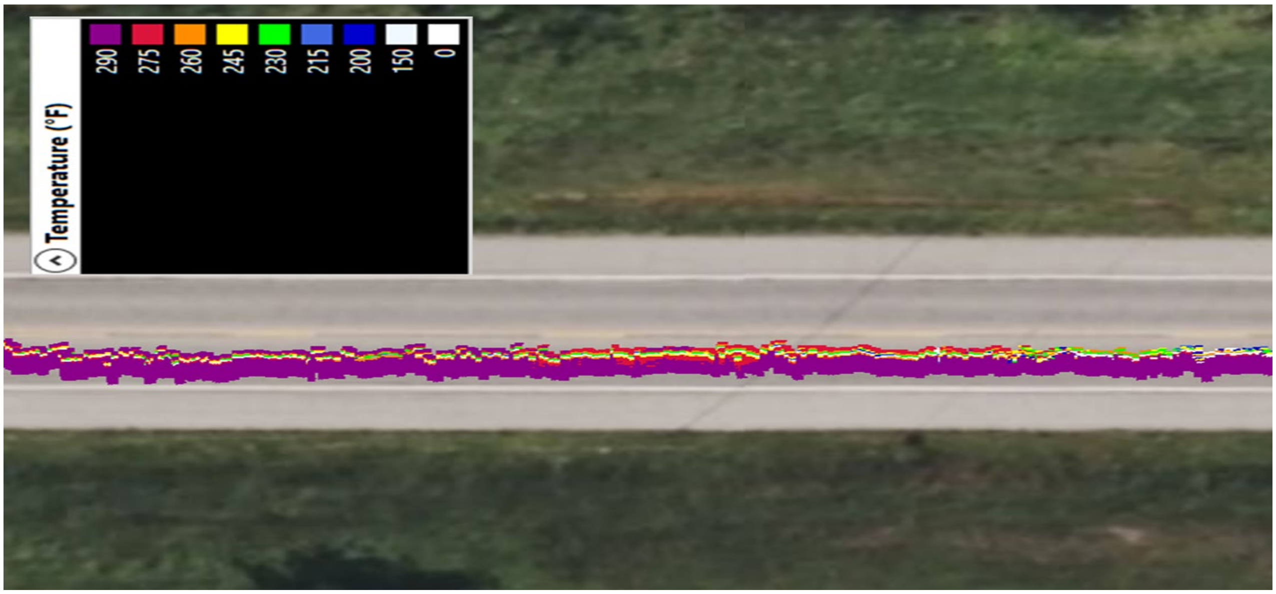
Consultant Support for Intelligent Compaction and Paver-Mounted Thermal Profiling Projects in 2024-2025



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16. Abstract

The 2024 MoDOT IC-PMTP Annual Report highlights achievements and challenges in implementing Intelligent Compaction (IC) and Paver-Mounted Thermal Profiling (PMTP) technologies. Key updates included aligning data validation tools with updated PMTP specifications and addressing challenges such as contractor's paving boundary data manipulation and data loss. Improved PMTP thermal segregation trends were noted, though IC coverage declined due to data loss issues. Feedback meetings emphasized the preconstruction Global Navigation Satellite System (GNSS) and cellular surveys, stricter paving boundary validation, and updated PMTP specifications. Training and support efforts in 2025 will address these challenges and changes, ensuring continued improvement in paving quality and IC/PMTP data reliability.

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List of Abbreviations and Acronyms

DRS: .... Differential Range Statistics

DUG: .... Daily Use Gateway

FOV: .... Field Of View

GNSS: .... Global Navigation Satellite System

GPS: .... Global Positioning System

IC: .... Intelligent Compaction

ICMV: .... Intelligent Compaction Measurement Values

IR: .... Infrared Scanning

MTOP: .... Mean Temperature at Optimum Pass

NIST: .... National Institute of Standards and Technology

PMTPS: .... Paver-Mounted Thermal Profile Systems

PPK: .... Post-Processed Kinematic

QA: .... Quality Assurance

RE: .... Resident Engineer

RTK: .... Real-time kinematic positioning system

SOW: .... Scope of Work

TPF: .... Transportation Pooled Fund

TTT: .... Train-the-Trainers

Executive Summary

The 2024 MoDOT IC-PMTP Consultant Support Annual Report highlights progress and challenges in implementing Intelligent Compaction (IC) and Paver-Mounted Thermal Profiling (PMTP) technologies. Key tasks included updating data validation tools, enhancing training programs, providing remote project support, and hosting feedback meetings.

Major updates included aligning project summary sheets and QA tools with updated PMTP specifications and incorporating revised thermal segregation classifications and FHWA-recommended data validation methods. Training programs focused on statewide workshops and Train-the-Trainers (TTT) sessions, emphasizing updated specifications, data validation, and analysis. Recorded sessions provided essential support for contractors dealing with staff turnover.

Analysis of 2024 project data revealed improved PMTP thermal segregation trends, though IC coverage decreased due to data loss. Data validation tools worked effectively when data collections were adequate and complete, but challenges like mismatched timestamps and invalid verification data persisted. Remote support addressed these issues while identifying areas for improvement.

Feedback meetings underscored the importance of preconstruction Global Navigation Satellite System (GNSS) and cellular coverage surveys and stricter boundary validation processes. 2025 training priorities include addressing boundary manipulation, using enhanced PMTP data validation methods, improving daily equipment verification, and providing guidance on transitioning between PMTP specifications.

The 2025 season aims to build on 2024's successes by addressing these challenges to further enhance paving quality and IC/PMTP data reliability across MoDOT's IC-PMTP projects.

Chapter 1 Introduction

1.1 Background

The MoDOT 2017-2023 Intelligent Compaction and Paver-Mounted Thermal Profiling (IC-PMTP) projects demonstrated paving quality improvements on numerous field projects. Therefore, MoDOT planned to include additional IC-PMTP projects in 2024 and 2025. The primary goal of this project was to ensure the continued success of the MoDOT IC-PMTP projects in 2024 and beyond. MoDOT procured consulting support (this project) for selected IC-PMTP projects and implemented many initiatives, such as independent data validation updates, project summary sheet updates, remote project support, feedback meetings, and more, as summarized below.

1.2 Project Scope and Summary of Workplan

This project's scope of work (SOW) included nine project tasks from January 2024 to March 2026, spanning 27 months. The tasks of this project are listed as follows:

- Task 1 – Kick-Off Meeting
- Task 2 – Project Summary and QA Tools Update
- Task 3 – Training Program
- Task 4 – Remote Project Supports
- Task 5 – Remote IC-PMTP Data QA Support
- Task 6 – Online Annual Feedback Meetings
- Task 7 – Annual Reports
- Task 8 – IC-PMTP Data QA Equipment
- Task 9 – Quarterly Reports

1.3 Structure of Report

This 2024 annual report is a deliverable for Task 7. The rest of this report is generally structured by task, with each chapter summarizing the accomplishments of the task (Table 1). Task 9 refers to general administration and submittal of quarterly reports and does not have a dedicated chapter. The 2025 events will be summarized in a future report.

Table 1. Structure of the Report

Chapter	Titles
Chapter 1	Introduction
Chapter 2	Task 2 – Project Summary and Quality Assurance (QA) Tools Update
Chapter 3	Task 3 – Training Program
Chapter 4	Tasks 4 and 5– Remote Project Supports (Including Data QA)
Chapter 5	Summary of Project Results

Chapter	**Titles**
Chapter 6	Task 6 – Online Annual Feedback Meetings
Chapter 7	Task 8 – Data QA Equipment
Chapter 8	Conclusions and Recommendations
Chapter 9	References

Chapter 2 Task 2 – Project Summary and Quality Assurance (QA) Tools Update

2.1 Introduction

The project summary sheet and QA tools were updated to address specification changes and recommendations from FHWA review. The following sections summarize how these tools are used in MoDOT's IC-PMTP program and the changes made under this project.

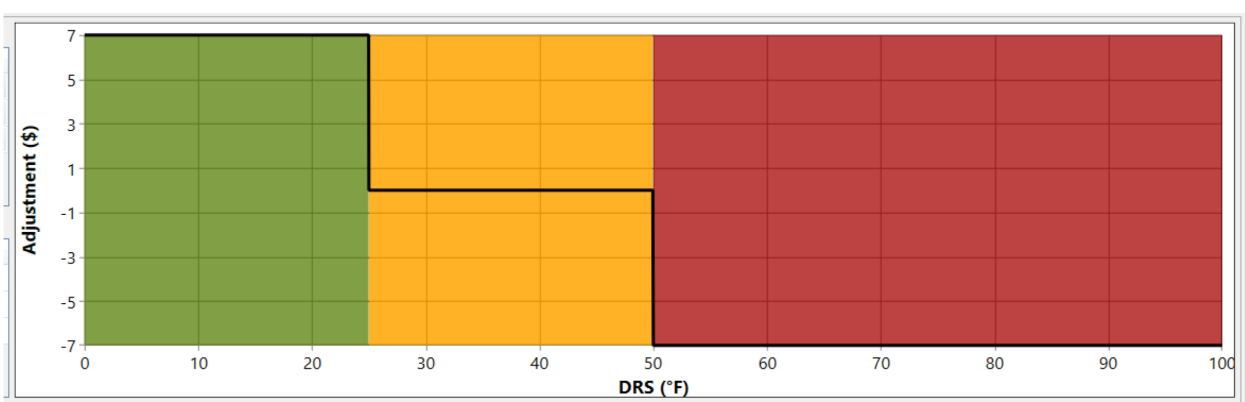
2.2 Project Summary Sheet

The project summary sheet is a macro-enabled Excel spreadsheet that records IC-PMTP project summary information and calculates price adjustments. MoDOT is moving towards using PMTP on all Superpave projects statewide and has updated the PMTP specification. The updated specification applies to projects let in 2024 and beyond. With the updated PMTP specification, updates to the summary sheet were required to calculate the updated segregation classifications and price adjustments. The new moderate segment splits the category into moderate or moderate-high, as summarized in Table 2.

Table 2. Updated thermal segregation classifications.

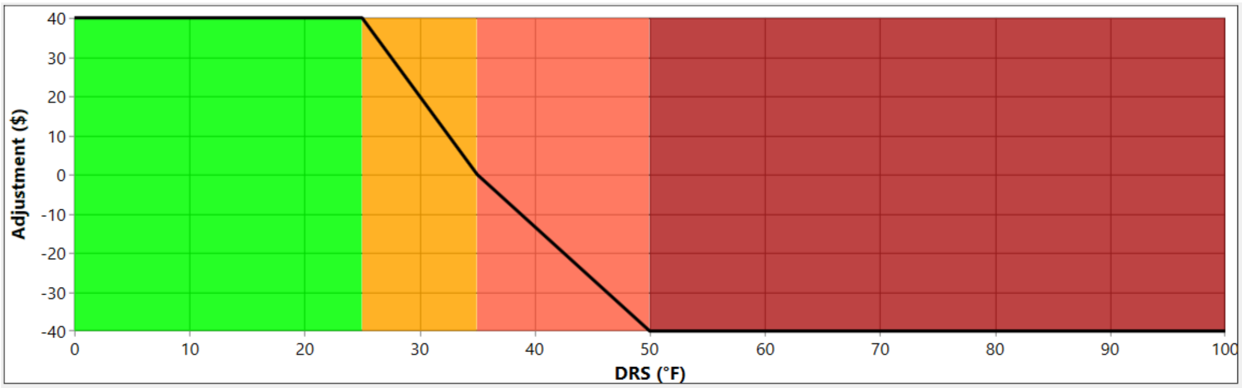
Differential Range Statistics (DRS)	Thermal Segregation Category
DRS ≤ 25.0°F	Low
25°F < DRS ≤ 35°F	Moderate
35°F < DRS ≤ 50°F	Moderate-High
DRS > 50°F	Severe

The original (for comparison) and revised price adjustments are shown in Figure 1 and Figure 2, respectively. The new moderate segments' price adjustments are variable based on the DRS value, as shown in Figure 2.



Source: The Transtec Group, 2024

Figure 1. Chart. Original price adjustments using the "old" special provisions specification.



Source: The Transtec Group, 2024

Figure 2. Chart. Revised price adjustments using the new PMTP specification.

Other changes were made to the summary sheet as follows:

- Minor code adjustments to improve display and usage optimization.
- Updates to address any issues caused by Microsoft's "ActiveX" framework removal in 2024.
- Removal of all ICMV columns from the IC results spreadsheet.

2.3 Quality Assurance (QA) Tools

The QA tools are macro-enabled Excel spreadsheets that perform independent data validation using MoDOT's verification data for IC and PMTP. Data validation is performed to meet the Code of Federal Regulations (CFR) requirements. 23 CFR 637 Subpart B addresses Quality Assurance Procedures for Construction. 23 CFR 637.207(a)(1)(ii)(b) states:

"Quality control sampling and testing results may be used as part of the acceptance decision provided that the quality of the material has been validated by the verification sampling and testing. The verification testing shall be performed on samples taken independently of the quality control samples."

