AASHTO Subcommittee on Materials and Pavements
103rd Annual Meeting
Phoenix, AZ

Technical Section 5a
Pavement Measurement
Annual Meeting

11:30 am PST, August 7, 2017

Annual Meeting Agenda

I. Call to Order and Opening Remarks
   A. Call to Order –?? am

II. Roll Call
   A. Introduction of members and guests
      i. Self-introductions of all meeting attendees. Voting members present ??, and total present ?? (quorum = members present at TS meeting) TS 5a has 21 voting members.
   B. Prospective new members and changes in membership
      i. Greg, Stellmach, OR DOT is Chair, Scott George, AL DOT, is Vice Chair; AASHTO liaisons: Evan Rothblatt and Tracy Barnhart.
      ii. Any new members – Friends of Committee (can include industry and academia) – request Chair to become Friend of Committee and reason why.
   C. Standard Stewards (Appendix C)

III. Approve August 2016 Technical Section annual meeting minutes:
    Motion by – Second by -
    Vote for - Vote against -

IV. Old Business

   A. 2016 SOM Ballot Items

<table>
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<tr>
<th>Ballot Name:</th>
<th>SOM 2016 Ballot</th>
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<tbody>
<tr>
<td><strong>Ballot Number</strong></td>
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<tr>
<td>Ballot Start Date:</td>
<td>10/2016</td>
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<tr>
<td>Ballot Due Date:</td>
<td>11/2016</td>
</tr>
<tr>
<td><strong>Item Number</strong></td>
<td>30</td>
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<tr>
<td>Description</td>
<td>Concurrent ballot item to revise M 331, Smoothness of Pavement in Weigh-in-Motion Systems. See Appendix D of meeting minutes.</td>
</tr>
<tr>
<td><strong>Affirmative 43/51. Negative 0/51. No Vote 8/51.</strong></td>
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<tr>
<td>Virginia Department of Transportation (Charles A. Babish) (<a href="mailto:andy.babish@vdot.virginia.gov">andy.babish@vdot.virginia.gov</a>)</td>
<td>Section 4.1.4 - should this be &quot;every two years&quot;, not &quot;each&quot;? <strong>Response: change made</strong> Sections 4.4.2 and 5.3.2 contain redundant language. It's not wrong, just repetitive. <strong>Response: no change, sections 4 and 5 are separate test</strong></td>
</tr>
</tbody>
</table>
Section 4.1.4 – The revision in the second sentence changes profile collection frequency from every year to every two years. I agree with the comment and proposed revision although one could make the case that two years might still be excessive. Also, the word ‘each’ should be removed in the second sentence and the first sentence should be revised to reflect verification every two years and not annually.

**Response:** change made to “every two”

Affirmative with an editorial comment: 1) Seems inconsistent to say in Section 4.1.2 that each WIM scale location should not exceed the value shown (i.e. Type I WIM 84.8 in./mile & Type II WIM 117.9 in./mile) and then provide a range in Section 4.5 where the ‘Lower’ threshold value listed is the maximum value allowed in Section 4.1.2 with the ‘Upper’ threshold value being a little over double the ‘Lower’ threshold value.

**Response – No change, the criteria in section 4.1.2 is used to select pavement sections to install a WIM while section 4.5 is the criteria to check an installed WIM location.**

In 4.1.4, revise from "each two years" to "every two years".

**Response: change made**

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<tr>
<th>Item Number</th>
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<tbody>
<tr>
<td>31</td>
<td>Concurrent ballot item to revise R 36, Evaluating Faulting of Concrete Pavements, by changing &quot;should&quot; to &quot;shall&quot; in sections 5.2.4 and 5.2.5.</td>
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**Affirmative 43/51. Negative 0/51. No Vote 8/51.**

No comments

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**B. Technical Section letter ballot**

**Ballot Name:** TS 5a Reconfirmation Ballot 2016

**Ballot Number** SOM_TS5A-16-01

**Ballot Start Date:** 11/10/2016

**Ballot Due Date:** 12/9/2016

**Item No.** 1

**Description** Reconfirmation ballot for AASHTO PP 67: Quantifying Cracks in Asphalt Pavement Surfaces from Collected Images Utilizing Automated Methods

**Affirmative 19/21, Negative 0/21, No Vote 2/21**

**Item No.** 2

**Description** Reconfirmation ballot for AASHTO PP 68: Collecting Images of Pavement Surfaces for Distress Detection

**Affirmative 19/21, Negative 0/21, No Vote 2/21**

**Illinois Department of Transportation (LaDonna.Rowden@illinois.gov)**

Is this intended for asphalt pavements only? The keyword list (Section 7.1) only includes "asphalt pavement surface". I believe the keyword "concrete
<table>
<thead>
<tr>
<th>Item No.</th>
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<tbody>
<tr>
<td>3</td>
<td>Reconfirmation for AASHTO PP 69: Determining Pavement Deformation Parameters and Cross Slope from Collected Transverse Profiles</td>
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</tbody>
</table>

