TPF-5(299)
Contract DTFH6117C00009
Calibration, Certification, and Verification of Transverse Pavement Profile Measurements
Pooled Fund Project Review
November 17, 2017
Golden, Colorado
Outline

Phase I Results
- Background & Review Technical Approach
- Data Requirements

Phase II Status
- Plan and Deliverables moving forward
- Discussion and Other items
Background

Ultimate Objective

*Enable transportation agencies to specify, monitor, and evaluate pavement testing programs that include transverse pavement profiles*

Scope

Develop methods to assess the precision and accuracy of Transverse Pavement Profilers (TPP) measurement systems and components that are traceable, objective, practical, transparent (without commercial bias) and consistent with AASHTO (PP 70 and PP 69).
Technical Approach

Objective
Match TPP capabilities with the application requirements

Approach
• Develop two assessment statements
  • Consistent format for efficient comparison

• Each Statement contains
  • Clear and Standardized Test Conditions
  • Clear Analysis Methods that define accuracy and precision
Technical Approach

Capability Statement (CS) for TPP

- Specific Transverse Pavement Profiler (TPP)
- Under an array of test conditions
  - Well-defined in Test Standards
    - Transparent and Objective
    - Vetted by expert peers in the community
    - New or existing AASHTO standard(s)
    - Standards developed and maintained by other organizations (ISO, NIST, ASTM…)
- Adapt to new technologies and wisdom gained through experience with these standards
- Emulate real roadway experience as closely as possible.
Technical Approach

Capability Statement (CS) for TPP

• High-Level Summary

<table>
<thead>
<tr>
<th>Test Standard</th>
<th>Accuracy and Precision</th>
<th>Graphical Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90%</td>
<td>50%</td>
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<tr>
<td>AASHTO 1234</td>
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<td>-1.27</td>
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<td>-0.10</td>
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</table>
Technical Approach

Requirements Statement (RS) for Data Requirements

- Specific to Data Requirement (Rut depth…)
- Standard test conditions
- High-Level Summary

<table>
<thead>
<tr>
<th>Test Standard</th>
<th>Accuracy and Precision</th>
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<tbody>
<tr>
<td></td>
<td>Lower Bounds (mm)</td>
<td>Bias</td>
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<td>NIST 543</td>
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<tr>
<td>TPF-5(299) Linearity Test, ver. 4</td>
<td>N/A</td>
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Technical Approach - RFP Attachment

- **A**: Sensor Requirements (e.g., laser specifications)
- **B**: Data Acquisition (e.g., raw sensor data)
- **C**: Data Analysis (e.g., filtering, smoothing)
- **D**: Data Interpretation (e.g., quarter-car simulation)

Requirements Definition

Calibration / Verification in Different Phases of Process
Technical Approach

Test Standards - Ground Truth & Chain of Traceability

*Ground Truth known to some accuracy and precision!
Technical Approach

Assessment*

Guiding Principle

The accuracy/precision with which a Transverse Pavement Profiler (TPP) is assessed cannot be determined to a finer degree than the least accurate/precise link in the chain of traceability.
Technical Approach

Ensuring Transparency, Independence, and Fairness

- No *direct* assessment of the proprietary methods
- Prescribe test conditions (the *what*), not process (the *how*
- Assessments have known inputs and outputs (with traceable accuracy) and prescribed test conditions.
Technical Approach

Object → Certified Lab → Calibration Object → Sensor → System → Process → Use

Known Input → Prop. Process → Output

Known Output → Assess → Capability

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Technical Approach - Capability Statement

- **Sensor**: Verification Tests
- **System**: Original Profile
- **Process**: Processed Profile
- **Use**: Data Requirement

<table>
<thead>
<tr>
<th>Accuracy and Precision</th>
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System Specifications

- Data Requirement Calculations
- Data Analysis (e.g., filtering, smoothing)
- Signal Processing
  - Filtering
  - Lateral Shift...
- Data Acquisition (e.g., raw sensor data)
- Test Conditions
  - Calibration Surface
  - Excitation
  - Speed...
- Sensor Requirements (e.g., laser specifications)

Verification Tests
- Ensure System Spec's. are met

Accuracy and Precision

Vehicle Terrain Performance Laboratory (VTPL)

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Vehicle Terrain Performance Laboratory (VTPL)

Original Profile

Vehicle terrain performance.

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Vehicle Terrain Performance Laboratory (VTPL)

Vehicle terrain performance.

Processed Profile

Data Requirement Calculations - Calculate Rut Depth, Cross-slope...

Data Interpretation (e.g. quarter-car simulation)

Data Analysis (e.g. filtering, smoothing)

Signal Processing - Filtering - Lateral Shift ...

Data Acquisition (e.g. raw sensor data)

Test Conditions - Calibration Surface - Excitation - Speed ...

Sensor Requirements (e.g. laser specifications)

Original Transverse Profile Assessment - Unfiltered Profile

Verified Transverse Profile Assessment - Filtered Profile

Accuracy and Precision

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Vehicle Terrain Performance Laboratory (VTPL)

Use

Data Requirement Calculations
- Calculate Rut Depth, Cross-slope...