Since IC and PMTP data are contractor-collected, MoDOT developed procedures to validate the data. These procedures have been summarized in past annual IC-PMTP reports and the 2022 project report titled Implementation of Data Quality Assurance (QA) for Innovative Technologies at MoDOT (Chang et al., 2022). The PMTP validation process compares temperatures from the infrared image with the contractor's data within the same footprint. An event marker is used to identify the location where the temperature comparisons are made.

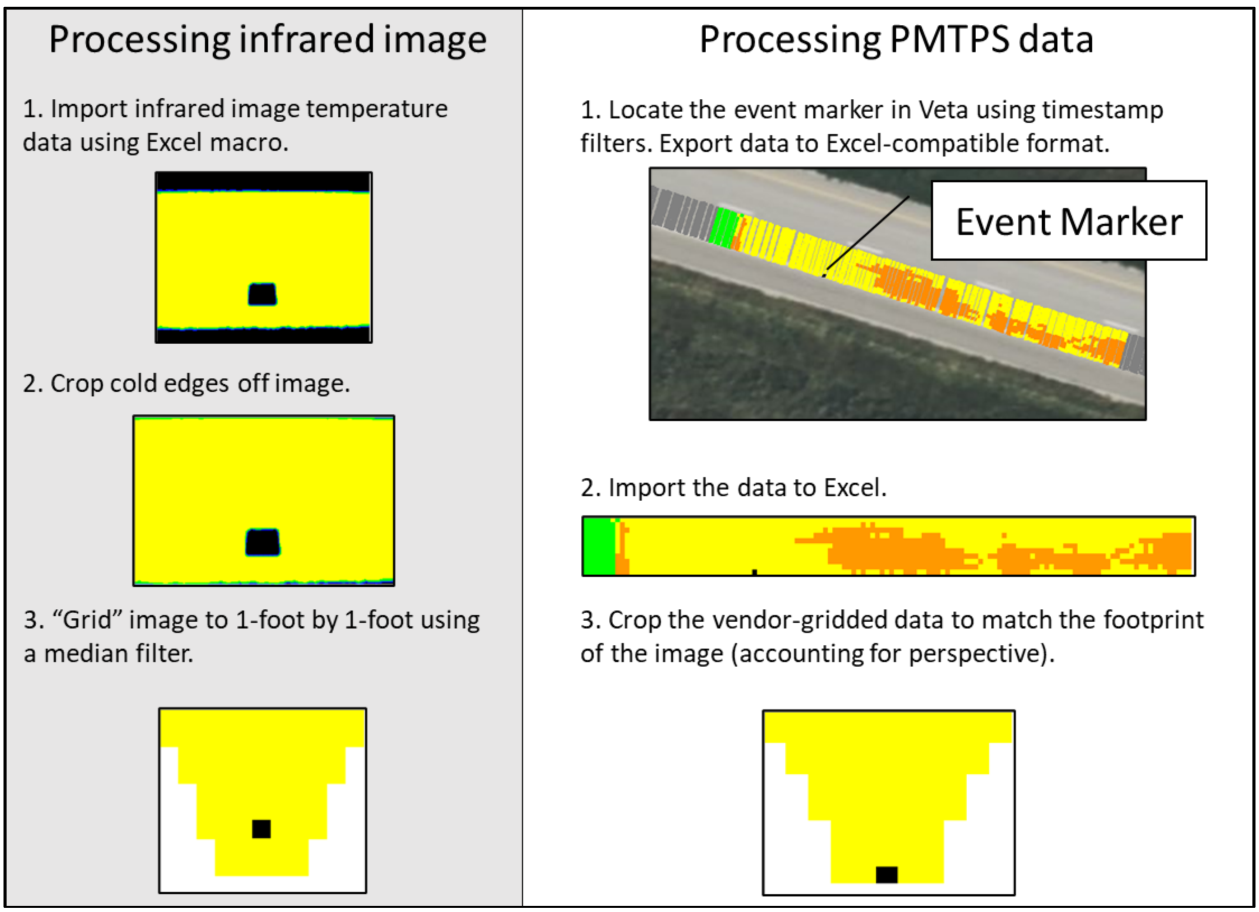
2.3.1 PMTP Validation

Changes to the PMTP QA spreadsheet were required to address recommendations following the FHWA review. FHWA recommended that the final evaluation criteria for data validation more closely align with the acceptance criteria (DRS). DRS is defined in AASHTO R 100 as the 98.5th percentile minus the 1st percentile of the temperature data within a 150-foot sublot.

The verification data is collected using an infrared image taken with a handheld thermal camera. As a result, the footprint of the verification data is significantly smaller than a 150-foot sublot. The term "pseudo" range statistic (PRS) was coined to address this difference in sample sizes and avoid confusion.

The PRS uses the 98.5th percentile minus the 1st percentile of the temperature data within an infrared image footprint.

The process and updated spreadsheet also include "gridding" the infrared image to average the data into a sample size comparable to PMTP data. PMTP data is exported at a maximum resolution of 12 inches by 12 inches. Since the data exported from the infrared image has a much higher resolution, a median filter is applied to "grid" the image to match the 12-inch by 12-inch resolution of PMTP data. An illustration of how the contractor and verification data are processed before validation is shown in Figure 3.



Source: The Transtec Group, 2024

Figure 3. Illustration. Processing the contractor and verification infrared image before validation.

The current evaluation criteria are as follows (in terms of allowable percent difference):

- Mean: 6%.
- Standard Deviation: evaluation only – no criteria.
- Min: evaluation only – no criteria.
- Max: evaluation only – no criteria.
- Sample Size: evaluation only – no criteria.
- 1 percentile: evaluation only – no criteria.

- 98.5 percentile: evaluation only – no criteria.
- PSR: 4% (chosen based on the threshold recommended for temperature verification in AASHTO R110-22).
- PSL (low, medium, severe): evaluation only – no criteria.

2.3.2 IC Validation

No changes were made to the IC pass-count validation tools. Feedback from FHWA recommended using one verification device per roller so that pass-count coverage could be measured and compared for validation. Currently, it is not economically feasible to purchase multiple verification devices per project.

2.3.3 Transportation Research Board Publication and Presentation

The contractor data verification and validation procedures were summarized and submitted to the 2025 Transportation Research Board Annual Meeting (TRBAM). The paper and presentation were accepted and were published and presented at TRBAM 2025 as Missouri DOT's Verification and Validation Procedures for Intelligent Compaction and Paver-Mounted Thermal Profiling Systems.

2.4 Summary

The macro-enabled Excel tools were updated to reflect specification changes and recommendations from FHWA. The summary sheet reflects the new PMTP thermal segregation classifications and price adjustments for all projects let in 2024 and beyond.

The PMTP data validation tool was updated to include “gridding” of the infrared image data using a median filter and to include the PRS as evaluation criteria. The updated Excel tools will be used in the upcoming 2025 season.

Chapter 3 Task 3 – Training Program

3.1 Introduction

Based on previous years' experiences, the training program was optimized to offer the most efficient training. The 2024 training program included conducting the annual statewide workshops and train-the-trainers (TTT) sessions. All training sessions were held online. The training materials were updated to reflect the most recent specification and protocol changes, as summarized in the following sections.

3.2 Training Materials Update

The training materials were updated to reflect the revised analysis procedures for the new PMTP specification. During the transition period in 2024. Some projects used old specifications, and others used new ones. The difference in specifications and procedures was highlighted in the statewide training workshops. The following updates were made to training materials:

- Revised the summary sheet (as summarized in chapter 2).
- Created a copy-and-paste Excel sheet with the new PMTP thermal segregation categories and price adjustments. The data in the Excel sheet can be copied into Veta to create the chart previously shown in chapter 2 (Figure 2).
- Updated the DocHelper SharePoint Navigator with instructions on using the "old" and "new" summary sheets and procedures. The DocHelper is a document that organizes all the training materials and construction forms with links to make navigation of materials more efficient. More information on the DocHelper can be found in previous annual reports.

3.3 Statewide Training Workshops

Two statewide workshops were held as follows:

- February 26, 2024, Statewide Training for Contractors.
- February 27, 2024, Statewide Training for MoDOT.

The contractor training was remote training on how to complete an IC-PMTP Veta project according to MoDOT protocols. The training walked participants step-by-step through the data collection, analysis, and reporting.

The MoDOT workshop was a remote training focused on reviewing contractor submittals and completing the data QA procedures using the DirtMate (to verify IC pass count) and FLIR cameras (to verify PMTP temperature).

Both training sessions were recorded, posted to IC SharePoint site, and linked in the DocHelper. Recording and posting the training sessions was particularly useful in 2024 as several contractors with employee turnover requested the recorded sessions.

3.4 Train the Trainers (TTT)

The TTT session was held online on June 13, 2024 for the new MoDOT interns. The TTT focused on completing the data validation for IC pass count and PMTP temperatures.

3.5 Summary

The 2024 training program was optimized based on prior experience to deliver efficient and effective training. It included annual statewide workshops and train-the-trainers (TTT) sessions, all conducted online. Training materials were updated to reflect new PMTP specifications and procedures, including revised summary sheets, Excel tools for data validation, and updates to the DocHelper SharePoint Navigator.

Chapter 4 Tasks 4 and 5 – Remote Project Supports

4.1 Introduction

All project support was held remotely on an as-needed basis. The following sections summarize the remote project support for 2024, including common issues and frequently asked questions (FAQs).

4.2 Summary or Remote Support

Remote support was facilitated through Microsoft Teams (MS Teams). Common support requests are as follows:

- Assistance with data analysis for contractors.
- Troubleshooting data loss issues for contractors.
- Support for MoDOT project staff with data QA collection or analysis.
- Full training sessions for new employees following contractor turnover.

The following sections summarize some of the common support requests in more detail.

4.3 Common Issues and FAQs

4.3.1 General Analysis

Several contractors had new employees performing the IC-PMTP analysis who did not attend the statewide training. Remote sessions were held upon request to go through the analysis process. The recorded training sessions were also available for new employees.

4.3.2 Data Loss

There were many issues with data loss in 2024. This is covered in more detail in chapter 5.

4.3.3 New PMTP Specification

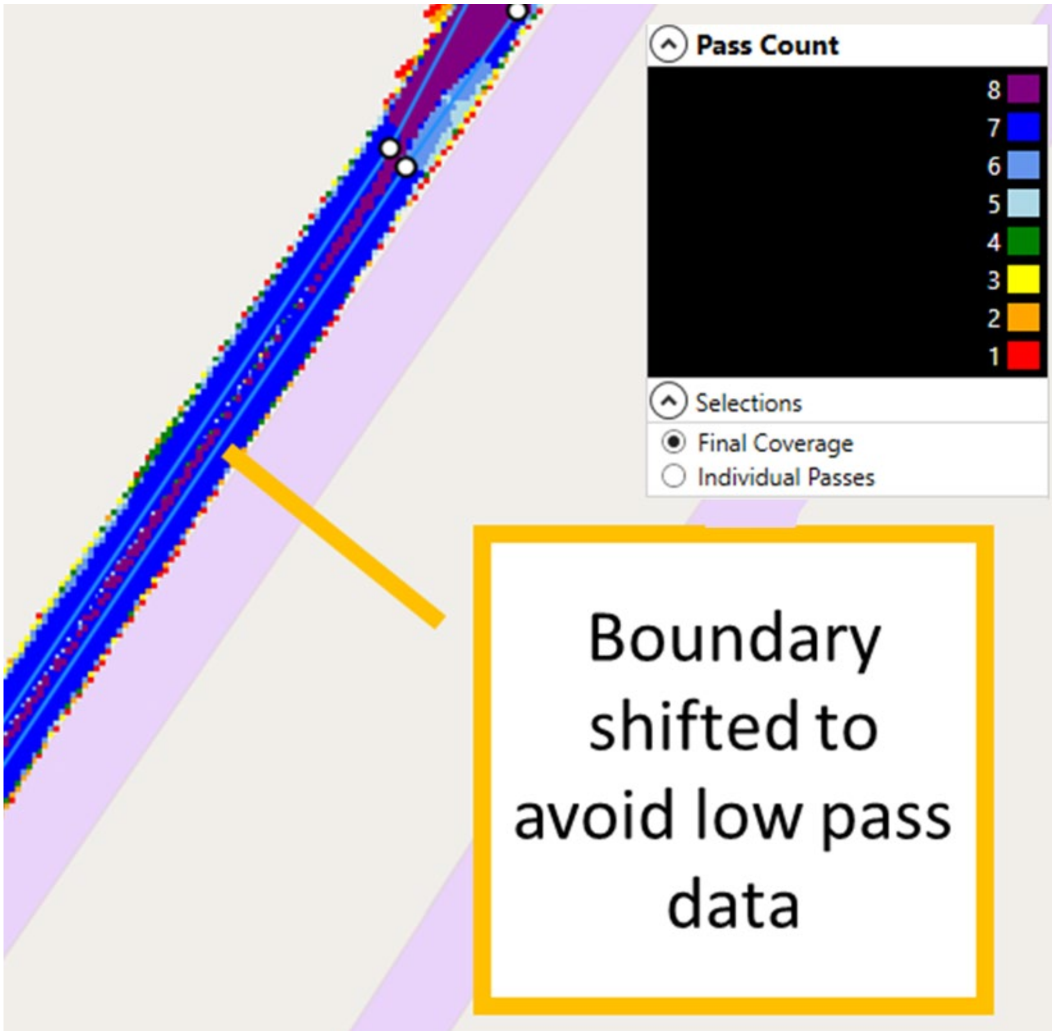
There was a transition period in 2024 where some projects used the old PMTP specifications, and others used the new PMTP specifications. As expected, this caused some confusion regarding data analysis and reporting. Remote sessions were conducted to train contractors and agencies on the correct methods.