Is this intended for asphalt pavements only? The keyword list (Section 10.1) includes "asphalt pavement surface". I believe the keyword "concrete pavement surface" should be added because the definition of "rut" would also include deformations in a concrete surface due to chains and/or studded tires. **Response: Agree will add concrete pavement surface to Keywords.**

<table>
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<th>Item No.</th>
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<tr>
<td>4</td>
<td>Reconfirmation for AASHTO PP 70: Collecting the Transverse Pavement Profile</td>
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<tr>
<td>5</td>
<td>Reconfirmation for AASHTO R 20: Procedures for Measuring Highway Noise</td>
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<td>6</td>
<td>Reconfirmation for AASHTO R 43: Quantifying Roughness of Pavements</td>
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<tr>
<td>7</td>
<td>Reconfirmation for AASHTO T 278: Surface Frictional Properties Using the British Pendulum Tester</td>
</tr>
</tbody>
</table>

C. Task Force Reports – none

V. New Business

A. AMRL/CCRL Issues – none

B. Research - Submit any proposals to Curt Turgeon, MN, TS 5a Research Coordinator.
   i. NCHRP update - In 2017 NCHRP approved $600k in funding for the RNS submitted “Calibration and Verification of Pavement Surface Images”. NCHRP has several projects ongoing that are expected to impact TS 5a on macrotexture, cracking, and rutting measurement.
ii. Any proposed NCHRP – International or Domestic Scans, NCHRP problem statements, NCHRP Synthesis Studies and 20-7 projects?

iii. Proposed RNS – Enhancement of Jointed Concrete Pavement Faulting Collection and Analysis Standards (attached)

C. Correspondence, calls, meetings/ Presentation by Industry – none


E. Proposed New Task Forces – none

F. Standards Requiring Reconfirmation – TPF-5(299) recommends reconfirm and adopt as full standards PP 67, PP 68, PP 69, and PP 70 and add “concrete pavement surface” to the Keyword sections of PP 68 and PP 69. Reconfirm with no changes: R 37, R 40, R 54, R 56, R 57, M 328, and T 317. Reconfirm with minor changes and remain provisional standard TP 98 and TP 99. Reconfirm with minor changes to remain compatible with ASTM standards M 261, M 286, T 242, and T 279. TPF-5(299) recommends sunsetting R 48 Rut Depth (5 point) and R 55 Cracking as PP 67-70 are improvements and written to incorporate advancements that are currently ongoing in several research projects.

*Discussion on R 48 and R 55 sunset recommendation: Four years ago discussion on sunsetting these standards occurred (including a survey of AASHTO Materials - 28 responses received; survey results were about 3 to 1 in favor of sunsetting) – decision was to keep without modification or updating and visit sunset issue again in four years. R 48 and R 55 have major precision and bias issues that are recognized, but have not been objectively quantified. The issue of sun-setting R 48 & R 55 came up at the June 2017 TPF 5(299) technical advisory committee (TAC = 21 SHA personnel) teleconference. There was discussion at the teleconference regarding the SHA’s that might still be using these and their reluctance to sunset them and it was also indicated that these may be referenced in Federal statutes. If the SOM agrees to sunset R 48 and R 55 they will not be maintained/no more updates but the standards are still available for SHA’s and others to use (e.g. Federal regulations related to pavement performance measurement). The TPF-5(299) TAC believes that newer technologies are available that will provide information that is more accurate and repeatable, and R 48 and R 55 are not in a format to incorporate these improvements, but PP 67-70 are in the format/conceptual approach and should become the focus of the tech section (PP 67 – 70 are recommended to become full standards this year). A significant amount of effort has gone into the development/refinement of PP 67 – 70, and there still needs to be a lot of work put into these PPs. There are several ongoing NCHRP and FHWA projects focused on further development/refinement of these PPs.

G. SOM Ballot Items (including any ASTM changes)
   a. Concurrent SOM ballot – Recommend motion to reconfirm and adopt as full standards PP 67, PP 68, PP 69, PP 70 and add “concrete pavement surface” to the Keyword Sections of PP 68 and PP 69.
      Motion       Second
      Vote for:     Negative:
b. TS ballot - Recommend motion for TS ballot to approve without modification R 37, R 40, R 54, R 56, R 57, M 328, and T 317.
   Motion Second
   Vote for: Negative:

   c. Concurrent SOM ballot – Recommend motion for concurrent TS/SOM ballot to reconfirm with minor changes and remain provisional standard TP 98 and TP 99. See appendix D.
   Motion Second
   Vote for: Negative:

   d. TS ballot – Recommend motion for TS ballot to reconfirm with minor changes. Reconfirm with minor changes to remain compatible with ASTM standards M 261, M 286, T 242, and T 279. See appendix D.
   Motion Second
   Vote for: Negative:

   e. TS or concurrent ballot – Recommend motion for **reconfirm or sunset** (based on discussion during section F) R 48 and R 55.
   Motion Second
   Vote for: Negative:

VI. Other Items: Pooled Fund Project related to PP67, PP 68, PP 69, and PP 70: TPF-5(299) Improving the Quality of Pavement Surface Distress and Transverse Profile Data Collection and Analysis, Mergenmeier, FHWA. If interested in participating in project, contact your Research Director to submit your commitment letters – web address: [http://www.pooledfund.org/Details/Study/543](http://www.pooledfund.org/Details/Study/543); Next meeting is at RPUG in November.

