor on a monthly basis
Cracking	Identifies frequency of quality control measures before and throughout testing		2	Vendor	See above
Cracking	Outlines acceptance criteria and allowable tolerances		2	Vendor	Quality acceptance to be within 95% of the limits
Cracking	Includes and describes training for data collection crews		2	Vendor	
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
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
Cracking	Includes cross-rater checks		2	Vendor	Not specified
Cracking	Includes QC checks during daily data reduction		2	Vendor	Daily verification checks are conducted by the contractor

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
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
Cracking	Includes documentation and reporting requirements		2	Vendor	Contractor to provide documentation and 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	Vendor	QC report is submitted by the contractor on a monthly basis
Rutting	Identifies frequency of quality control measures before and throughout testing		2	Vendor	See above
Rutting	Outlines acceptance criteria and allowable tolerances		2	Vendor	Quality acceptance to be within 95% of the limits
Rutting	Includes and describes training for data collection crews		2	Vendor	
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
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
Rutting	Includes cross-rater checks		0		Not specified
Rutting	Includes QC checks during daily data reduction		2	Vendor	Daily verification checks are conducted by the contractor
Rutting	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
Rutting	Includes documentation and reporting requirements		2	Vendor	Contractor to provide documentation and reporting requirements
Faulting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		Unclear	Vendor	QC report is submitted by the contractor on a monthly basis
Faulting	Identifies frequency of quality control measures before and throughout testing		Unclear	Vendor	See above
Faulting	Outlines acceptance criteria and allowable tolerances		Unclear	Vendor	Quality acceptance to be within 95% of the limits
Faulting	Includes and describes training for data collection crews		Unclear	Vendor	
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		Unclear	Vendor	Discusses how contractor to utilize up to 5 additional sites to verify different distresses
Faulting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		Unclear	Vendor	Contractor manages real-time alerts due to equipment malfunction
Faulting	Includes cross-rater checks		Unclear		Not specified
Faulting	Includes QC checks during daily data reduction		Unclear	Vendor	Daily verification checks are conducted by the contractor
Faulting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		Unclear	Vendor	Corrective action includes rejection of deliverable where contractor must recollect
Faulting	Includes documentation and reporting requirements		Unclear	Vendor	Contractor to provide documentation and reporting requirements
All	State DOT reviews and keeps record of QC results for all metrics		1	Agency	Corrective actions and quality control are documented by the contractor but the extent is not clear

Massachusetts

Metric	Does DQMP include the following regarding quality control measures?	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		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	Agency	See above; IRI QC is primarily conducted pre-data collection and monthly
IRI	Outlines acceptance criteria and allowable tolerances		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	Agency	

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
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	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	Agency	Checks roadway cameras, 3D system, and profiler are working correctly throughout collection
IRI	Includes cross-rater checks		0		Not specified
IRI	Includes QC checks during daily data reduction		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		1	Agency	Specifies whether to identify and fix, identify and test, or re-collect data
IRI	Includes 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		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	Agency	See above; Distress QC is primarily conducted pre-data collection and monthly
Cracking	Outlines acceptance criteria and allowable tolerances		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	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	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)		2	Agency	Checks roadway cameras, 3D system, and profiler are working correctly throughout collection
Cracking	Includes cross-rater checks		0		Not specified
Cracking	Includes QC checks during daily data reduction		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		1	Agency	Specifies whether to identify and fix, identify and test, or re-collect data
Cracking	Includes 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		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	Agency	See above; Rutting QC is primarily conducted pre-data collection and monthly
Rutting	Outlines acceptance criteria and allowable tolerances		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	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	Agency	