4.3.4 Data Validation Issues

Several MoDOT inspectors ran into issues with the macro-enabled Excel spreadsheets. The verification image reader developed to export the data from the infrared photos requires Microsoft .NET Framework 4.8 and Microsoft Visual C++ Redistributable for Visual Studio 2013 (Microsoft Visual). Several computers required the installation of this software for the image reader to function correctly. Future versions of Microsoft Visual are not compatible with the image reader. Multiple versions can coexist, so the 2013 version will be provided with the image reader.

4.3.5 Contractor's Paving Boundary Data

A request was made to investigate suspicious manually collected contractor's paving boundaries. The investigation revealed that some boundaries had been manipulated to improve pass count coverage (Figure 4). Additional checks of other projects uncovered similar issues. It is recommended that manually collected boundaries be thoroughly reviewed in all future projects. Projects using alignment files are less susceptible to manipulation than those with manually collected boundaries.



Source: The Transtec Group, 2024

Figure 4. Image: Example of contractor paving boundary data tampering.

4.4 Summary

In 2024, remote support and training addressed several challenges and updates. New employees required additional IC-PMTP analysis training, while data loss issues and confusion over new PMTP specifications were resolved with remote sessions. Data validation problems were linked to missing software dependencies, requiring updates for proper functionality. An investigation into manually collected contractor boundaries revealed manipulation to improve pass counts, highlighting the need for stricter checks in future projects.

Chapter 5 Summary of Project Results

5.1 Project Overview

The projects that had data uploaded to SharePoint during the 2024 construction season and the IC-PMTP equipment vendors used for each project are shown in Table 3. Some originally planned projects were delayed or did not have data uploaded to SharePoint. Contractors and projects are displayed anonymously by a code. The contractor and project codes are decoded in Appendix A (removed for the public version).

Table 3. Summary of IC and PMTP systems.

Contractor Code	Project Code	IC system	PMTP system
7	1	Trimble	MOBA
5	2	CAT Trimble	MOBA
12	3	CAT Trimble	MOBA
1	4	Topcon	MOBA
4	5	Topcon	Topcon
4	6	Topcon	Topcon
8	7	Trimble	Trimble-IR
8	8	Trimble	Trimble-IR
5	9	Trimble	MOBA
1	10	Topcon	MOBA
5	11	CAT Trimble	MOBA
8	12	Trimble	MOBA
8	13	Trimble	MOBA

5.2 Project Analysis

Projects were analyzed in Veta using the procedures and requirements in the protocols and specifications. A summary of the data analysis process is described in this section.

5.2.1 Data Import and Legend Customization

The daily IC and PMTP data were imported to one Veta project file using applicable coordinate systems. The pass count legend was customized to reflect the optimum pass count established during the trial section.

5.2.2 Project Filters

Table 4. Summary of filters used for analysis.

Filter Type	Filter Name	Applicable Equipment	Description
Data Filter	Temperature	PMTP	Filters the temperatures that are less than 180˚F.
Operation Filter	Common Location Filter	IC	Filters the IC data using a paved area boundary collected using GNSS equipment. Custom endpoints are used as the start and stop locations for sublots.
Operation Filter	PMTP Location Filter Override	PMTP	Overrides the common location filter. This filter is required because the GNSS precision of the PMTPS does not meet the precision of the boundary GNSS, and therefore, data may not fall within the boundary. Custom endpoints are used as the start and stop locations for sublots.
Operation Filter	Cold Edge and Ride Bracket	PMTP	Statistically removes cold edges of adjacent pavement or hot paver smoothing skis.

5.2.3 Spot Tests

The core locations and resulting densities were added to the spot tests screen. The specifications do not explicitly require adding the spot test locations and resulting values in Veta. Therefore, this was not always completed.

5.2.3.1 IC Analysis Setup

The IC setup includes selecting final coverage, all passes, and individual pass data. Required data metrics for analysis include pass count and temperature. Sublot analysis was not required but was recommended as an additional quality control tool to generate compaction curves.

A cumulative pass count specification was set according to the optimum pass count established during the trial section. The pass count legend should be customized to match the optimum pass count since the coverage chart legend is based on this.

The MoDOT temperature specification is based on the mean temperature at the optimum pass (MTOP). Veta has no feature to support this specification, so contractors manually check for this.

5.2.3.2 PMTP Analysis Setup

PMTP sublots were analyzed at 150 feet, and paver-stops were removed as per AASHTO R 110-22 and MoDOT specifications. The required data metric for analysis was temperature segregation, but speed was recommended as an extra quality control tool.

“Old” (2024 and earlier) Specification

The PMTP data were analyzed according to the Differential Range Statistics (DRS) described in AASHTO R 110-22.

"New" (projects let in 2024 and beyond) Specification

The PMTP data were analyzed according to the new thermal segregation classifications described in chapter 2 of this report. Note that at this time, no project has been completed using the new spec, although some are in progress. These projects will be reported in the 2025 annual report.

5.2.4 Reporting

PDF reports were generated for each system (IC and PMTP) and uploaded to SharePoint with associated data. The following results were pulled from the reports and manually input into the supplemental Excel summary sheet:

- IC Overall coverage was reported for pass count data (based on the optimum pass).
- IC MTOP
- PMTP number of low, moderate, moderate-high (if applicable), and severe segregation classifications.

5.3 Project Results

This section includes a summary of IC and PMTP results from the 2024 construction season and cumulative results from 2017 through 2024.

5.3.1 2024 Construction Season

The data management protocols include contractor data submission and Resident Engineer (RE) data submission. Table 5 and Table 6 summarize the 2024 data management assessment for contractors and REs, respectively. The results below assess whether the data was submitted to the IC SharePoint site.

The legend for the tables is described as follows:

- Y: Yes, data was submitted to IC SharePoint.
- N: No, data was not submitted to IC SharePoint.
- P: Some data was submitted. Some data were incomplete or missing.
- N/A: The data was not needed for this project.

Table 5. Contractor data management results.

Contractor Code	Project Code	Trial Section Data	IR Data	IC Data	GPS Data	Spot Test Data	Analysis Complete
7	1	Y	Y	Y	N	Y	Y
5	2	Y	Y	Y	Y	Y	Y
12	3	Y	Y	Y	Y	P	Y
1	4	N	Y	Y	Y	Y	Y
4	5	Y	Y	Y	Y	Y	Y
4	6	Y	Y	Y	Y	N	Y
8	7	Y	Y	Y	Y	N	Y
8	8	Y	Y	Y	Y	N	Y
5	9	N	Y	Y	Y	Y	Y
1	10	Y	Y	Y	Y	P	Y
5	11	N/A	N/A	Y	Y	N	Y
8	12	Y	Y	Y	N	N	Y
8	13	Y	Y	Y	N	N	Y

Most contractors submitted the required data to the IC SharePoint site, and the most commonly missing data are the trial section data, GPS paving boundary data, and spot test data. Contractors should be encouraged to submit missing data for verification and record keeping.

Table 6. RE data management results.

Contractor Code	Project Code	RE check List	RE QA Complete	Dirtmate Data	Flir Data
7	1	N	P	N	Y
5	2	N	N	N	N
12	3	N	P	N	Y
1	4	N	N	N	N
4	5	N	P	Y	Y
4	6	N	P	Y	Y
8	7	N	N	N	N
8	8	N	P	N	Y
5	9	N	P	Y	Y

Contractor Code	Project Code	RE check List	RE QA Complete	Dirtmate Data	Flir Data
1	10	Y	P	N	Y
5	11	N	N	N	N/A
8	12	N	N	N	N
8	13	N	N	N	N

General observations from Table 6 include the following:

- REs may be completing the checklist and diary but not uploading them to SharePoint. These files are recommended to be uploaded to SharePoint to complete the database.
- Nearly all project staff uploaded FLIR photos to SharePoint.
- Only a few projects generated Dirtmate files. Due to higher costs and subscription fees, only a few Dirtmates were distributed this year.

Due to the complexity of the data QA analysis, in 2024, project staff were only responsible for collecting the data. Analysis was performed by the Field Office interns and the Consultant (Transtec). The results were discussed in detail during the Feedback Meeting, as summarized in chapter 6.

5.3.1.1 IC Results by Project

The IC data were evaluated according to MoDOT specification NJSP-18-08. A summary of the criteria is as follows:

- IC coverage: IC coverage is based on the coverage within the daily paving boundary at the optimum pass. Coverage less than 70 percent is considered deficient, coverage between 70 and 90 percent is considered moderate, and coverage above 90 percent is considered passing.
- The mean temperature at the optimum pass (MTOP): The overall mean temperature at the optimum pass shall be 180˚F. Segments that do not meet this requirement are considered deficient.
- Passing segments receive price incentives. Moderate segments receive no price adjustment. Deficient segments receive price disincentives.
- Target ICMV: The final coverage overall ICMV should be greater than 70 percent of the target ICMV. Segments that do not meet 70 percent are flagged but do not affect price adjustments. Because the target ICMV is for informational purposes only, few contractors reported ICMV data. Because there is insufficient valid ICMV data, the target ICMVs are not included in this report.

A summary of the 2024 IC coverage (% of the optimum pass) is shown in Figure 5. The chart shows the average IC coverage, the segment classification thresholds, and the optimum pass count for each project.

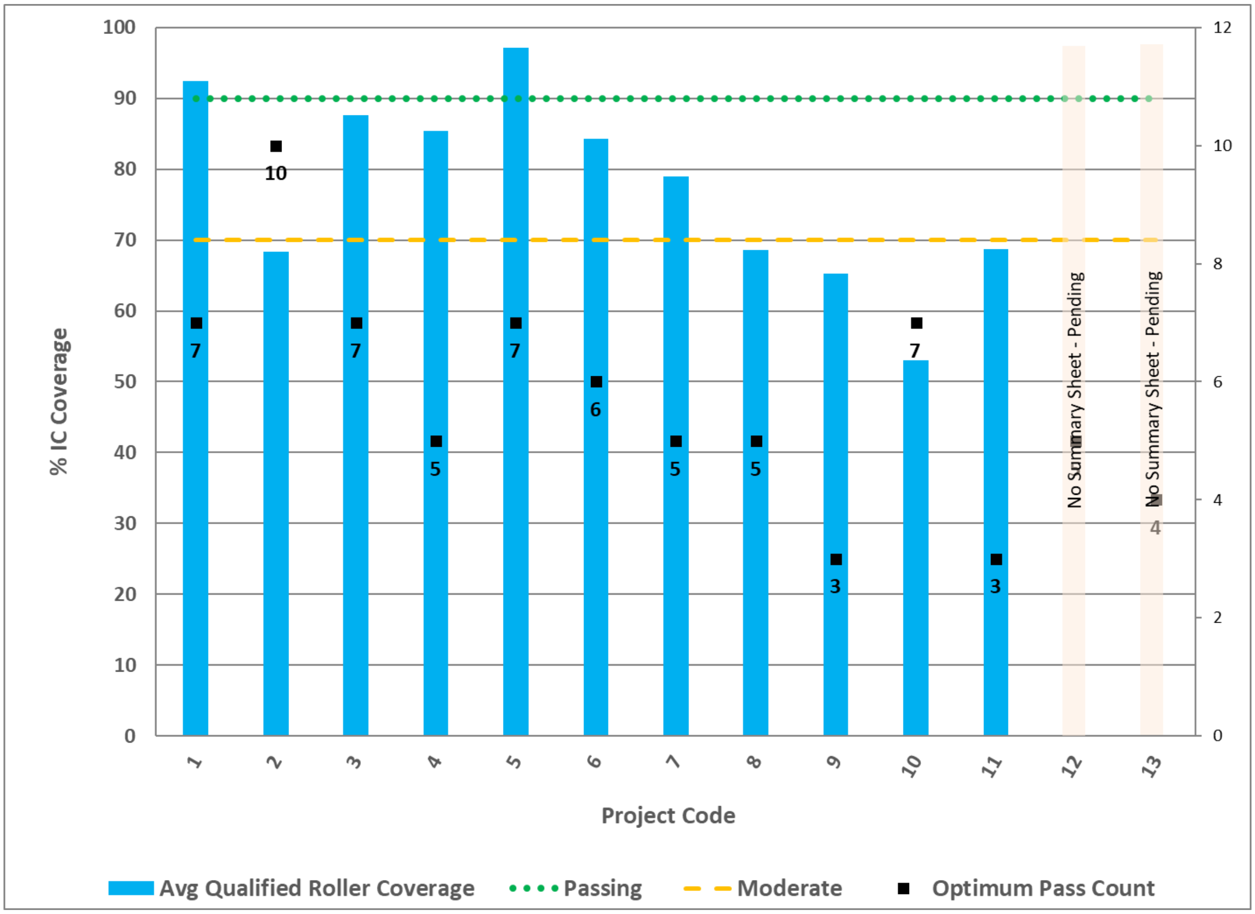


Figure 5. Chart. Average IC coverage per project and optimum pass counts.