   A. TPF-5(063) Improving the Quality of Pavement Profiler Measurement. New pooled fund study by South Dakota DOT, to continue work on longitudinal profile.
   B. Any “Hot Topics” for Thursday Roundtable?
   C. If there is a need, a mid-year meeting will be planned.

VII. Adjourn – Time ???? pm

Appendixes

A- Agenda (no separate agenda - it is part of the minutes, so no appendix A for 2017 annual Tech Section 5a meeting minutes)
B- Attendance Roster
C- Standards
D- Ballot Items
E- RNS
<table>
<thead>
<tr>
<th>STATE</th>
<th>MEMBERS REPRESENTATIVE</th>
<th>E-MAIL ADDRESS</th>
<th>PHONE NUMBER</th>
<th>Member Y/N (Proxy?)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>Scott George</td>
<td><a href="mailto:georges@dot.state.al.us">georges@dot.state.al.us</a></td>
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<td>James Williams</td>
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<td>Donald Streeter</td>
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<td>Ontario</td>
<td>Becca Lane (non-voting)</td>
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<td>416-235-3512</td>
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<tr>
<td>Oregon</td>
<td>Greg Stellmach</td>
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<td>503-986-3061</td>
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<td>Tennessee</td>
<td>Heather Hall</td>
<td><a href="mailto:heather.purdy.hall@tn.gov">heather.purdy.hall@tn.gov</a></td>
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<td>Texas</td>
<td>Darren Hazlett</td>
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<td>512-416-2456</td>
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<tr>
<td>FHWA</td>
<td>Katherine Petros</td>
<td><a href="mailto:katherine.petros@dot.gov">katherine.petros@dot.gov</a></td>
<td>202-493-3154</td>
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<td>FHWA</td>
<td>Jack Springer</td>
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<td>Andy Mergenmeier</td>
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<td>410-962-0091</td>
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<td>(720) 963-3247</td>
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<tr>
<td>AMRL</td>
<td>Maria Knake (non-voting member)</td>
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<td>301-975-2383</td>
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<td>Fugro Consultants</td>
<td>Jerome Daleiden (non-voting friend)</td>
<td><a href="mailto:JDaleiden@fugro.com">JDaleiden@fugro.com</a></td>
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<td>GGfGA Engineering</td>
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<td>770-337-5817</td>
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<td>Tracy Barnhart</td>
<td><a href="mailto:tbarnhart@aashtoresource.org">tbarnhart@aashtoresource.org</a></td>
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<td>7</td>
<td>T 242-96 (2009) (E 274-97)</td>
<td>Frictional Properties of Paved Surfaces Using a Full-Scale Tire</td>
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<td>T 256-01 (2011)</td>
<td>Pavement Deflection Measurements</td>
<td>NY, AMRL</td>
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<td>T 278-90 (2012) (E 303-93 (2008))</td>
<td>Surface Frictional Properties Using the British Pendulum Tester</td>
<td>WV, MD</td>
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<td>T 282-01 (2010) (E 356-95 (2000))</td>
<td>Calibrating a Wheel Force or Torque Transducer Using a Calibration Platform (User Level)</td>
<td>MN, TX, MI</td>
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<td>T 317-04 (2009)</td>
<td>Prediction of Asphalt-Bound Pavement Layer Temperatures</td>
<td>NY, ON, FHWA (Weaver)</td>
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<td>R 32-09</td>
<td>Calibrating the Load Cell and Deflection Sensors for a Falling Weight Deflectometer</td>
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<td>R 40-10</td>
<td>Measuring Pavement Profile Using a Rod and Level</td>
<td>MS, FHWA (Springer)</td>
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<td>Measuring Pavement Profile Using a Dipstick</td>
<td>FHWA (Springer), MS</td>
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<td>R 43/MR 43-07</td>
<td>Quantifying Roughness of Pavements</td>
<td>FL, FHWA (Orthmeyer), AL</td>
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<td>19</td>
<td>R 48-10</td>
<td>Determining Rut Depth in Pavements</td>
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<td>R 36-12</td>
<td>Evaluating Fading of Concrete Pavements</td>
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<td>R 37-04 (2009)</td>
<td>Application of Ground Penetrating Radar (GPR) to Highways</td>
<td>FL, FHWA (Yu), TX</td>
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<td>R 55-10</td>
<td>Quantifying Cracks in Asphalt Pavement Surface</td>
<td>MD, TX, OR</td>
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<td>Certification of Inertial Profiling Systems</td>
<td>WV, FHWA (Springer), TX</td>
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<td>Operating Inertial Profilers and Evaluating Pavement Profiles</td>
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<td>Pavement Ride Quality When Measured Using Inertial Profiling Systems</td>
<td>WA, FHWA (Swanlund), TX</td>
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<td>M 328-10</td>
<td>Standard Equipment Specification for Inertial Profiler</td>
<td>TN, FHWA (Springer)</td>
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<td>27</td>
<td>M 331-13</td>
<td>Smoothness of Pavement in Weigh-in-Motion (WIM) Systems</td>
<td>T(A Walker, Wiser both at TFHRC), TX</td>
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<td>T 360</td>
<td>Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method</td>
<td>MN, TX</td>
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<td>PP 70-10</td>
<td>Collecting the Transverse Pavement Profile</td>
<td>AL, OR</td>
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<td>PP 69-10</td>
<td>Determining Pavement Deformation Parameters and Cross-Slope from Collected Transverse Profiles</td>
<td>AL, MS</td>
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<td>31</td>
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<td>Collecting Images of Pavement Surfaces for Distress Detection</td>
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<td>PP 67-16</td>
<td>Quantifying Cracks in Asphalt Pavement Surfaces from Collected Images Utilizing Automated Methods</td>
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<td>TP 98-13</td>
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<td>34</td>
<td>TP 99-13</td>
<td>Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)</td>
<td>FHWA (Orthmeyer), CO</td>
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Standard Method of Test for

Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method

AASHTO Designation: TP 98-13 (2015)¹

Technical Section: 5a, Pavement Measurement Technologies
Standard Method of Test for

Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method

AASHTO Designation: TP 98-13 (2015)\(^1\)

Technical Section: 5a, Pavement Measurement Technologies

1. SCOPE

1.1. This test method describes a procedure for measuring the influence of road surfaces on highway traffic noise. The Statistical Isolated Pass-By (SIP) Method provides a quantitative measure of the sound pressure level at locations adjacent to a roadway. The SIP method allows for the comparison of vehicle noise on roadways of varying surfaces and across studies by comparing measured sound levels to a reference noise curve.

1.2. Measurements capture the sound pressure level from isolated vehicles in existing traffic. The SIP method is to be applied on roadways where measuring sound levels from single-vehicle pass-by events is possible without contamination from sound from other vehicles.

1.3. This standard is intended for use by acoustic professionals. Competency with acoustical measurement and analysis techniques is assumed.

1.4. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENTS

2.1. **AASHTO Standards:**

- T 360, Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method
- TP 99, Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)

2.2. **ASTM Standard:**

- F2493, Standard Specification for P225/60R16 97S Radial Standard Reference Test Tire

2.3. **FHWA Reports:**

- FHWA-PD-96-008, Development of National Reference Energy Mean Emission Levels for the FHWA Traffic Noise Model (FHWA TNM\(^6\)), Version 1.0
2.4. IEC Standards:
- IEC 60942: 2003, Electroacoustics—Sound Calibrators

2.5. ANSI Standard:

3. TERMINOLOGY

3.1. Definitions:

3.1.1. Continuous-Flow Traffic Time-Integrated Method (CTIM)—a test method for measuring the influence of road surfaces on highway traffic noise. The CTIM method captures the sound from existing traffic for all vehicles on all roadway lanes and includes propagation effects over the roadway pavement and adjacent terrain to the nearby measurement location.

3.1.2. data set—the data collected to determine the reported Statistical Isolated Pass-By index (SIPI).

3.1.3. designated speed—the arithmetic average of all measured pass-by vehicle speeds for a single vehicle category.

3.1.4. maximum sound level—the highest sound pressure level recorded by the measuring instrument during a vehicle pass-by, using the A-weighted frequency network and a fast sound level meter response time (0.125-s exponential average).

3.1.5. measured vehicle sound level, \( L_{veh} \)—the sound level determined at the designated speed from a regression line of the maximum A-weighted sound pressure level versus the logarithm of vehicle speed, calculated for each vehicle category for the measured data for a single microphone position [either 25 ft or 50 ft (7.6 m or 15.2 m) from the center of the travel lane] for a single pavement type.

3.1.6. measurement period—a period of time over which measurements are made during one site visit. A data set may combine one or more consecutive measurement periods to capture enough data to properly represent the site.

3.1.7. On-Board Sound Intensity (OBSI) Method—a measurement procedure to evaluate the tire/pavement noise component resulting from the interaction of an ASTM F2493, Standard Reference Test Tire (SRTT) on a pavement surface. Sound intensity measurements are taken at defined locations near the tire/pavement interface.

3.1.8. powertrain noise—the noise generated from the powertrain, including the vehicle engine, exhaust system, air intake, fans, transmission, differential, and axles.

3.1.9. reference noise curve—the reference noise curve is extracted from the portion of the Reference Energy Mean Emission Level (REME) curve that is primarily attributed to tire/pavement noise (FHWA-PD-96-008). The reference noise curve is defined as \( A \times \log_{10}(\text{speed in mph}) + B \). The
coefficients for each vehicle category are shown in Table 1 for the 50-ft (15.2-m) position (extracted from FHWA-PD-96-008, Section 7.4) and in Table 2 for the 25-ft (7.6-m) position [calculated by shifting the 50-ft (15.2-m) curve up by 6 dB]. For data measured at the 50-ft (15.2-m) position, the $L_{\text{veh,ref}}$ shall be extracted from the 50-ft (15.2-m) reference curve for comparison. For data measured at the 25-ft (7.6-m) position, the $L_{\text{veh,ref}}$ shall be extracted from the 25-ft (7.6-m) reference curve for comparison. (The measurement positions are described in more detail in Section 10.)