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
Rutting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	
Rutting	Includes cross-rater checks		0		Checks roadway cameras, 3D system, and profiler are working correctly throughout collection
Rutting	Includes QC checks during daily data reduction		0		None specified
Rutting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		1	Agency	Page 17, for control site tests
Rutting	Includes documentation and reporting requirements		2	Agency	As part of data collection team's responsibility
Faulting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		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
Faulting	Identifies frequency of quality control measures before and throughout testing		2	Agency	See above; Profiler QC is primarily conducted pre-data collection (annually)
Faulting	Outlines acceptance criteria and allowable tolerances		1	Agency	No allowable tolerance
Faulting	Includes and describes training for data collection crews		2	Agency	
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	
Faulting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		2	Agency	Checks roadway cameras, 3D system, and profiler are working correctly throughout collection
Faulting	Includes cross-rater checks		0		None specified
Faulting	Includes QC checks during daily data reduction		0		
Faulting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		1	Agency	Page 17, for control site tests
Faulting	Includes 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
All	State DOT reviews and keeps record of QC results for all metrics		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

New Hampshire

Metric	Does DQMP include the following regarding quality control measures?	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
IRI	Identifies frequency of quality control measures before and throughout testing		2	Agency	Process controls are specified for prior to collection or during collection
IRI	Outlines acceptance criteria and allowable tolerances		2	Agency	Identifies thresholds for difference distress metrics
IRI	Includes and describes training for data collection crews		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	Agency	DCU establishes at least three control sites to check contractor certification
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
IRI	Includes cross-rater checks		2	Agency	Conduct repeat runs to confirm repeatability
IRI	Includes QC checks during daily data reduction		0	Agency	None specified (except bounce testing)
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
IRI	Includes documentation and reporting requirements		2	Agency	

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
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
Cracking	Identifies frequency of quality control measures before and throughout testing		Unclear	Agency	Process controls are specified for prior to collection or during collection
Cracking	Outlines acceptance criteria and allowable tolerances		2	Agency	Identifies thresholds for difference distress metrics
Cracking	Includes and describes training for data collection crews		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	Agency	DCU establishes at least three control sites to check contractor certification
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
Cracking	Includes cross-rater checks		2	Agency	Conduct repeat runs to confirm repeatability
Cracking	Includes QC checks during daily data reduction		0	Agency	None specified (except bounce testing)
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
Cracking	Includes documentation and reporting requirements		2	Agency	
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
Rutting	Identifies frequency of quality control measures before and throughout testing		2	Agency	Process controls are specified for prior to collection or during collection
Rutting	Outlines acceptance criteria and allowable tolerances		2	Agency	Identifies thresholds for difference distress metrics
Rutting	Includes and describes training for data collection crews		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	Agency	DCU establishes at least three control sites to check contractor certification
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
Rutting	Includes cross-rater checks		2	Agency	Conduct repeat runs to confirm repeatability
Rutting	Includes QC checks during daily data reduction		0	Agency	None specified (except bounce testing)
Rutting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		2	Agency	Corrective actions handled by contractor
Rutting	Includes documentation and reporting requirements		2	Agency	
Faulting	Includes methods and processes for written QC procedures that include routine verification procedures that will be conducted before and during data collection		N/A	Agency	No PCC pavements
Faulting	Identifies frequency of quality control measures before and throughout testing		N/A	Agency	No PCC pavements
Faulting	Outlines acceptance criteria and allowable tolerances		N/A	Agency	No PCC pavements
Faulting	Includes and describes training for data collection crews		N/A	Agency	No PCC pavements
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		N/A	Agency	No PCC pavements
Faulting	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		N/A	Agency	No PCC pavements
Faulting	Includes cross-rater checks		N/A	Agency	No PCC pavements
Faulting	Includes QC checks during daily data reduction		N/A	Agency	No PCC pavements
Faulting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		N/A	Agency	No PCC pavements
Faulting	Includes documentation and reporting requirements		N/A	Agency	No PCC pavements
All	State DOT reviews and keeps record of QC results for all metrics		2	Agency	