General observations from Figure 5 include the following:

- Two projects averaged above the 90 percent threshold.
- Six projects averaged above the 70 percent threshold.
- Five projects fell below the 70 percent threshold. Upon investigation of the data, it appears that many of these projects had issues with missing data.
- Two projects did not submit a summary sheet, and the results were not included.

A summary of the average MTOP for each project in 2024 is shown. Figure 6.

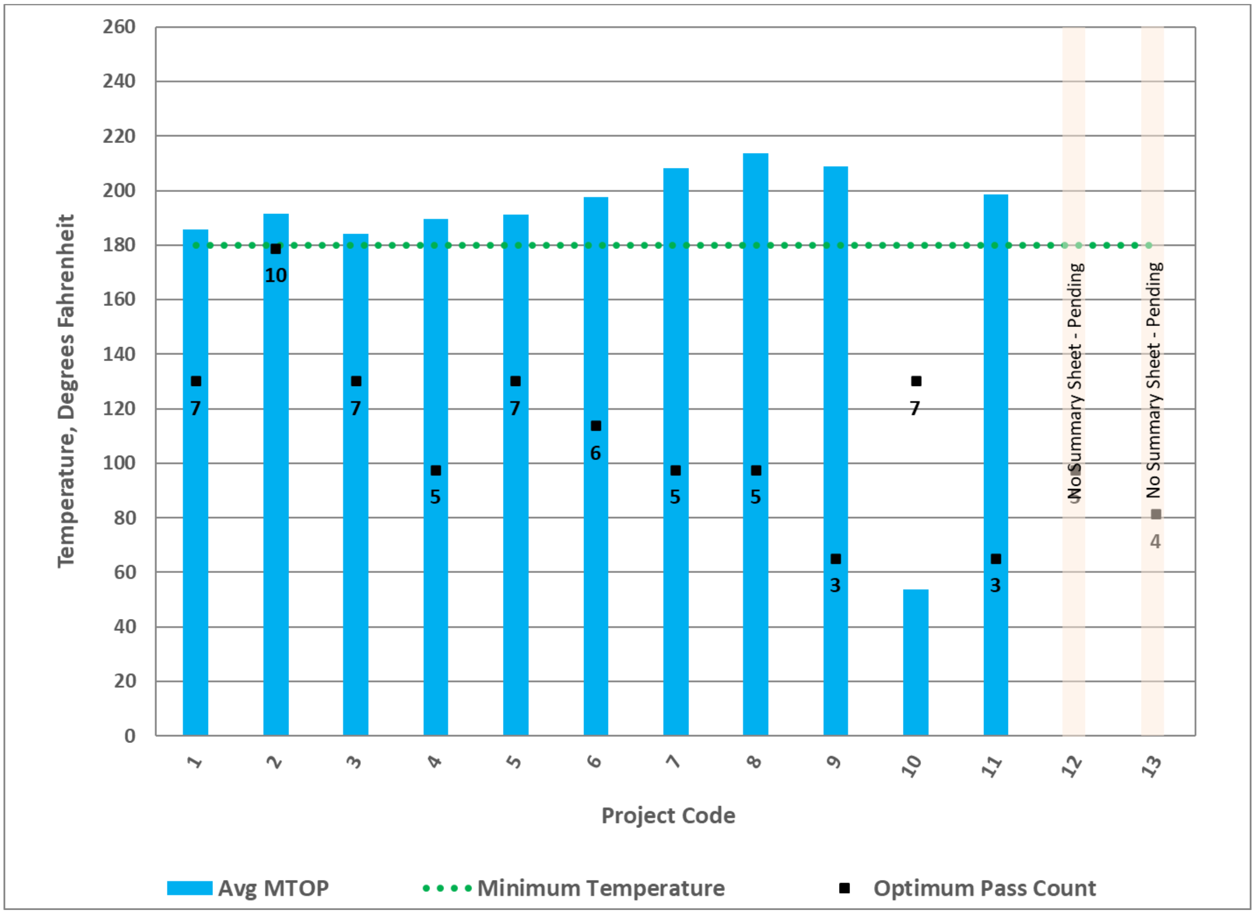


Figure 6. Chart. The average MTOP per project and optimum pass counts.

All projects that submitted summary sheets averaged MTOPs above 180 except for project code 10. The average temperatures for this project are less than 60°F. These extremely low temperatures are erroneous and may be due to equipment malfunction. No project notes on the low roller temperatures were available on SharePoint.

5.3.1.2 IC Results by Contractor

Figure 7 shows the average roller coverage for each contractor. Some contractors had multiple projects during the season, and some had just one.

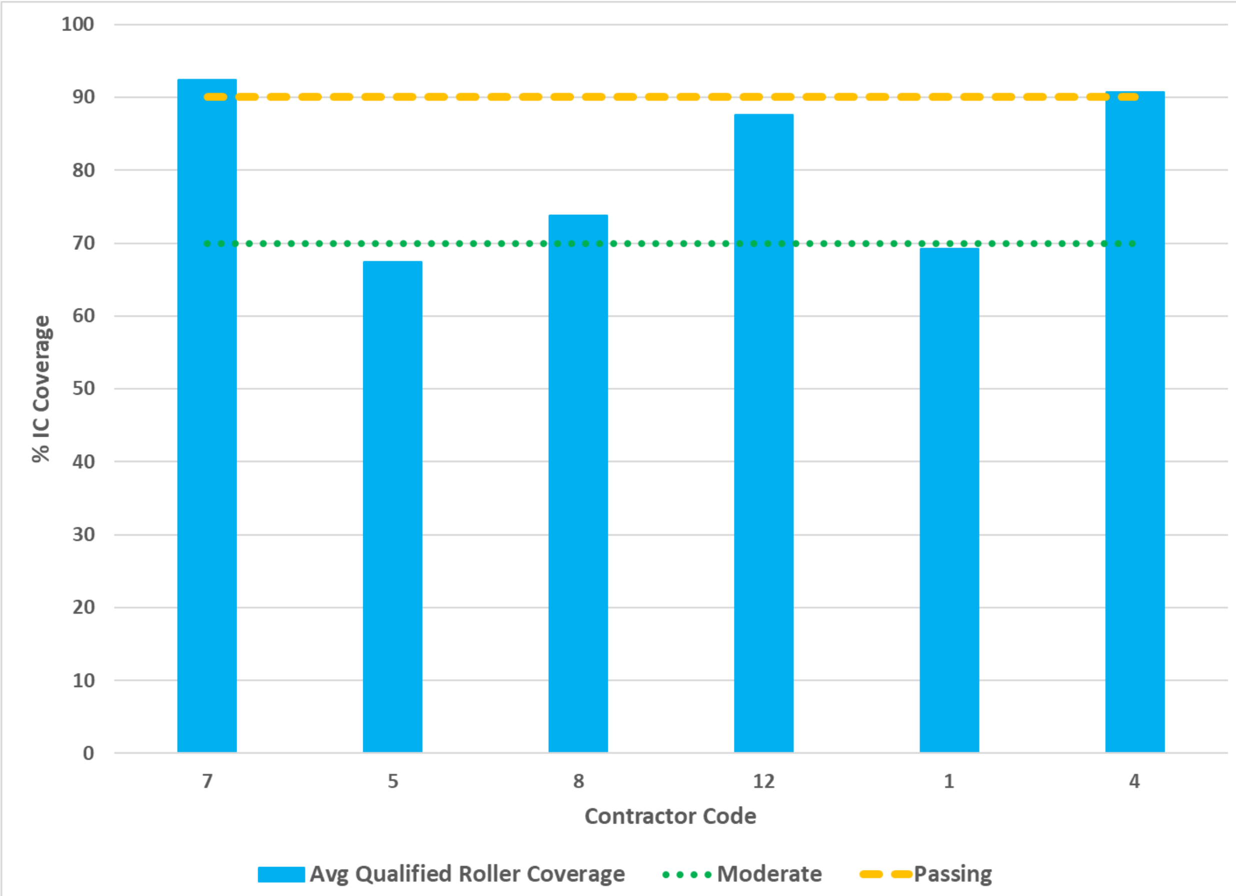


Figure 7. Chart. Average roller coverage by the contractor.

Two contractors had projects averaging above 90 percent coverage, two met the 70 percent threshold, and two fell below the 70 percent threshold.

5.3.1.3 IC Validation using MoDOT Verification Data

This section summarizes the results from the validation procedure using the IC pass count verification device. More information on the procedure can be found in the 2022 Implementation of Data QA for Innovative Technologies at MoDOT report (Chang et al.). IC verification data was used to validate contractor data on two projects. More projects may have used a verification device, but the file was unavailable or could not be generated due to missing installation dimensions.

The pass and fail criteria were based on pass count mean, standard deviation, coefficient of variance (C0V), and variance with thresholds summarized in Table 7.

Table 7. Pass and fail criteria for IC verification data.

Statistic	Threshold
Mean	0.00%
Standard Deviation	5.00%
CoV (%)	10.00%
Variance	15.00%

Sometimes, a verification file was generated, but the validation could not be completed due to one or more issues. The percent of the time that validation was completed is shown in Figure 8.

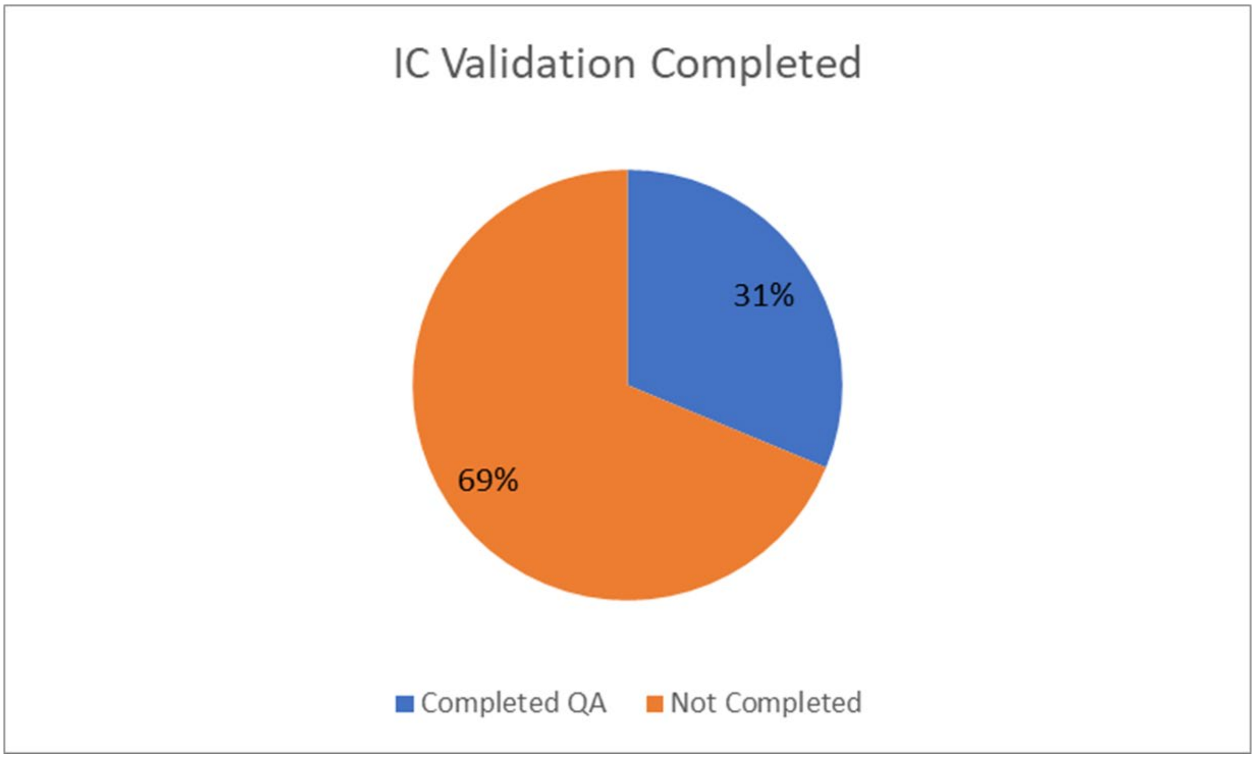


Figure 8. Chart. Percent of IC verification data where validation was completed.

The results of the validation that was completed are shown in Figure 9.