Data Interpretation (e.g. quarter-car simulation)

Data Analysis (e.g. filtering, smoothing)

Signal Processing
- Filtering
- Lateral Shift ...

Data Acquisition (e.g. raw sensor data)

Test Conditions
- Calibration Surface
- Excitation
- Speed ...

Sensor Requirements (e.g. laser specifications)

Original Transverse Profile Assessment
- Unfiltered Profile

Processed Transverse Profile Assessment
- Filtered Profile

Verification Tests
- Ensure System Spec’s. are met

Accuracy and Precision

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Data Requirements (Use)

Available Information

- Agencies
  - 16 TPF-5(299) participating agencies
  - the Illinois Tollway
  - Australia, the United Kingdom, and New Zealand.

- Summary
  - 9 agencies have a contractor collecting the data
  - 7 agencies collect data with agency personnel
  - 3 agencies use both (contractor and agency personnel).
  - The majority of data collection (13 agencies) is being done with 3D technology.
  - 5 agencies use the scanning laser rut bar.
Data Requirements (Use)

Available Information

- HPMS requires
  - Rutting - Full Extent, item 50, Metadata
  - Faulting* - Full Extent, item 51, Metadata
  - Cracking Percent* - Full Extent, item 52, Metadata
  - IRI* - Full Extent item (item 47), in the Metadata
  - Pavement Serviceability Rating* - Full Extent, item 48
    - Speed < 40 MPH, PSR can replace IRI.
  - Curve Classification* - SP item 43
  - Grade Classification* - SP item 45

* require auxiliary measures or are traditionally acquired through longitudinal profiling
Data Requirements (Use)

- Final Set of Data Requirements
  - Rut Depth (Network and Project Level)
  - Curb / Edge Detection (Network and Project Level)
  - Cross Slope (Network and Project Level)

- Possible Future Data Requirements
  - Rut Width and Rut Area
  - Lane Markers and Rumble Strips
  - Lane Width
Rut Depth Specifications

Requirements Definition

1. Data Requirement Calculations - Calculate Rut Depth, Cross-slope...
2. Data Interpretation (e.g. quarter-car simulation)
3. Data Analysis (e.g. filtering, smoothing)
4. Data Acquisition (e.g. raw sensor data)
5. Test Conditions - Calibration Surface - Excitation Speed...
6. Sensor Requirements (e.g. laser specifications)
7. System Specifications - Transverse Resolution - Transverse Width...

Process Flow

Assessment:
- Data Requirement Assessment - Accuracy & Precision
- Processed Transverse Profile Assessment - Filtered Profile
- Original Transverse Profile Assessment - Unfiltered Profile
- Verification Tests - Ensure System Spec’s. are met
Rut Depth Specifications

- Longitudinal Resolution (Network): 3.0 m (maximum)
- Longitudinal Resolution (Project): 0.5 m (maximum)
- Transverse Resolution: 10 mm (maximum)
- Transverse Measurement Width: 4.0 m (minimum)
- Transverse Positioning: +/- 25 mm (maximum)
- Vertical Resolution: 0.1 mm (maximum)

1 Specifications required before accuracy and precision can be established
2 Resolution limits statements of accuracy and precision
Resolution

Prec (std dev): 0.010
Resolution: 0.010

Prec (std dev): 0.010
Resolution: 0.001
Rut Depth Specifications\textsuperscript{1}

Vertical Resolution (maximum): 0.1 mm

\begin{itemize}
  \item The UK (Sec 3.9.2): 0.1 mm
  \item Australian AGAM-T009-16, Sec 8: 0.1 mm
  \item AASHTO PP-70 (Sec 5.2): 1 mm
  \item HPMS reporting to nearest 0.1” 2.5 mm
\end{itemize}

\item Vendor published specs range widely
Rut Depth Specifications

Transverse Resolution: 10 mm (max)
Rut Depth Specifications

Transverse Positioning: +/- 25 mm (max)

<table>
<thead>
<tr>
<th>Profile #</th>
<th>Severity Level</th>
<th>Ground Truth</th>
<th>Absolute Error</th>
<th>Relative Error</th>
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### Plan and Deliverables

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**Phase I**
- Task 1
- Task 3
- Task 4
- Phase I Final Report
- Task 5

**Phase II**
- Task 2
- Task 6
- Phase II Final Report
- Task 7
- GRAs
- Quarterly Reports Due
- VTTI

**Phase III**
- AASHTO Standards

**Task 7**
- GRAs

**Academic Year**
- GRAs
- Quarterly Reports Due
- VTTI

**Academic Year**
- GRAs
The Vehicle Terrain Performance Laboratory Transverse Pavement Profiler (VTPL TPP) is *not* assumed to be the “golden” TPP.
Outline

Phase I Results
- Background & Review Technical Approach
- Data Requirements

Phase II Status
- Plan and Deliverables moving forward
- Discussion and Other items

Questions?

Thank you!