Rhode Island

Metric	Does DQMP include the following regarding quality control measures?	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	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	Practical Guide for Quality Management of Pavement Condition Data Collection	0	Vendor	None specified
IRI	Outlines acceptance criteria and allowable tolerances	Practical Guide for Quality Management of Pavement Condition Data Collection	0		None specified
IRI	Includes and describes training for data collection crews	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	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)		0		None specified
IRI	Includes cross-rater checks		0		None specified
IRI	Includes QC checks during daily data reduction		0		None specified
IRI	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		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	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		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		0		None specified
Cracking	Outlines acceptance criteria and allowable tolerances		0		None specified
Cracking	Includes and describes training for data collection crews		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		1	Vendor	Verification of the equipment and raters at two blind sites selected by the RIDOT

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
Cracking	Includes real-time data checks (real-time data displays for out of range/malfunctioning data)		0		None specified
Cracking	Includes cross-rater checks		0		None specified
Cracking	Includes QC checks during daily data reduction		0		None specified
Cracking	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		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	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		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		0		None specified
Rutting	Outlines acceptance criteria and allowable tolerances		0		None specified
Rutting	Includes and describes training for data collection crews		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		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)		0		No specified; daily checks are proposed
Rutting	Includes cross-rater checks		0		None specified
Rutting	Includes QC checks during daily data reduction		0		None specified
Rutting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		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		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		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		0		None specified
Faulting	Outlines acceptance criteria and allowable tolerances		0		None specified
Faulting	Includes and describes training for data collection crews		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		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)		0		None specified
Faulting	Includes cross-rater checks		0		Not specified
Faulting	Includes QC checks during daily data reduction		0		Not specified
Faulting	Includes corrective action for data not meeting allowable tolerances - may include returning to manufacturer for re-calibration		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	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		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.

Connecticut

Metric	Does DQMP include the following regarding quality control measures?	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:
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
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
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
All	Data collector is notified of acceptance requirements and corrective action plan prior to data collection		0		Data collected in-house
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

Maine

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
All	Specifies the data acceptance criteria for each metric		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
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		Does not specifically mention
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	Data is flagged and discussed; depending on the error, there may be recalculating/reprocessing or recollection
All	Corrective action plan includes a method to troubleshoot why data was incorrect to avoid same error after re-collecting		0		Does not specifically mention
All	Data collector is notified of acceptance requirements and corrective action plan prior to data collection		N/A		Data collected in-house

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
All	State DOT reports and keeps records of error resolution and data acceptance results		0		Does not specifically mention

Vermont

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
All	Specifies the data acceptance criteria for each metric		2	Agency	Specifies acceptance criteria based on stats on each distress metric
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		Does not specifically mention
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 are taken throughout entire collection process; Includes recollection by contractor
All	Corrective action plan includes a method to troubleshoot why data was incorrect to avoid same error after re-collecting		2	Vendor	Corrective actions are taken throughout entire collection process; Includes recollection by contractor
All	Data collector is notified of acceptance requirements and corrective action plan prior to data collection		2	Agency	Corrective actions and requirements are assessed yearly; contractor is notified
All	State DOT reports and keeps records of error resolution and data acceptance results		0		Does not specifically mention

Massachusetts

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
All	Specifies the data acceptance criteria for each 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)
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		Does not specifically mention
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	Specifies whether to identify and fix, identify and test, or re-collect data
All	Corrective action plan includes a method to troubleshoot why data was incorrect to avoid same error after re-collecting		0		Does not specifically mention
All	Data collector is notified of acceptance requirements and corrective action plan prior to data collection		0		Data collected in-house
All	State DOT reports and keeps records of error resolution and data acceptance results		0		Utilizes a QC log, but not an error resolution log

New Hampshire

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
All	Specifies the data acceptance criteria for each metric		Unclear	Agency	Specified types of errors, but not specifics with regards to metrics
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	Agency	None specified
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 reprocessing and recollecting
All	Corrective action plan includes a method to troubleshoot why data was incorrect to avoid same error after re-collecting		2	Agency	Common error types are described
All	Data collector is notified of acceptance requirements and corrective action plan prior to data collection		0	Agency	None specified
All	State DOT reports and keeps records of error resolution and data acceptance results		0	Agency	None specified