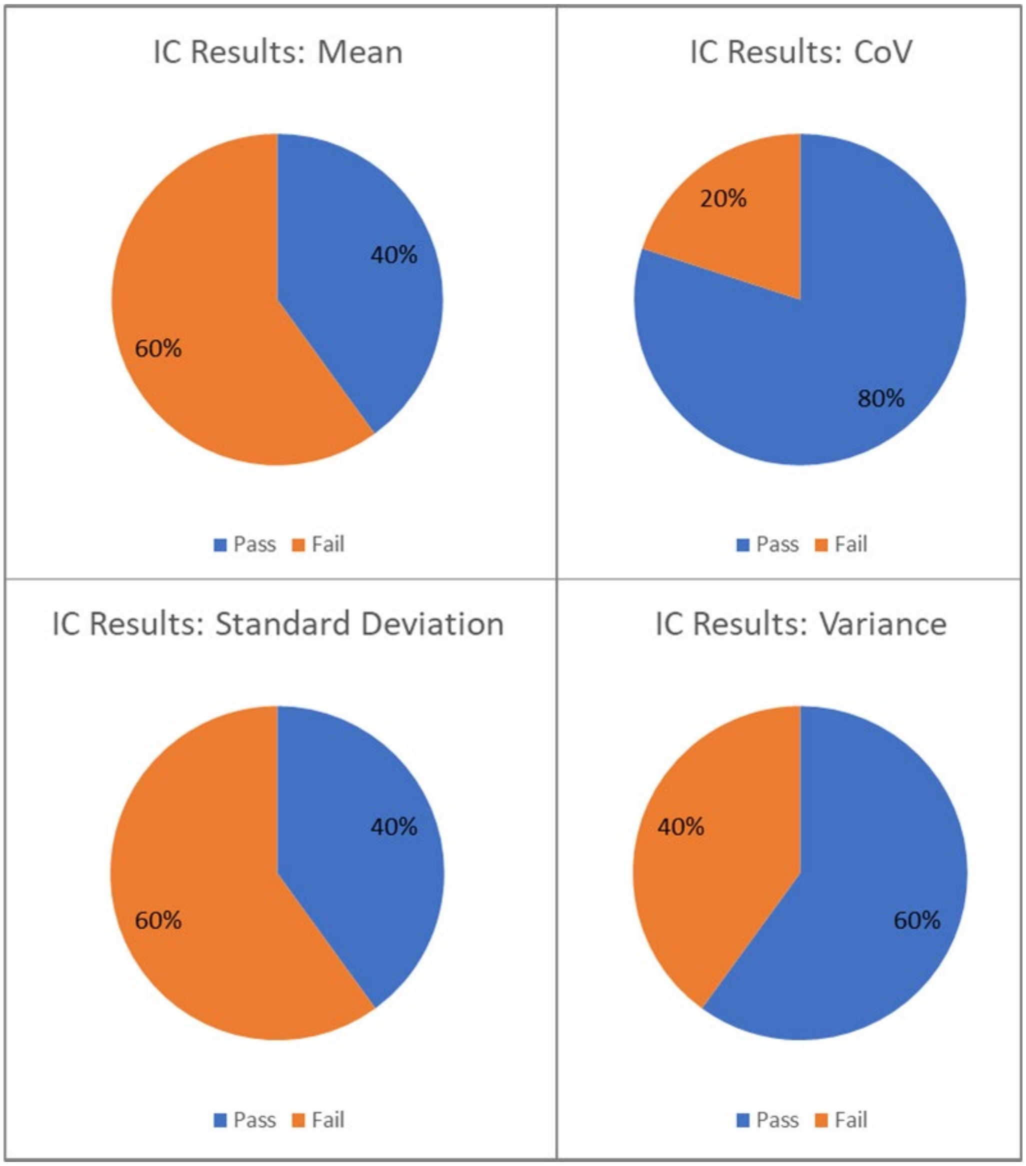


Figure 9. Chart. IC data validation results.

In cases where the validation could not be completed or did not have passing results, why was noted. These reasons are summarized in Figure 10.

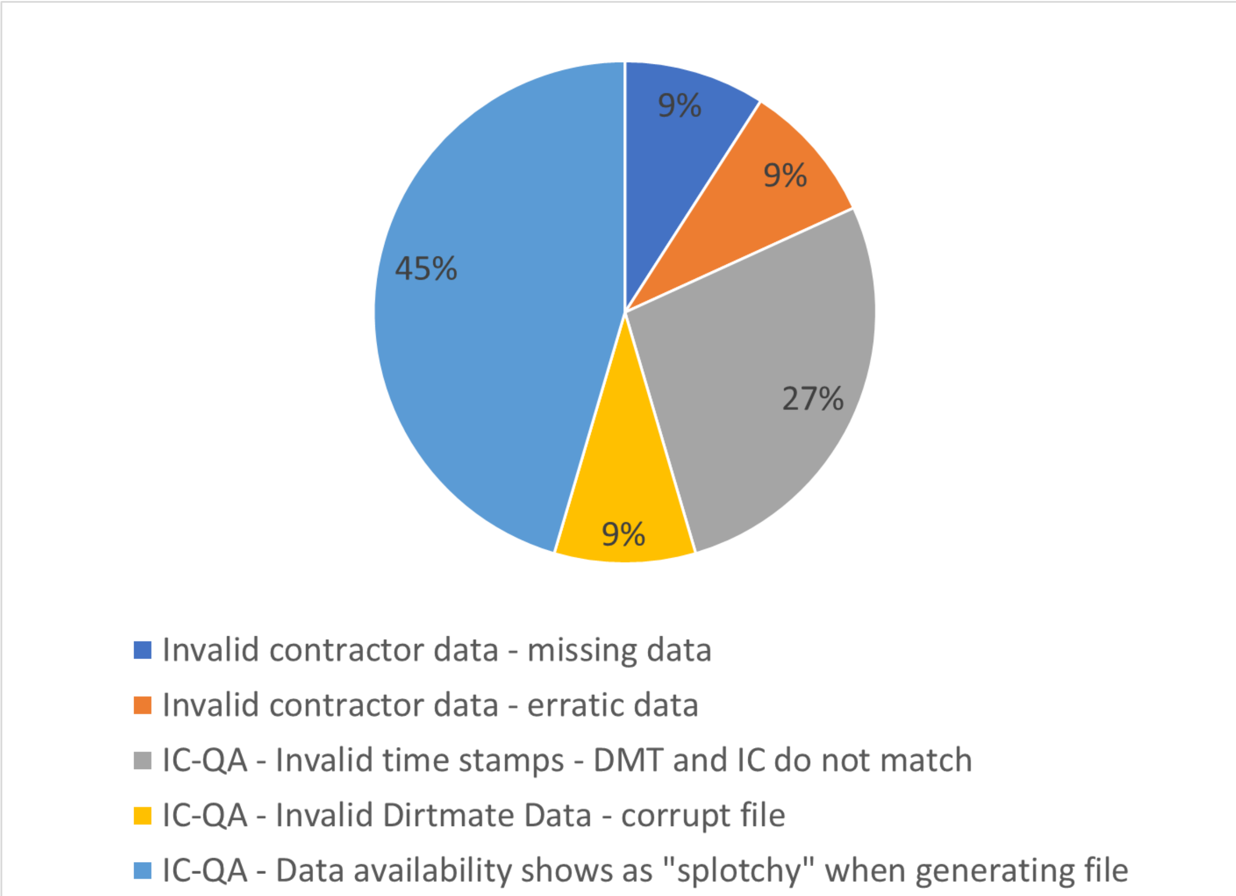


Figure 10. Chart. Reasons why IC validation could not be completed or did not get a "passing" result.

The most common issue with data that could not be analyzed or that did not have a passing result was missing verification data. Incomplete data was observed when generating the file, as shown in Figure 11. The discontinuous green bar indicates that data was not completely transmitted from the verification device using the daily use gateway (DUG) hotspot. Future devices from the equipment manufacturer have a built-in hotspot, which should mitigate some data transmission issues if the newer model is used. Note that although Figure 11 shows "Data Availability" at 100%; the green bar indicates missing data. The equipment vendor confirmed that the 100% was a software bug.

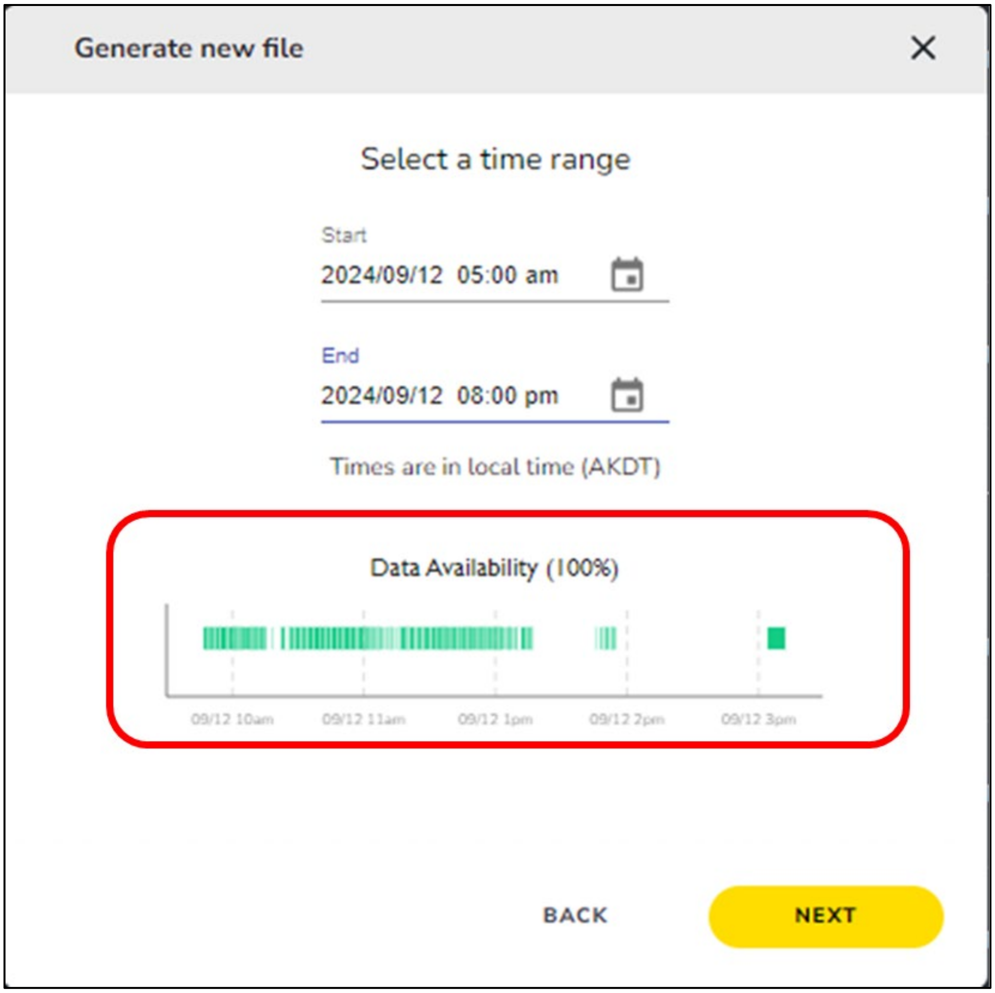


Figure 11. Image. The data availability bar is discontinuous, indicating missing verification data.

Several files showed inconsistencies with the verification device and contractor IC time stamps. The IC timestamps seemed valid based on the corresponding PMTP stamps. Therefore, it is assumed that the issue was with the verification device. This issue was reported to the verification device manufacturer but was not resolved.

Other issues were missing contractor data, invalid contractor data, or invalid or corrupt verification data. Some invalid or corrupt data files may have been due to the untimely generation of verification files. The verification files use post-processed kinematic (PPK) GNSS using the MoDOT virtual reference station (VRS) network. The VRS network only keeps the corrections for 30 days. Therefore, if the file is not generated within 30 days, the corrections are unavailable, and the file is invalid.

Overall, the validation process works well if valid data are collected and no issues with data transmission occur.

5.3.1.4 PMTP Results by Project

The PMTP data were evaluated according to MoDOT specification NJSP-18-10. Some ongoing projects used the new 406 specification, but only completed projects were included in this report. Thermal segregation was calculated according to AAHSTO R 110-22 using the DRS method. Price adjustments were calculated as follows:

- Each low segregation segment: $7 incentive.
- Each moderate segregation segment: No price adjustment.
- Each severe segregation segment: $7 disincentive.

A summary of the 2024 PMTP results by project is shown in Figure 12.