**Table 1**—Reference Noise Curve Parameters for Position of Microphone—50 ft (15.2 m) from the Center of the Lane, 5 ft or 12 ft (1.5 m or 3.7 m) above the Roadway Plane

<table>
<thead>
<tr>
<th>Reference Curve Coefficients for Reference Pavement</th>
<th>Automobiles</th>
<th>Medium Trucks</th>
<th>Heavy Trucks</th>
<th>Buses</th>
<th>Motorcycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>41.740807</td>
<td>33.918713</td>
<td>35.879850</td>
<td>23.479530</td>
<td>41.022542</td>
</tr>
<tr>
<td>B</td>
<td>0.223836</td>
<td>19.495961</td>
<td>20.306023</td>
<td>38.006238</td>
<td>7.333072</td>
</tr>
</tbody>
</table>

**Table 2**—Reference Noise Curve Parameters for Position of Microphone—25 ft (7.6 m) from the Center of the Lane, 5 ft (1.5 m) above the Roadway Plane

<table>
<thead>
<tr>
<th>Reference Curve Coefficients for Reference Pavement</th>
<th>Automobiles</th>
<th>Medium Trucks</th>
<th>Heavy Trucks</th>
<th>Buses</th>
<th>Motorcycles</th>
</tr>
</thead>
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<td>41.022542</td>
</tr>
<tr>
<td>B</td>
<td>6.223836</td>
<td>25.495961</td>
<td>26.306023</td>
<td>44.006238</td>
<td>13.333072</td>
</tr>
</tbody>
</table>

3.1.10. *reference surface*—the reference surface is defined as the average pavement type from the FHWA Traffic Noise Model (FHWA TNM®) (FHWA-PD-96-009, FHWA-PD-96-010), measured in the Reference Energy Mean Emission Level (REMEL) study (FHWA-PD-96-008). All results shall be compared to the Reference Noise Curve based on the average pavement [dense-graded asphaltic concrete (DGAC) and portland cement concrete ([PCC] combined) found in the TNM vehicle noise emission level database [REMELs (FHWA-PD-96-008)]. See Section 3.1.9 for reference curve coefficients.

3.1.11. *reference vehicle sound level, $L_{\text{veh,ref}}$*—the sound level determined at the designated speed from the reference noise curve.

3.1.12. *regression uncertainty*—the uncertainty in the location of the true regression line for the linear regression analysis of sound level data as a function of speed. The procedure for calculating regression uncertainty is found in Section 14.1.4.

3.1.13. *statistical isolated pass-by index (SIPI)*—SIPI is defined as:

$$\text{SIPI} = L_{\text{veh}} - L_{\text{veh,ref}}$$

where $L_{\text{veh}}$ is the measured vehicle sound level and $L_{\text{veh,ref}}$ is the reference vehicle sound level. The SIPI is the difference between sound levels representing two sets of data: (1) measured data for a single pavement type and single vehicle category, and (2) data representing the reference pavement and a single vehicle category. The SIPI can be used for the comparison of different pavements, for the assessment of the acoustical characteristics of a pavement over time, or for other comparison uses not specified. The procedure for calculating SIPI is found in Section 14.1.

3.1.14. *statistical isolated pass-by (SIP) method*—the measurement procedure designed to evaluate vehicle noise generated on different road surfaces by measuring the sound pressure level from isolated vehicles in existing traffic. The measurements are taken from a large number of vehicles operating normally on the road. Results obtained using this procedure are compared to reference vehicle sound levels.
3.1.15.  
**tire/pavement noise**—the sound generated by the interaction of the tire with the pavement surface as it traverses the pavement.

3.1.16.  
**traffic noise**—the overall noise emitted by multiple vehicles running over the road being evaluated.

3.1.17.  
**vehicle category**—consists of vehicles that have certain common features easy to identify in the traffic stream, such as the number of axles and the size. The common features are assumed to correspond to similarities in their sound emission when driven under the same operating conditions. The vehicle categories in Table 3 are considered to be sufficient for description of the noise characteristics of road surfaces and are used in the SIP method.

### Table 3—Vehicle Categories

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>Number of Axles, Number of Tires, Gross Vehicle Weight (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobiles</td>
<td>2 axles, 4 tires, and generally &lt;9,900 lb (4500 kg) (designated primarily for transportation of 9 or fewer passengers or for transportation of cargo—cars, pickup trucks, and sports utility vehicles)</td>
</tr>
<tr>
<td>Medium trucks</td>
<td>2 axles, more than 4 tires, and generally &gt;9,900 lb (4500 kg) and &lt;26,400 lb (12 000 kg)</td>
</tr>
<tr>
<td>Heavy trucks</td>
<td>3 or more axles and generally &gt;26,400 lb (12 000 kg)</td>
</tr>
<tr>
<td>Buses</td>
<td>2 or 3 axles (designated for transportation of 9 or more passengers)</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>2 or 3 tires (with an open-air driver and/or passenger compartment)</td>
</tr>
</tbody>
</table>

Notes:
1. The definitions for these vehicle categories are intended for U.S. applications, including the FHWA Traffic Noise Model (FHWA-PD-96-009, FHWA-PD-96-010) and its vehicle noise emission database (FHWA-PD-96-008). The vehicle category definitions can be found in those references as well as the FHWA highway noise measurement manual (FHWA-PD-96-046).
2. Only vehicles that clearly fall within any of the types described in this section shall be measured. Where there is any doubt in classifying a vehicle, the measurement for that vehicle shall be discarded from the study.