Rhode Island

Metric	Does DQMP include the following regarding quality control measures?	Referenced Protocol	Score	Responsibility	Comments
All	Specifies the data acceptance criteria for each metric		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)		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		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		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		Not stated in DQMP
All	State DOT reports and keeps records of error resolution and data acceptance results		2	Agency	Yes, provided through vendor

Appendix B. Availability of Control Sites

This appendix contains 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 was 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 7 and Figure 9) and 1 in Hopkinton, NH (Figure 8); 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 7. Photo. Smooth IRI site at Hazen Drive, Concord, NH, next to NHDOT office.

Figure 8. Photo. Medium-smooth IRI site at Jewett Road, Hopkinton, NH (not being used).

Figure 9. Photo. 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 the NHDOT office in Concord, NH (Figure 10) and 1 in Dunbarton, NH (Figure 11).
   - **Number of sites and sections**: 2 locations with 1 section per site.
   - **Test frequency**: Weekly.
   - **Reference data**: Collected using straightedge and wedge at 5-ft 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 12) is being considered as a substitute control site for when existing sites are repaved.

Figure 10. Photo. Fair rut & crack site at Charles Doe Drive, Concord NH, next to NHDOT office.

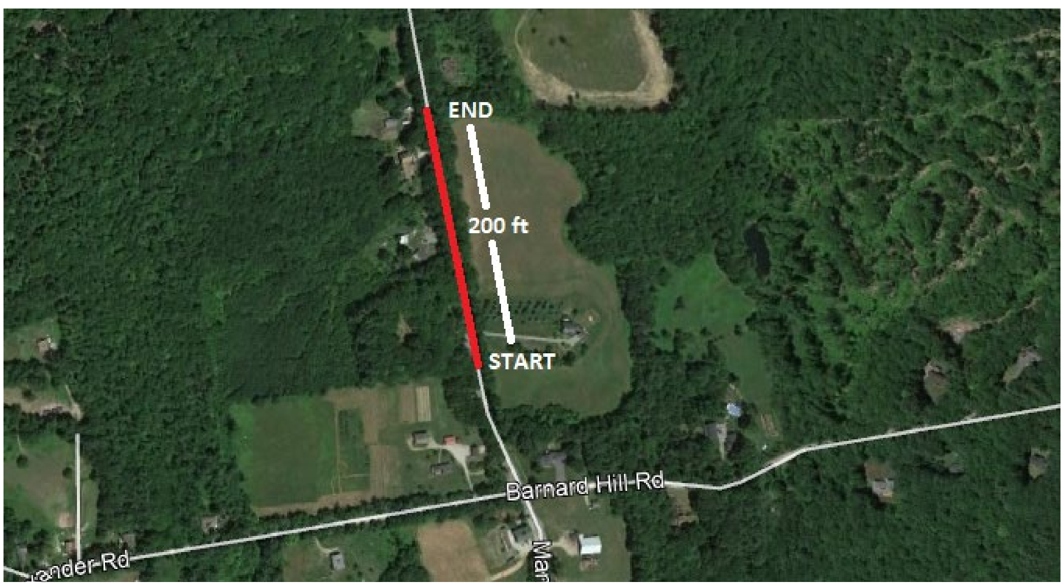

Figure 11. Photo. Poor rut site at Mansion Road, Dunbarton, NH (not being used).