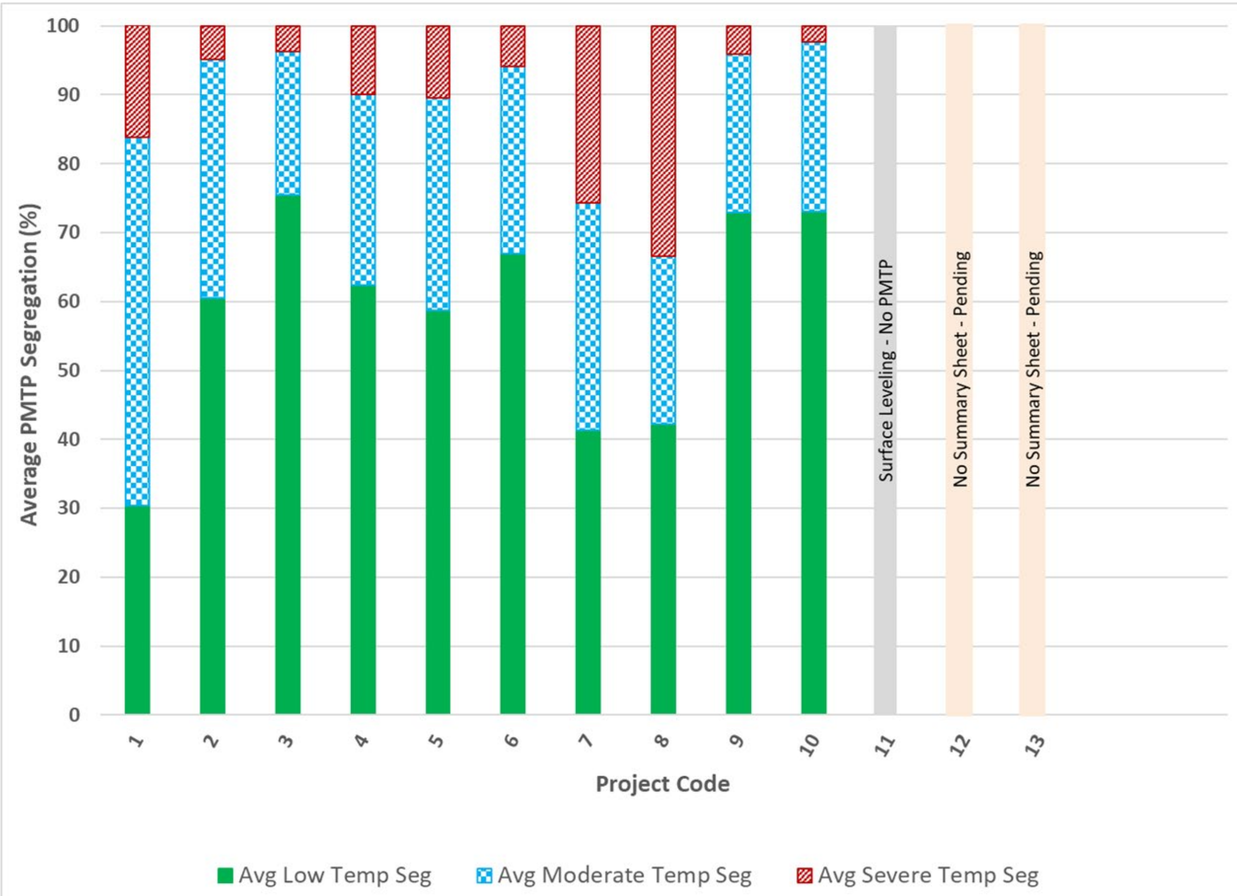


Figure 12. Chart. Thermal segregation results by project.

Several of the projects achieved less than 5 percent severe segregation on the project. These projects also had 70 percent of sublots classified as low segregation. Two projects had over 20 percent severe segregation. Upon further investigation, the same contractor completed project codes 7 and 8 (those with the highest severe segregation) (contractor code 8). Project code 8 had the most severe segregation. This project seemed to have some data issues, as shown in Figure 13. The data is "staggered" and seems to have a cold edge or ride bracket that was not removed from the data. More investigation is needed to determine the cause of the "staggered" data and the cause of the consistent low-temperature data. The equipment vendor was notified of these issues. Project code 7 did *not* display the same cold edge or ride bracket shown in Figure 13.

Figure 13. Image. Issues with PMTP data.

5.3.1.5 PMTP Results by Contractor

Figure 14 shows the average PMTP results for each contractor. Some contractors had multiple projects during the season, and some had just one.

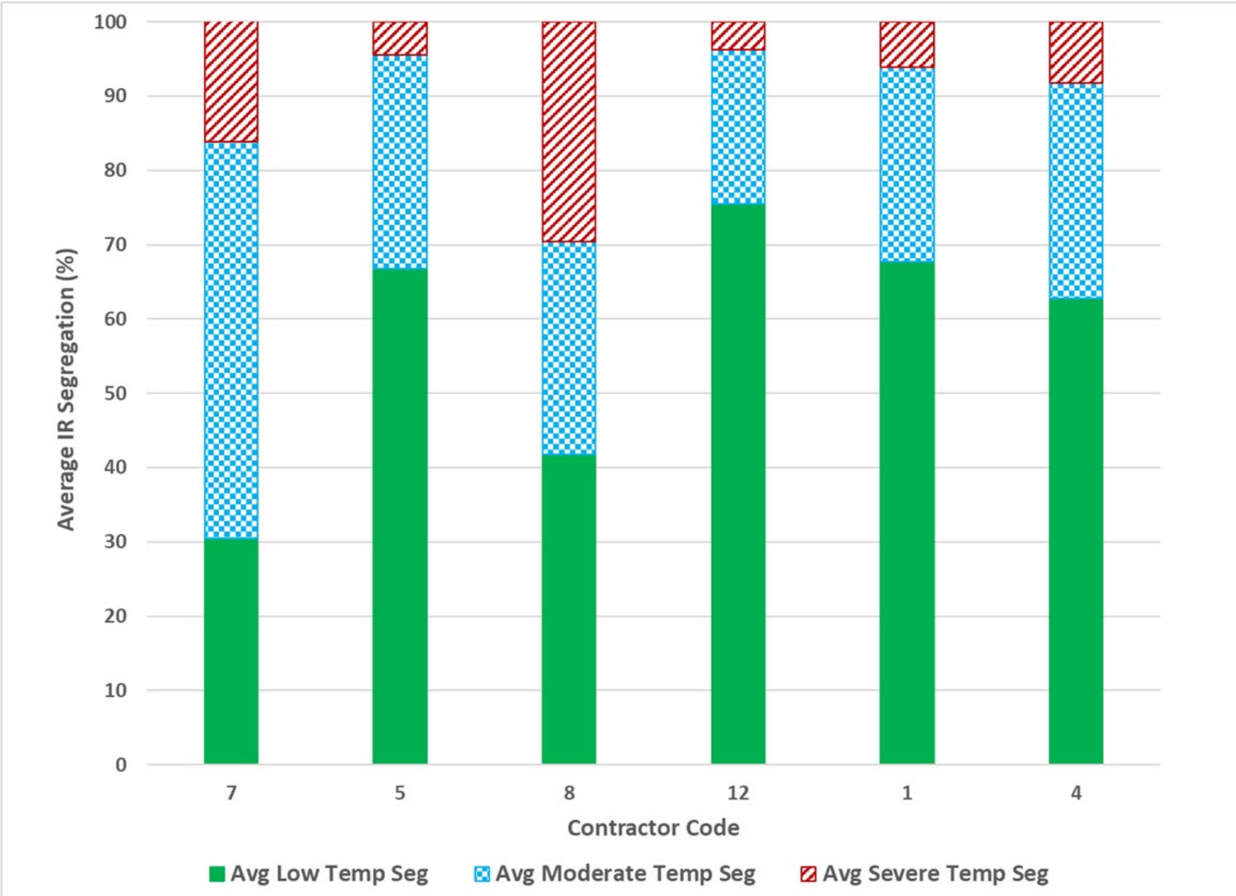


Figure 14. Chart. Thermal segregation results by the contractor.

Contractor code 8 had the highest amount of severe segregation (as mentioned in section 5.3.1.4). Contractor codes 5, 12, 1, and 4 had the highest percentages of low segregation and lowest percentages of severe segregation. Contractor code 7 had the highest percentage of moderate segregation.

5.3.1.6 PMTP Validation using MoDOT Verification Data

This section summarizes the results from the validation procedure using the PMTP temperature verification device. More information on the procedure can be found in the 2022 Implementation of Data QA for Innovative Technologies at MoDOT report (Chang et al.) and chapter 2. PMTP verification data was used to validate contractor data on six projects. More projects may have used a verification device, but the verification data (infrared photos) were not uploaded to SharePoint.

The pass and fail criteria were based on either mean temperature (allowable % difference of 0.06) or the PRS (allowable difference of 4 [reference chapter 2]). The PRS was developed later in the construction season and was only piloted for a few project files.

Sometimes, a verification infrared photo was generated, but the validation could not be completed due to one or more issues. The percent of the time that validation was completed is shown in Figure 15.

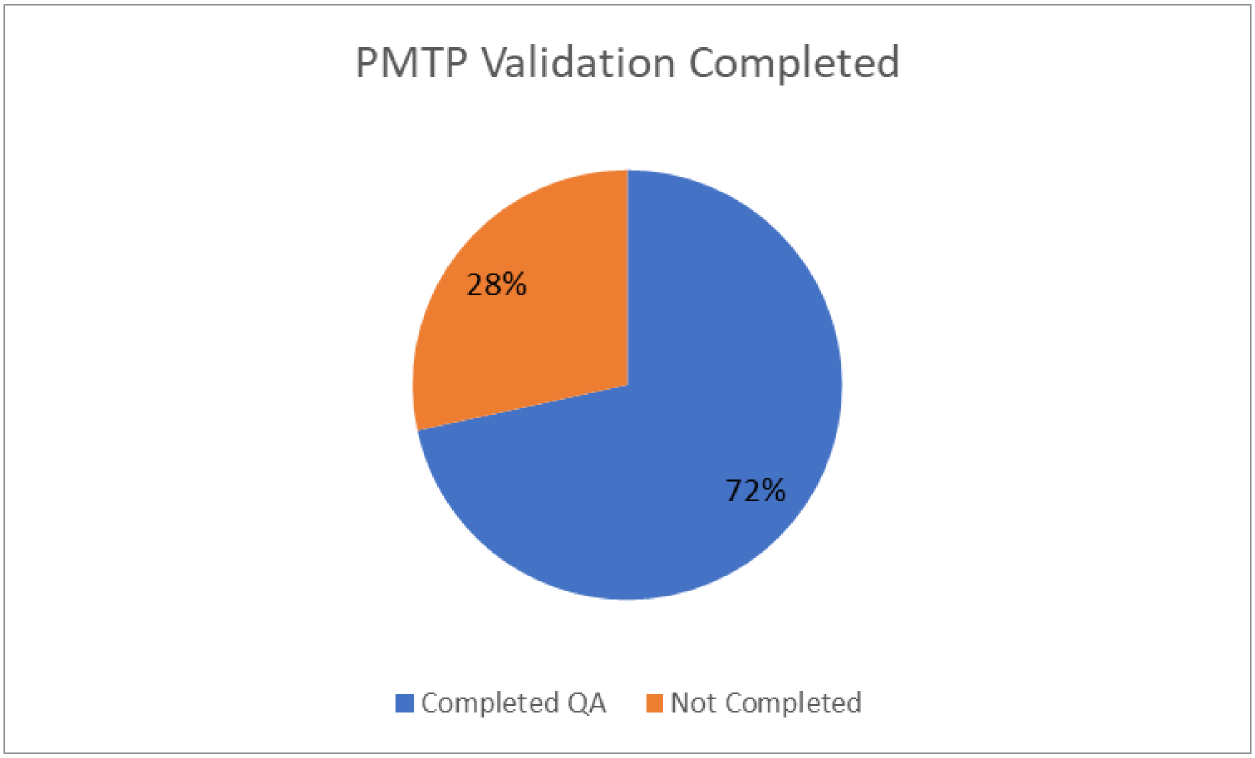


Figure 15. Chart. Percent of PMTP verification data where validation was completed.

The results of the validation that was completed are shown in Figure 16.