3.1.18.  
**vehicle noise**—the total noise from a vehicle, including a combination of noise generated by the tire/road interaction (tire/pavement noise), air turbulence, and the powertrain.

### 4. SUMMARY OF TEST METHOD

#### 4.1. Measuring the Sound Level

In the SIP method, the maximum A-weighted sound pressure levels of a statistically significant number of individual vehicle pass-bys are measured at a specified roadside location together with the vehicle speeds. Each measured vehicle is classified into one of five categories: automobiles, medium trucks, heavy trucks, buses, and motorcycles. At a minimum, the automobile and heavy truck categories should be evaluated in order to determine the influence of each roadway surface (the other vehicle categories are optional).

#### 4.2. Analysis of Data

Each individual pass-by level, together with its vehicle speed, is recorded, and a linear regression of the maximum A-weighted sound pressure level versus the logarithm of the speed is calculated for each vehicle category. From this regression line, the measured vehicle sound level, $L_{veh}$, and regression uncertainty are determined at the designated speed. The measured sound level is called the measured vehicle sound level, $L_{veh}$. For each roadway surface or pavement type, the $L_{veh}$ is calculated for each vehicle category.

#### 4.3. Comparison of Data to Reference

The $L_{veh}$ Value is compared to the Reference Vehicle Sound Level, $L_{veh,ref}$ using the reference surface, both at the designated speed. The difference between the two values is calculated and reported as the Statistical Isolated Pass-by Index (SIPI).

4.3.4.4. The method is detailed below, and additional SIP considerations are available in a memorandum to FHWA dated April 20, 2017, “Additional Considerations for AASHTO Standard Methods of Test TP 98 (SIP) and TP 99 (CTIM).” The memorandum is available at: [http://downloads.transportation.org/TP98-TP99/SIP_CTIM_Considerations_Memo.pdf](http://downloads.transportation.org/TP98-TP99/SIP_CTIM_Considerations_Memo.pdf)
5. SIGNIFICANCE AND USE

5.1. This test method provides an objective measure of the influence of road surfaces on vehicle noise at locations adjacent to a roadway and allows for the comparison of vehicle noise on roadways of varying surfaces by comparing measured sound levels to those representing the tire/pavement noise for a reference surface, thus allowing comparison of results across studies.

5.2. Use of this method, in conjunction with other measurement methods, will increase the understanding of the influence of pavement on noise and eventually be applicable to pavement design and selection.

5.3. The SIP procedure reports broadband A-weighted maximum sound pressure levels. While it is possible to measure one-third octave band levels in conjunction with the broadband levels, methods to analyze the one-third octave band data are not included in this procedure.

5.4. In situations where it is not possible to measure single vehicle pass-by events without contamination from other vehicles, TP 99, Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM), or another method that allows for measuring continuously flowing traffic should be applied. The appropriate measurement technique should be selected based on site and traffic conditions. The SIP method is preferred over TP 99 due to its ability to compare results across sites and/or studies.

5.5. The SIP test method may be used in conjunction with the on-board sound intensity (OBSI) method described in AASHTO T 360 that measures the tire/pavement component of vehicle noise exclusively.

6. APPARATUS

6.1. Sound Level Instrumentation—The sound level meter (or equivalent measuring system) shall meet the requirements of a Class 1 instrument according to IEC 61672-1.

Note 1—It is recommended to use a pressure response/random incidence microphone at grazing incidence (i.e., vertical orientation); see Figure 1. Microphone positions are discussed in Section 10 and Appendix X2.

![Figure 1](image)

Figure 1—Illustration of Directions for Microphone Orientation

6.2. Windscreens—A windscreen that does not detectably influence the measured sound levels shall be used.
6.3. **Frequency Analysis Instrumentation**—Frequency analysis of the measured sound using one-third octave band resolution is recommended, but not mandatory. The frequency range of 50 to 10,000 Hz (center frequencies of one-third octave bands) shall be covered. The one-third octave band filters shall conform to IEC 61260.

6.4. **Calibration Instrumentation**—The calibration device used shall meet the requirements of a Class 1 instrument according to IEC 60942. (Note that some calibrators require correction for environmental conditions. The manufacturer’s specifications should be consulted.)

6.5. **Vehicle Speed Measurement Instrumentation**—The vehicle speed shall be measured using a measuring instrument with an accuracy of ±1 mph (±1.6 km/h). A list of measuring devices/methods is found in *Measurement of Highway-Related Noise* (FHWA-PD-96-046) and includes radar gun, stopwatch, light sensors, and pneumatic lines. Care must be taken to avoid interfering with the pass-by sound level measurements, including actions that could influence driver behavior and/or generating any intrusive noise caused by a measurement device.