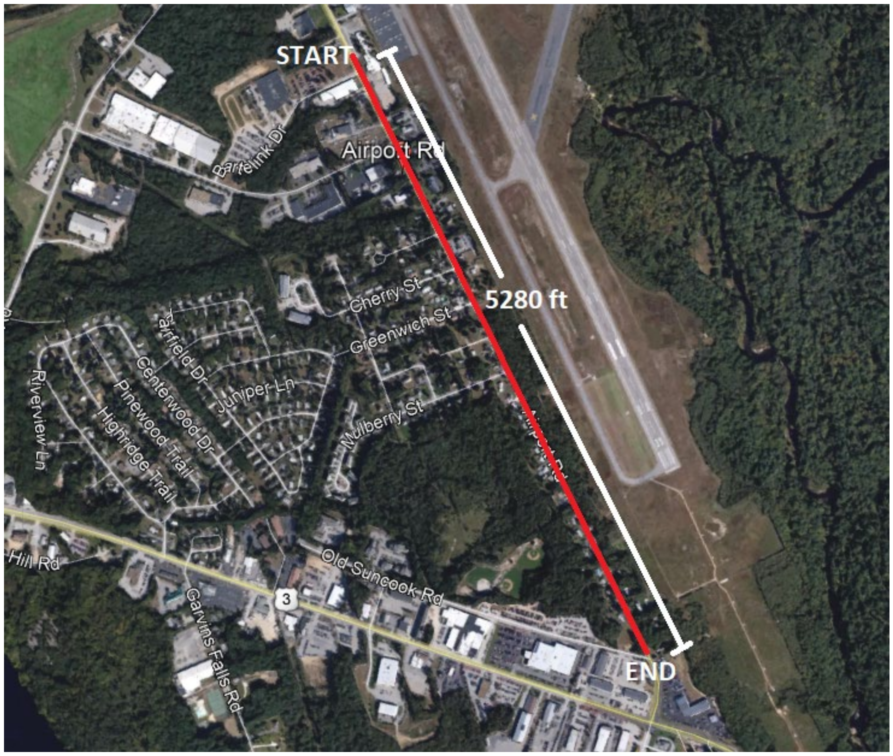

Figure 12. Photo. DMI site at Airport Road, Concord, NH.

4. Cracking site for NHDOT and contractor verification
   - **Test**: Cracking verification of NHDOT and contractor data collection vehicles.
   - **Site locations**: 1 next to the NHDOT office in Concord, NH (Figure 10).
   - **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 12).
   - **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).

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 100-ft lead in and 100-ft lead out for reference profile collection with lane closure; 300-ft lead in and 200-ft 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 comparison with vendor production data. Used to assess vendor data following the submission of production data.
   - **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.

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 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.

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 (Figure 13).
    - **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 14) and transverse profile (Figure 15) 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 13. Photo. Location of CTDOT Validation Site

Figure 14. Photo. Marking of CTDOT Site for IRI Certification

Figure 15. Photo. 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**: 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.

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 the 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.

Appendix C. Control Site Experimental Matrix

				Site/Section Requirements									Test Requirements			Applicable to					
Metric	**Equipment**	**Test Type**	**Protocol / Field Testing**	**Section #**	**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	X	X	X	X	X	X
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	X	X	X	X	X	X
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	X	X	X	X	X	X
Section Length (part of IRI test)	DMI	Certification	AASHTO R56	1	AC/ Composite	N/A	≥ 1,000' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	N/A	No	Field	at least 3 per speed	2 speeds: maximum operation speed and minimum operation speed	Measuring Tape	X	X	X	X	X	X
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	X	X				
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	X	X				
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	X	X				
Section Length (part of IRI test)	DMI	Certification	AASHTO R56	1	JCP/CRCP	N/A	≥ 1,000' with lead-in & stopping distance	N/A	avoid: (1) significant grade or grade change; (2) significant horizontal curvature or superelevation	N/A	No	Field	at least 3 per speed	2 speeds: maximum operation speed and minimum operation speed	Measuring Tape	X	X	X	X	X	X