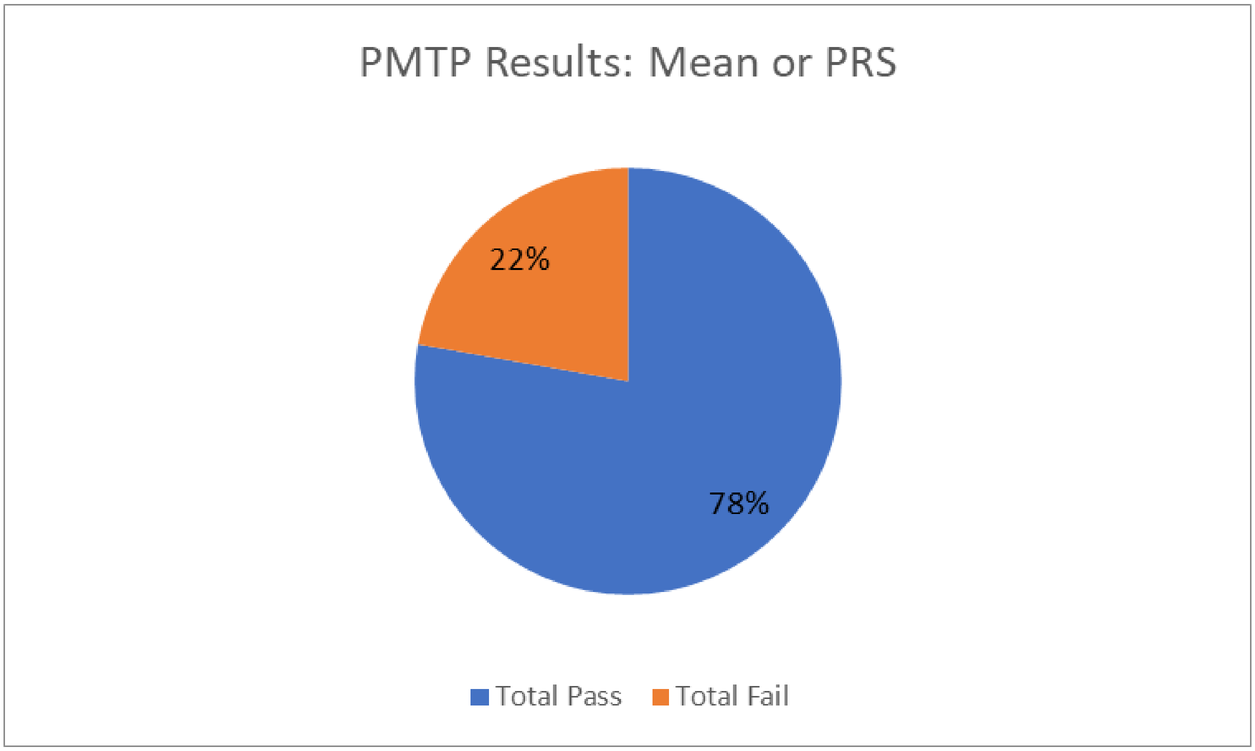


Figure 16. Chart. PMTP data validation results.

In cases where the validation could not be completed or did not have passing results, the reason why was noted. These reasons are summarized in Figure 17. Note that if the verification photo was invalid, it was not analyzed and is included in Figure 17. Overall, the quality of verification photos has improved over previous years.

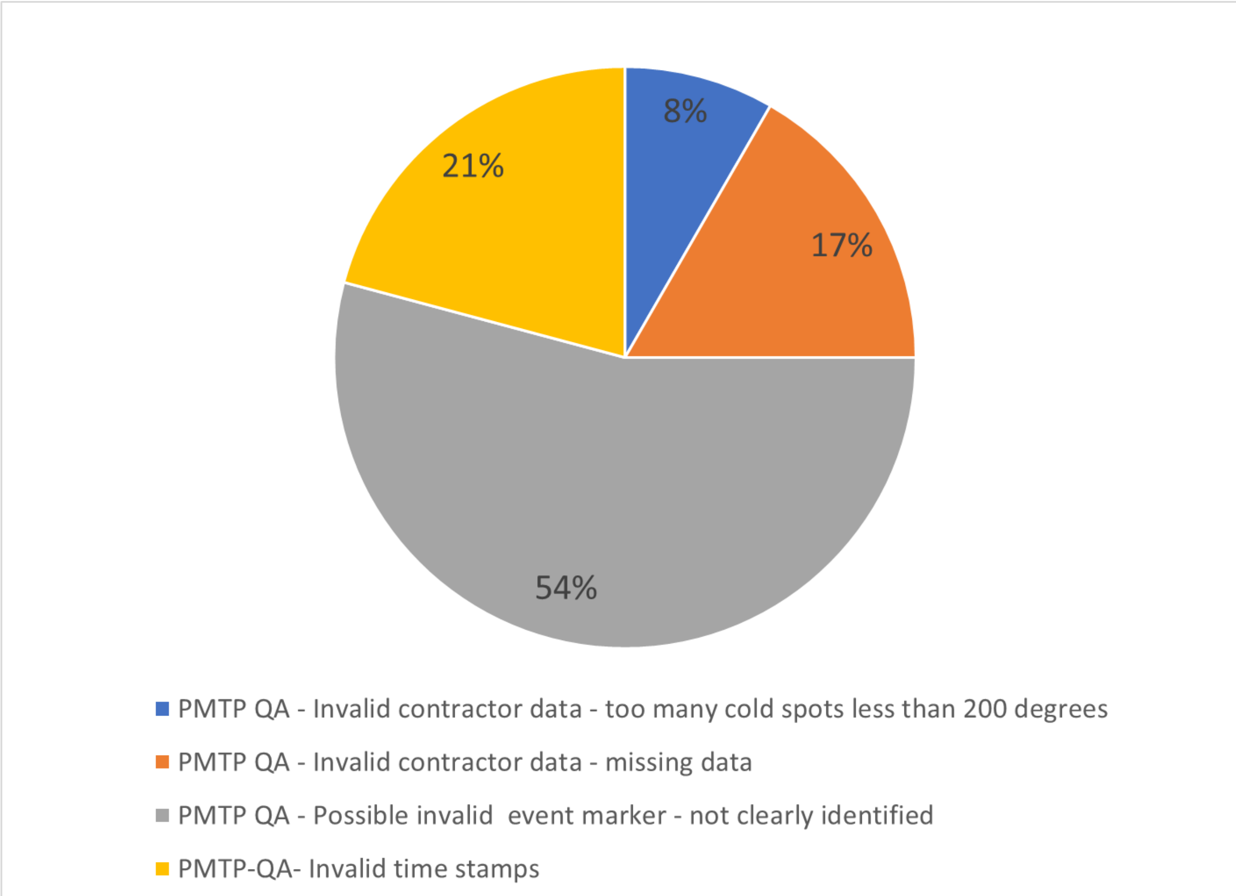


Figure 17. Chart. Reasons why PMTP validation could not be completed or did not get a "passing" result.

The most common issue was the correct placement of the event marker. The event marker must be placed within the field of view (FOV) of the contractor's PMTP equipment. There are two main reasons why an event marker is placed incorrectly, as follows (and illustrated in Figure 18):

- It is not close enough to the back of the paver to be collected (not in the "zone" in Figure 18).
- It is placed in a shoulder, and the contractor does not collect data in the shoulder.

Other common issues included missing contractor data, excessive cold spots, and invalid timestamps. When the timestamp of the verification device does not match the contractor's data timestamps, the event marker cannot be accurately located. Additionally, if project or contractor staff enter the PMTP

FOV during placement over the event marker, they appear in the data as cold spots. This creates ambiguity, as personnel and the event marker are recorded as cold spots and cannot be distinguished.

These issues will be addressed in the 2025 spring training workshops.

Source: Adapted from Wirtgen America

Figure 18. Illustration. Correct placement of the event marker.

5.3.2 2017 through 2024 Trends

Data from 2017 through 2024 were compiled to identify general trends.

5.3.2.1 IC Trends

The average IC percent coverage was averaged across all projects during each construction season. The average IC percent coverage trends are illustrated in Figure 19.

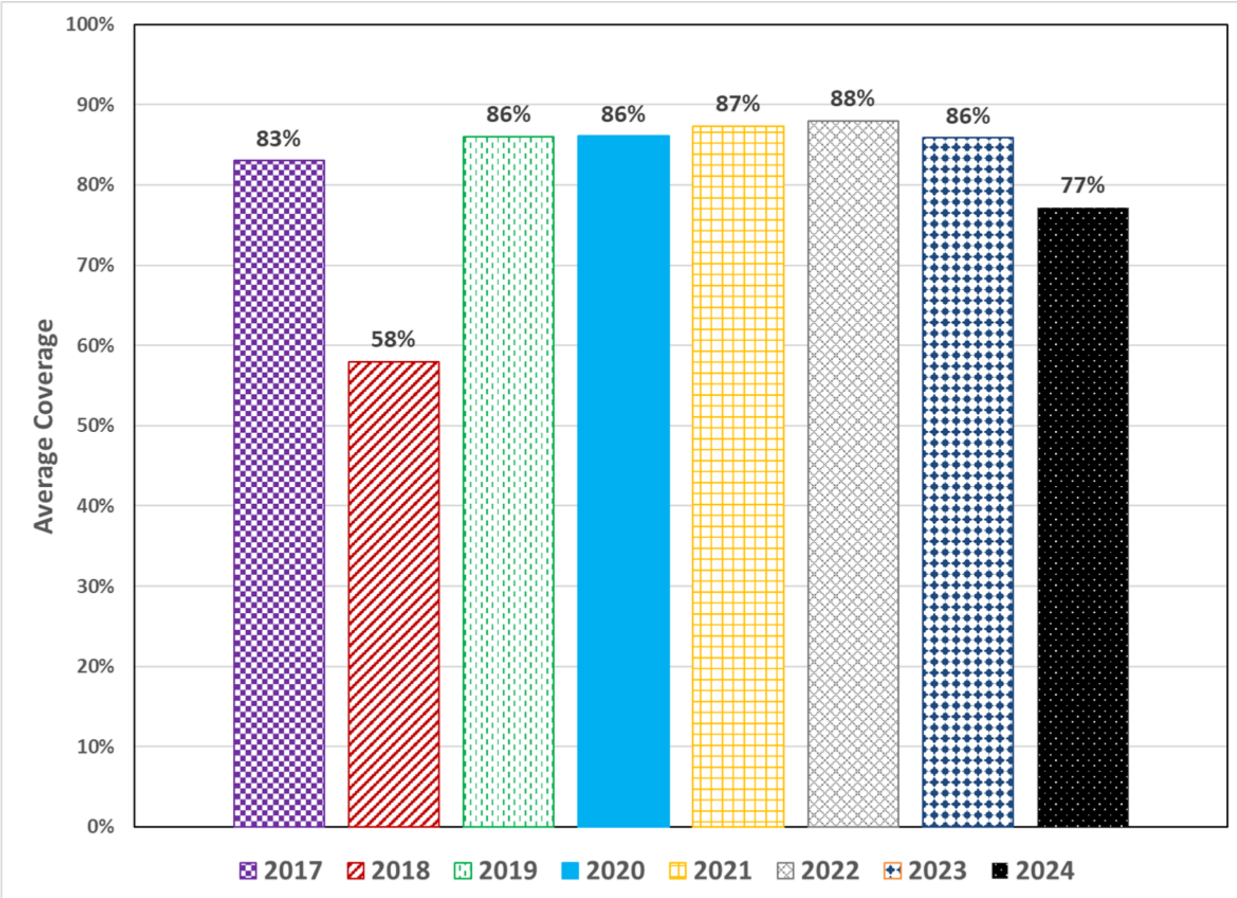


Figure 19 Chart. Average IC percent coverage for all projects per construction season.

General observations from Figure 19 include the following:

- The year 2018 shows an average percent coverage of 58%. The low IC coverage is attributed to the learning curve associated with the technology and specifications. Nearly every project had onsite support in 2017, and the onsite support in 2018 was significantly less. Therefore, most contractors used the technology without additional technical support. The consistently higher IC percent coverage in 2019 through 2023 indicates that many contractors may better understand and implement the IC technology.
- 2024 had a noticeable drop in IC coverage. The average coverage was approximately 10 percent lower than the past 5 years. Several projects had issues with data loss in 2024. Many of these projects reported the results and received the price disincentive. Some project summary sheets reported issues with data loss, while others did not. Future specifications that include preconstruction surveys of GNSS and cellular coverage may help mitigate issues with data loss. Equipment malfunction must be resolved with the help of equipment manufacturers.

The same IC data were analyzed for the percent of projects that met the 70 percent threshold (moderate: no incentive or disincentive) and the percent of projects that met the 90% threshold (passing: eligible for an incentive) illustrated in Figure 20.