6.6. **Temperature Measurement Instrumentation**—The air temperature measuring instrument(s) shall have an accuracy of ±2°F (±1.2°C). Meters using an infrared technique shall not be used for air temperature measurements.

6.7. **Wind Measurement Instrumentation**—The wind speed measuring instrument(s) shall have an accuracy of ±2 mph (±0.9 m/s). The wind direction–measuring instrument(s) shall have an accuracy of ±10 degrees.

7. **SELECTION OF TEST SITES**

7.1. The following considerations apply for site selection:

7.1.1. Each road test section shall extend at least 100 ft (30.5 m) on both sides from the microphone location.

7.1.2. The road shall be essentially level and straight. Horizontal curves should be avoided when possible. Roadway geometry and approximate grade shall be noted.

7.1.3. A test section shall have the same nominal material and surfacing for its length. The road surface should be homogeneous over the entire test section and the test section should be representative of the road under study. The condition of the road should be documented and pictures included of the typical surface when possible.

   For example, if pavement is generally free of distress, the test section should be selected to exclude any portion of pavement that exhibits surface cracking, bleeding, or excessive stone loss. If, however, pavement distress is prevalent, then the test section should include these same distresses.

7.1.4. It is recommended that the On-Board Sound Intensity (OBSI) Method (AASHTO T 360) be applied to help determine potential SIP locations to represent a roadway section; the best locations would be those with OBSI levels most prevalent in the roadway section of interest. OBSI testing may reveal variations in pavements that appear homogeneous from visual inspection.

   **Note 2**—The noise characteristics of some road surfaces change quickly after opening for traffic. Changes in noise characteristics of newly constructed surfaces (aged less than 2 to 6 months) may not provide a reliable baseline for representing aging effects over the lifespan of the pavement.

7.1.5. The road surface shall be free of extraneous material, such as gravel or road debris, to the extent practical.
7.1.6. The site shall consist of an open space free of large reflecting surfaces within 100 ft (30.5 m) of
the path between the measured vehicle and the microphone(s) that could affect the sound
measurements, such as parked vehicles, signboards, buildings, hillsides, safety barriers (or any
other type of barrier), and guardrails.

7.1.7. The ground surface between the roadway and the microphone(s) should consist of relatively flat
and acoustically hard terrain (e.g., pavement). The ground surface and any foliage located between
the roadway and the microphone(s) shall be documented.

7.1.8. The line-of-sight from the microphone(s) to the roadway shall not be obscured within an arc of
120 degrees.

7.1.9. The site shall be located away from intersections, lane merges, or any other features that would
cause traffic to accelerate or decelerate, so that measured vehicles are operating under cruise
conditions.

7.1.10. The traffic vehicle mix on the road section should contain sufficient numbers of each category of
vehicle of interest to enable a full analysis. See Section 8.3 for an explanation of the minimum
number of acceptable vehicle pass-by events needed for each vehicle type.

7.1.11. The requirements on background noise at the test site according to Section 8.2.1 shall be observed.

7.1.12. The site should be located away from known intrusive noise sources that could influence the noise
measurements, such as airports, construction sites, rail yards, or other heavily traveled roadways.

7.2. Additional considerations for site selection:

7.2.1. For long-term pavement studies, it is beneficial to select a site that is expected to have minimal
physical or operational changes that could bias the results.

7.2.2. It may be possible to use the paired measurement technique by collecting data simultaneously at
two or more contiguous sites, which could reduce uncertainty when comparing these sites due to
the elimination of differences in traffic composition and meteorological conditions. (Refer to
Appendix X3.)

8. TRAFFIC CONDITIONS

8.1. Vehicle Classification—Only vehicles that clearly fall within any of the types described in
Section 3.1.17 shall be measured. Where there is any doubt in classifying a vehicle, the
measurement for that vehicle shall be discarded from the study.

8.2. Selection of Vehicles for Measurement—Measurements shall be taken only on individual vehicle
pass-bys in a single lane of travel that can be clearly distinguished acoustically from other traffic
on the road. The following criteria shall be used to judge if a vehicle pass-by is distinguishable:

8.2.1. Background noise, including the collective sound from other traffic and nontraffic noise sources,
shall be at least 10 dB below the measured maximum A-weighted sound pressure level of the
vehicle intended for measurement (target vehicle maximum sound level), at the time the maximum
sound level is generated. To achieve this, two criteria must be met:

- Background Noise for All Sources Other Than Traffic on the Roadway of Interest—The
  A-weighted sound pressure level shall be at least 10 dB below the target vehicle maximum
  sound level before, during, and after the target vehicle pass-by event.
Background Noise for Other Vehicles on the Roadway of Interest—The A-weighted sound pressure level shall be at least 6 dB below the target vehicle maximum sound level just prior to and just after the passage of the target vehicle, as indicated in Figure 2. The 6-dB requirement before and after the vehicle pass-by event is an indication that, at the time of the target vehicle maximum sound level, the difference between the target vehicle maximum sound level and the sound level associated with a nearby vehicle should be at least 10 dB due to sound levels dropping off from the nearby vehicle. (It is possible that there may be some contamination from nearby vehicles, depending on their associated sound level drop-off rates.)