Metric	Equipment	Test Type	Protocol / Field Testing	Section #	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 PP106 - Static	1	N/A	N/A	N/A	≥ 13.5 ft	mini ramps and jack stands	N/A	N/A	Garage ?	10 scans	NA	13' Straightedge & block	X	X	X	X	X	X
Rutting	Transverse Profiler	Certification	AASHTO PP107 - Body Motion	1	AC	N/A	8' section 0.25 mile lead-in + stopping distance	≥ 14 ft	Unknown	Unknown	Yes	Field	2 per speed	3 speeds 5, 8, 12 mph	Flat Plates & Excitation Boards	X	X	X	X	X	X
Rutting	Transverse Profiler	Certification	AASHTO PP108 - Navigation Drift	1	AC	N/A	178'	79'	Unknown	Unknown	Yes	Field	5	8 mph	Global position survey	X	X	X	X	X	X
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	Unknown	Unknown	Yes	Field	3 per speed	7 speeds 15 to 105, every 15 mph	Hand-held Scanner	X	X	X	X	X	X
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	Unknown	Unknown	Yes	Field	3 per speed	7 speeds 15 to 105, every 15	Hand-held Scanner	X	X	X	X	X	X
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	X	X	X	X	X	X
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	X	X	X	X	X	X
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	X	X	X	X	X	X

Metric	Equipment	Test Type	Protocol / Field Testing	Section #	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 & 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	X	X				
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	X	X				
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	X	X				
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	X	X				
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	X	X				
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	X	X				
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	X	X	X	X	X	X
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	X	X	X	X	X	X

Appendix D. Project Webinar Presentation

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Webinar
July 18, 2023

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

Gonzalo Rada, Ph.D., P.E., Amy Simpson, Ph.D., P.E. and Connor Bruce
WSP USA Environment & Infrastructure Inc.

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Agenda

- Problem statement
- Objectives
- Approach, findings, and outcomes
- Summary, deliverables, and benefits

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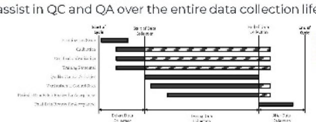
Problem Statement

- NETC members spend significant time and resources collecting pavement surface data to support reporting and decision-making functions.
- Pavement networks represent large assets and significant M&R budgets.
- Data quality and management are critical to stated functions.
- DQMPs mandated by Congress in 23 CFR 490.319(c) provide means to assist in QC and QA over the entire data collection life cycle.



Specific steps not clear; guidelines needed

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Objectives

- Review NETC pavement surface condition DQMPs.
- Summarize control sites used in NETC region with potential for inter-agency sharing.
- Develop recommendations for regional efficiencies in collection and analysis of QC/QA data.
- Develop recommendations to assist NETC members with data reporting requirements for compliance with FHWA-approved DQMPs.

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Information Gathering: Considerations

1. Gather, review, and analyze latest DQMPs and work-in-progress updates from NETC members.
2. Identify how each NETC member organizes control sites and provide recommendations for potential future changes to control sites setup.
3. Identify regional efficiencies in collection and analysis of validation/control QC/QA data.
4. Develop standard terminology that can potentially be used among NETC members.

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National DQMP Scoresheets Summary

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
Division1-New England	63%	62%	38%	68%	71%	54%
Division2-Middle Atlantic	62%	59%	21%	71%	75%	53%
Division3-East North Central	34%	34%	13%	33%	53%	42%
Division4-West North Central	50%	38%	26%	64%	54%	55%
Division5-South Atlantic	53%	57%	21%	54%	61%	38%
Division6-East South Central	34%	27%	00%	45%	46%	49%
Division7-West South Central	59%	38%	47%	78%	81%	68%
Division8-Mountain	56%	45%	26%	70%	71%	66%
Division9-Pacific	34%	35%	28%	32%	54%	35%

FHWA-RC-20-0007, *Successful Practices for Quality Management of Pavement Surface Condition Data Collection and Analysis*

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NETC DQMP Scoresheets Summary

DOT	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
State 1	75%	74%	60%	80%	75%	67%
State 2	49%	27%	00%	68%	58%	33%
State 3	47%	48%	09%	61%	42%	40%
State 4	79%	82%	50%	88%	100%	40%
State 5	48%	69%	44%	24%	75%	75%
State 6	78%	74%	63%	89%	75%	67%

Spreadsheet used in FHWA-RC-20-0007 and NECT 21-1 projects to arrive at individual and overall scores in above table has been provided to the New England states.