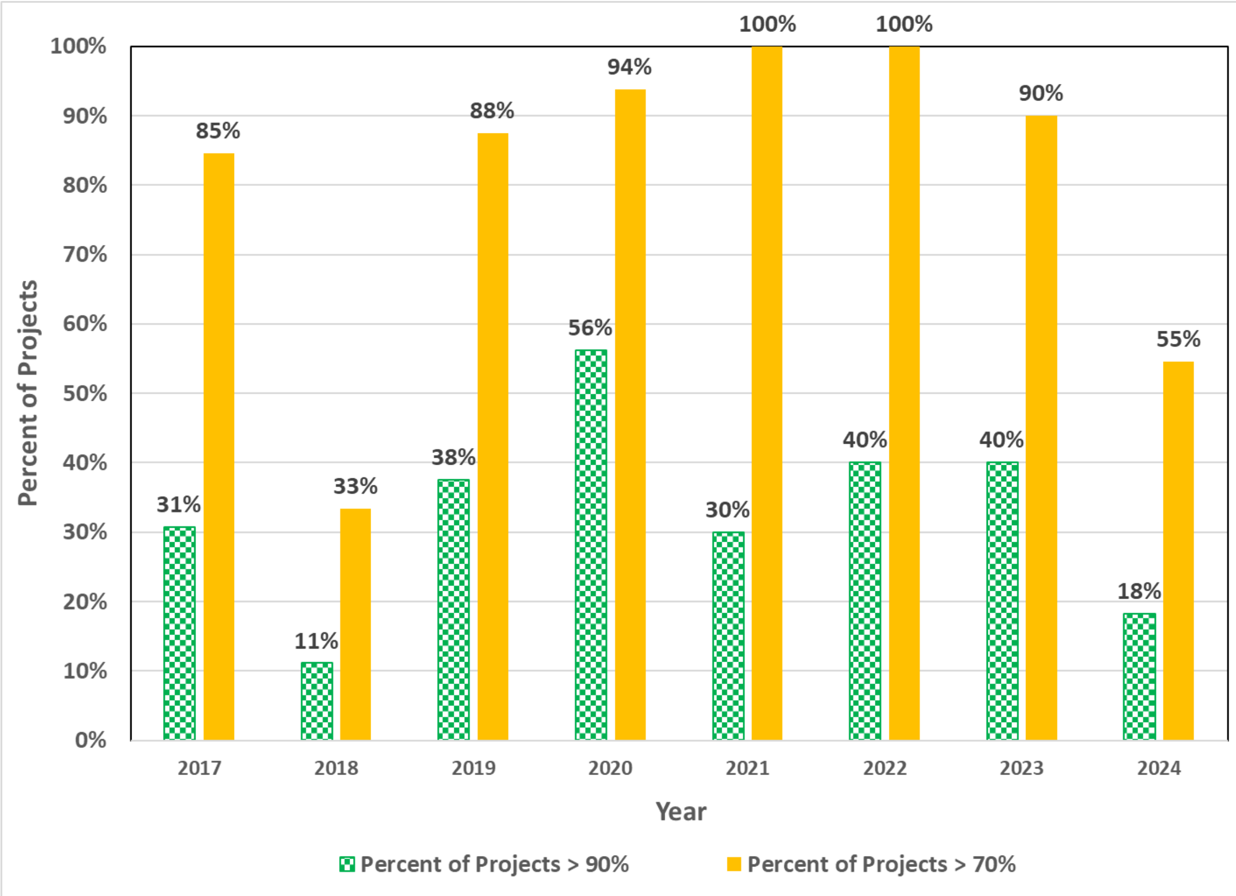


Figure 20. Chart. Percent of projects that meet the 70 percent and 90 percent thresholds per construction season.

The percentage of projects meeting the 70 and 90 percent thresholds decreased significantly in 2024. This is attributed to data loss. More investigation is required to determine whether the data loss is related to GNSS, cellular, or equipment malfunction.

5.3.2.2 PMTP Trends

The thermal segregation classifications were averaged across all projects during each construction season. The average PMTP segregation classifications are illustrated in Figure 21.

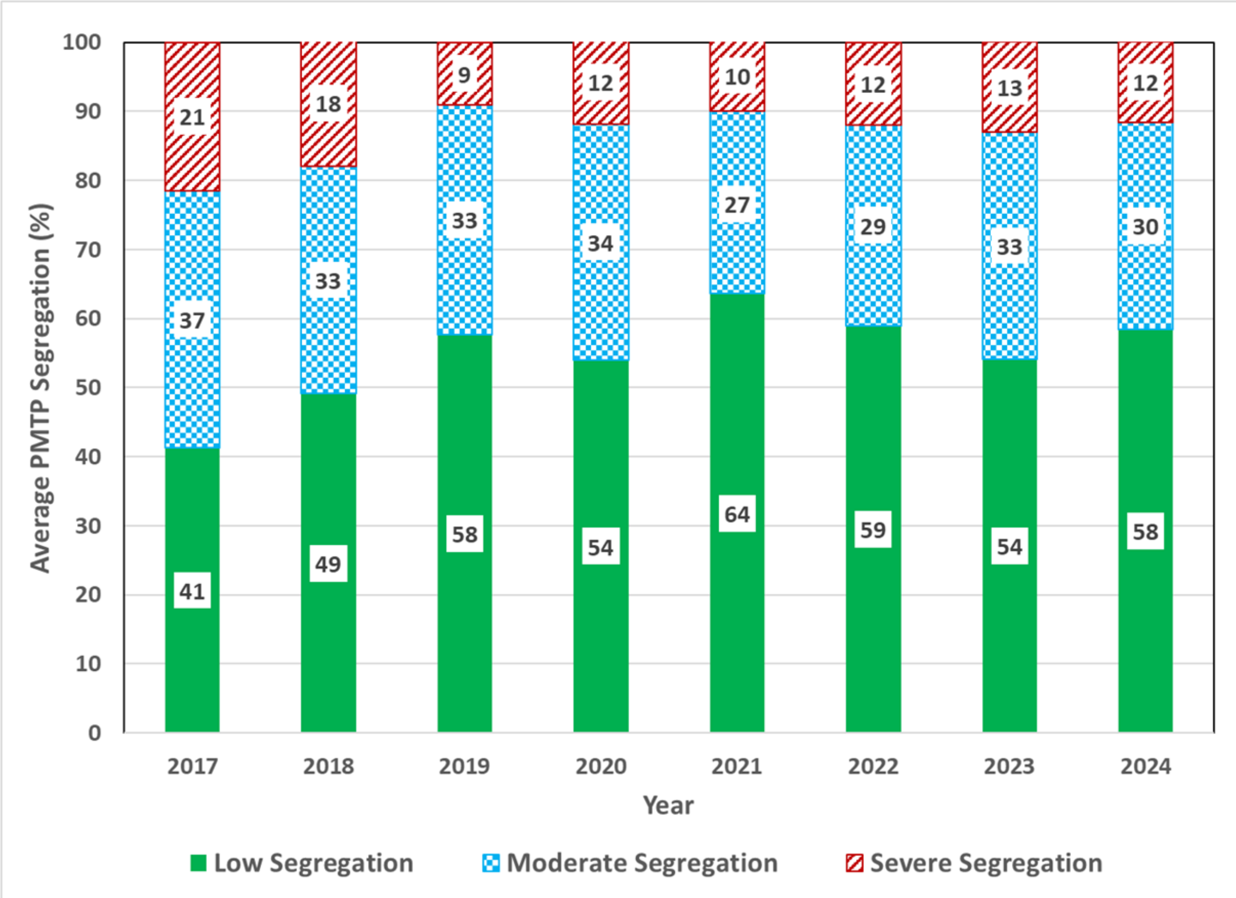


Figure 21. Chart. Average PMTP thermal segregation classification for all projects per construction season.

General observations from Figure 21 include the following:

- Low segregation (DRS < 25˚F) increases from 2017 to 2019. After 2019, the low segregation remains consistent, ranging from 9 to 13 percent.
- There was a slight decrease in moderate segregation (25.0˚F < DRS ≤ 50.0˚F) from 2017 to 2018. Since then, the moderate segregation ranges from 27 to 33.
- Severe segregation (DRS > 50.0˚F) decreases from 2017 to 2019. Severe segregation has remained lower compared to the initial years of implementation in 2017 and 2018.
- Overall, the PMTP data trend shows that this technology improved thermal segregation by promoting successful practices.

5.4 Summary

The strengths of the 2024 construction season are summarized as follows:

- PMTP thermal segregation trends show improvement with the technology since implementation.
- In general, most contractors follow intelligent construction protocols and data analysis.

The lessons learned and areas for improvement based on the data analysis results of the 2024 construction season are summarized as follows:

- Fewer REs submit their diaries and intelligent construction data checks to the intelligent construction SharePoint Site. It is recommended that REs begin uploading their diaries and data checks to SharePoint for successful data management.
- One project showed erroneous data collected on one of the roller temperature sensors. One project showed potential issues with the PMTP data. Equipment verification is important to ensure reliable data are collected. The MoDOT protocols require daily verification, which should be emphasized in future training sessions.
- There was an increase in data loss for IC data. This resulted in the lowest average IC coverage in the past 5 years.
- The data validation procedures work well but still have several common issues that will be emphasized during the spring 2025 training.

Although improved since implementation, consistency in data management, including naming conventions and folder management, by some contractors and MoDOT personnel requires further improvement. Data management should be emphasized during the 2025 construction season.

Chapter 6 Task 6 – Online Annual Feedback Meetings

The 2024 feedback meetings were held on December 17, 2024. Two meetings were held: an industry meeting (with contractors, equipment vendors, and MoDOT personnel) and an internal meeting with MoDOT personnel only.

6.1 Key Discussions

The key discussions during the meetings are summarized in the following sections.

6.1.1 Industry Meeting

6.1.1.1 Invalid Data

The issues related to invalid IC and PMTP data were shared. The equipment vendors requested more details on which projects and what equipment had issues so that they could be resolved in future seasons. This includes invalid temperature data, issues with PMTP data, and issues with missing data. The consultant will send specific issues will be sent to vendors for troubleshooting.

6.1.1.2 New Specifications

Several equipment vendors applauded the idea of a preconstruction investigation to determine GNSS and cellular coverage. This information is now part of the quality control plan for PMTP projects. The vendors did not see any issues with helping contractors to provide this information.

6.1.1.3 Innovative Paving Boundary Data Collection

One equipment vendor asked for information and experiences on the innovative paving boundary data collection. A few contractors shared positive experiences using LiDAR equipment to collect surface data that could be used to export an alignment file.

6.1.2 Internal Meeting

6.1.2.1 Contractor's Paving Boundary Data Manipulation

There was a discussion on ensuring no contractor's paving boundary data manipulation took place. The validation of the contractor's boundary data will be addressed in the spring 2025 training session.

6.1.2.2 Data Validation Procedures

There was some open discussion from MoDOT project staff on successful practices for transmitting the IC verification data using the DUG. One comment was that the new MoDOT pickup trucks had no magnetic location to mount the DUG. A solution was to create a hitch mount plate to place it.

6.2 Summary

The 2024 feedback meetings, held on December 17, included an industry meeting with contractors, vendors, and MoDOT personnel and an internal MoDOT-only meeting. During the industry meeting, vendors requested details on specific projects with invalid IC and PMTP data to troubleshoot issues and supported preconstruction investigations for GNSS and cellular coverage as part of quality control plans. Positive feedback was shared about using LiDAR for boundary collection. The internal meeting focused on preventing contractors from manipulation of paving boundary data, with validation procedures to be addressed in spring 2025 training. MoDOT staff also discussed solutions for mounting DUGs in new trucks.

Chapter 7 Task 8 – Data QA Equipment

This task was to supply IC pass count and PMTP temperature data verification equipment for MoDOT in the 2024-2025 seasons and beyond. The equipment purchased under this project is as follows:

- Five subscriptions were purchased for the IC pass count verification devices.
- Eight infrared cameras with National Institute of Standards and Technology (NIST) calibration for PMTP verification data.

More details on the data verification procedures and equipment are covered in the final report from the companion project, Implementation of Data QA for Innovative Technologies at MoDOT (Chang et al., 2022).

Chapter 8 Conclusions and Recommendations

The 2024 MoDOT IC-PMTP Annual Report outlines the achievements, challenges, and lessons learned from implementing Intelligent Compaction (IC) and Paver-Mounted Thermal Profiling (PMTP) technologies in construction projects. Project tasks included updating data validation tools, enhancing training programs, providing remote project support, and hosting annual feedback meetings.

The project summary sheet and data QA independent validation tools were updated to align with new PMTP specifications. Key updates included revised thermal segregation classifications and price adjustments, reflected in macro-enabled spreadsheets. Validation tools were enhanced to address FHWA recommendations, incorporating “pseudo” range statistics (PRS) for thermal data and gridding techniques to improve sample size alignment between contractor and verification data. The validation tools were summarized in a report that was published and presented at TRBAM 2025.

The 2024 training program focused on statewide workshops and Train-the-Trainers (TTT) sessions, all conducted online. Materials were updated to reflect new PMTP specifications and included guides for transitioning between “old” and “new” specifications. Recorded sessions provided ongoing support, especially for contractors experiencing staff turnover. The training emphasized data validation, IC-PMTP analysis, and updated tools, laying the groundwork for expanded focus areas in 2025.

Remote support addressed common challenges, including data loss, transitioning specifications, and new employee training. Sessions also resolved software compatibility issues affecting validation tools and identified contractor’s paving boundary manipulation.

Analysis of 2024 data showed mixed results. PMTP trends revealed improved thermal segregation, with many projects achieving low levels of severe segregation. However, IC coverage dropped by 10%, primarily due to data loss. Independent validation tools worked well when data were complete, but issues like mismatched timestamps and event marker placement affected results. Persistent challenges included incomplete data submissions, underscoring the need for continuous training.

Feedback meetings emphasized the importance of preconstruction investigations to assess GNSS and cellular coverage and the need for stricter validation of contractor boundaries to prevent manipulation. Positive feedback highlighted the potential of using LiDAR for more precise paving boundary collection and alignment file generation. These insights informed the focus areas for 2025 training, which will include:

- Identifying and addressing contractor’s paving boundary data manipulation.
- Completing data validation using updated tools.
- Emphasis on daily equipment verification protocols to prevent issues with poor quality data.
- Guidance applying “old” versus “new” PMTP specifications during the transition period.
- Training on GNSS and cellular preconstruction surveys.

The 2025 season aims to build on the successes of 2024 while addressing the challenges that emerged to ensure continued improvement in the IC-PMTP program.

Chapter 9 References

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AASHTO (2022) R 111-22: Standard Practice for Intelligent Compaction Technology for Embankment and Asphalt Pavement Applications, Washington DC.

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