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Information Gathering: Findings

- NETC member DQMPs ranked well when compared to peers.
  - Especially strong in QC before and after data collection and data sampling, review, and checking.
- Four NETC members had well-rated equipment and calibration practices within DQMPs.
  - Strengths of NETC members can be leveraged to improve other two members practices.
- Control site properties and definitions vary between NETC members.
  - Limited information on level of processing and data format for all States.

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Information Gathering: Outcomes

DQMPs
- Strengths
- Weaknesses
- Needs

Terminology
- Calibration
- Certification
- Validation
- Verification
- Quality Control
- Quality Assurance
- Control Site

Control Site (also known as certification, validation or verification sites) – locations with known length and condition values used to calibrate, validate, or verify the equipment and operators.

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Control Sites: Characteristics and Locations

Control sites are important to agency's pavement performance data collection efforts
- Goes to heart of data quality (garbage in, garbage out)

Control sites have requirements to meet
- Metrics and needs (certification/validation/verification)

Control sites should meet certain desirable characteristics
- Safety, representative of network, state control, etc.

Control sites are not permanent because conditions change over time
- Need to periodically reassess them

Goal is to reduce number of control sites while meeting requirements and desired characteristics
- Sharing of sites and automating identification of potential sites is way to go

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Control Site Requirements

- AASHTO protocols and successful practices were used to develop a matrix of requirement factors recommended for control site selection.
- Key elements:
  - Metric type – IRI, DMI, rutting, or cracking
  - Test type – certification, validation, or verification
  - Guidance type – established standards (i.e., AASHTO R56) or NETC member practices
- Matrix also provides overview of equipment needed, site requirements (e.g., surface condition and length), test requirements, and NETC members for which different tests are applicable

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Control Site Requirements

Test Type	Protocol/ Field Testing	Section #	Surface Type	Distress Level	Section Length
Certification	AASHTO R56	1	AC/Composite	Smooth (30-75 in/mile)	≥ 528' with lead-in & stopping distance
Certification	AASHTO R56	2	AC/Composite	Medium-Smooth (90-135 in/mile)	≥ 528' with lead-in & stopping distance
Certification	AASHTO R56	3	AC/Composite	Medium-Rough (<200 in/mile)	≥ 528' with lead-in & stopping distance

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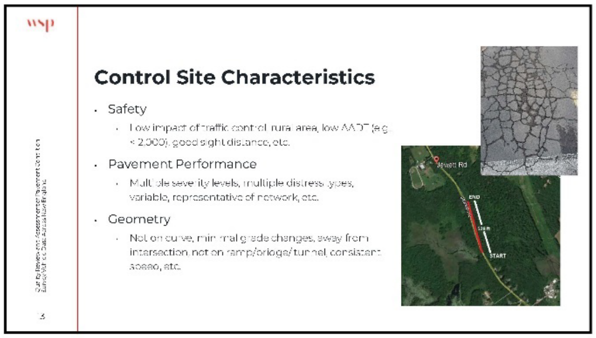

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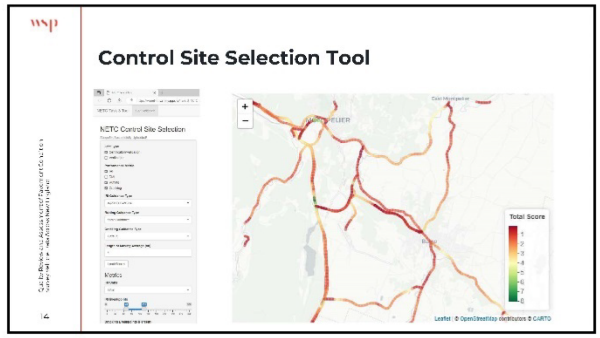

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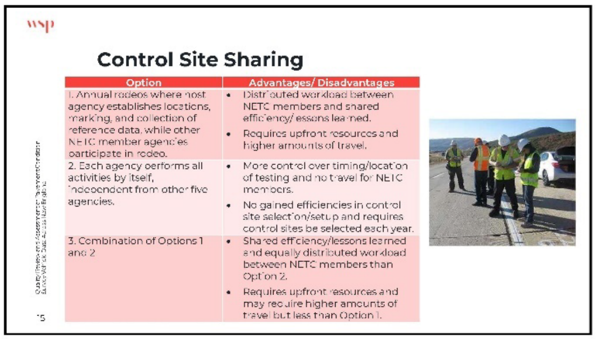

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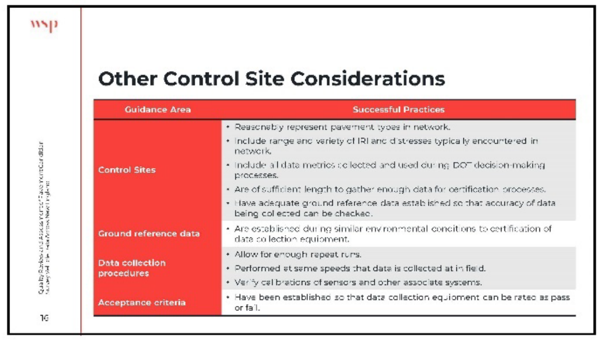

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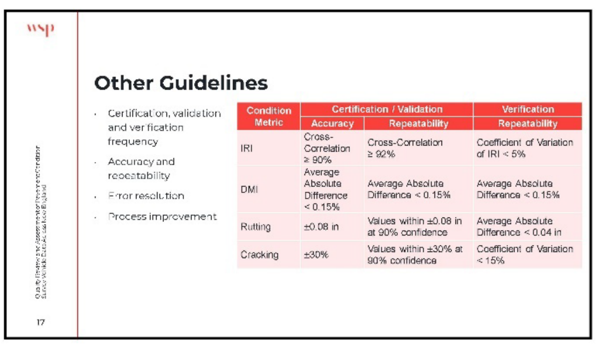

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Summary

- Quality pavement surface condition data critical to NETC members; "garbage in, garbage out."
- Federal-mandated DQMPs provide means to assist NETC members, but specific steps not clear; guidelines needed.
- DQMPs were reviewed to better understand strengths and weaknesses of NETC data quality management practices.
- Interviews held with NETC member staff, with focus on identification/selection of control sites to establish reference values.
- Reference measurements obtained at certification, validation, and verification control sites are at the heart of establishing data quality.

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Deliverables

Information gathered during project used to develop:

- Common terminology to facilitate clear and concise data quality-related communications between the NETC members.
- Guidelines and supporting tool for identification and selection of control sites, which consider site requirements and characteristics.
- Recommendations for control site inter-agency sharing options to spread resource requirements amongst NETC members.
- Other recommendations and guidelines, such as certification, validation, and verification frequency, accuracy and repeatability acceptance limits, and error resolution.

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Benefits

Adoption of recommendations and guidelines will lead to several benefits:

- Common terminology will improve data quality-related communications.
- Improved control site identification and selection process will lead to better reference data.
- Inter-agency sharing of control sites will lead to improved regional efficiencies.
- Recommendations and guidelines will assist with compliance of federal-mandated DQMPs data reporting requirements.

Terminology
Calibration
Certification
Validation
Verification
Quality Control
Quality Assurance
Control Site

Sharing Option
1. Annual rodeos with host member establishes locations, marking, and collection of reference data; other members participate in rodeo
2. Each agency performs all activities, independent from others
3. Combination of Options 1 and 2

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Thank you!

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