Note 3—Use of a 6-dB criterion allows some quieter vehicles to be included in the data set, but it may prevent inclusion of the quietest vehicles. (A more restrictive 10-dB criterion would likely prevent measurable contamination from nearby vehicles, but it may also prevent inclusion of any quieter vehicles, which is why the 6-dB criterion is preferred.)

![Figure 2](image_url)

Figure 2—Example of Required Signal-to-Noise Ratio for Individual Vehicle Pass-Bys at 25-ft (7.6-m) Position (Refer to Appendix X4 for additional information.)

8.2.2. Care should also be taken to ensure that sound from other vehicles overtaking the target vehicle or passing in the opposite direction do not influence the measured result. In these cases it is possible that the maximum sound level from the target vehicle and other traffic will occur approximately simultaneously so that the peaks obtained are then indistinguishable. Such measurements shall be discarded.

8.2.3. Vehicles that clearly exhibit unusual or atypical noise characteristics such as might occur due to a faulty exhaust system, flapping straps or tarps, loud audio systems, vehicle body rattles or audible-warning devices shall be discarded from the measurement. Vehicles with auxiliary equipment that emits audible sound should also be discarded.
8.2.4. The sound levels should be measured only from vehicles judged to be moving at constant speed operating under cruise conditions. Individual vehicles judged to deviate significantly in their lateral position from the median axis of the test lane shall be discarded from the analysis.

8.3. Number of Vehicles—For any of the vehicle categories, the minimum number of acceptable vehicle pass-by events measured is 30, with a desirable number of acceptable vehicles of 100.

Note 4—It is typical for 100 automobile measurements to be easily obtained within a reasonable timeframe (one or two 4- to 6-h measurement periods); it may be difficult to measure 100 heavy trucks during this same time frame. Also note that to obtain 30 acceptable events, it may be necessary to measure more than 30 vehicles.

9. METEOROLOGICAL CONDITIONS AND INFLUENCES

9.1. Wind—A measurement pass-by event shall not be made when the instantaneous wind speed at the primary microphone height exceeds 11 mph (5 m/s), regardless of wind direction.

It may be useful to monitor and record the wind velocity (direction and speed) to help explain discrepancies between data, e.g., due to propagation effects. Measured sound levels shall not be adjusted for possible variations caused by wind. If examining wind direction, it must be noted in relation to the roadway orientation in order to understand its effects on sound levels.

9.2. Air Temperature—The air temperature during the measurement period shall be recorded at least once per hour.

Extreme temperatures may influence results when comparing data to the reference data. For the purposes of comparing data to the reference data, air temperature shall be between 40 and 100°F (4 and 38°C). [Note that the reference curve data was primarily measured between air temperatures of 55 and 85°F (13 and 29°C).]

For pavement comparison studies, average air temperatures for a data set should be within ±7°F from one data set to the next in order to increase precision and minimize the influence of temperature on sound levels.

Measured sound levels shall not be adjusted for possible variations caused by temperature.

9.3. Sky Condition—The sky condition (for example, clear, scattered clouds, partly cloudy, mostly cloudy, or overcast) during the measurement period should be recorded at least once per hour.

9.4. Pavement Moisture—Measurements shall be carried out only when road surfaces are visibly dry.

10. MICROPHONE POSITIONS

10.1. There are two primary microphone positions: (1) a position located at a horizontal distance of 25 ft (7.5 m) from and a height of 5 ft (1.5 m) above the center of the lane of travel for the vehicles to be measured, and/or (2) a position located at a horizontal distance of 50 ft (15 m) from and a height of 12 ft (3.7 m) above the center of the lane of travel for the vehicles to be measured, or placed at both locations. The vertical height of the microphone is measured relative to the center of the lane of travel, not relative to the ground directly under the microphone. [Refer to Appendix X2 for considerations concerning the choice of microphone position(s).]

10.2. If the measurement site does not permit one of the primary positions, successful measurements can still be made using one of the two primary locations. For each measurement position, a comparison shall be made to the appropriate reference data (see Section 3.1.9).

10.3. Additional microphone positions could be considered for research needs, for comparison to historical data, or for comparison to other measurement methods. (Refer to Appendix X2.)
10.4. All microphone positions shall be located a minimum of 5 ft (1.5 m) above the ground surface to minimize ground effects. For measurement sites where the ground slopes up with increased distance from the roadway, a minimum height of 5 ft (1.5 m) above the ground must be maintained, even if it results in the height of the microphone being greater than specified in Section 10.1. The height above the roadway plane must be noted.

11. **CALIBRATION AND STANDARDIZATION**

11.1. At the beginning of the measurements, and following all warm-up procedures specified by the manufacturer, the sound level measurement system shall be field calibrated using an acoustic calibrator or piston phone.

11.2. At a minimum, verification shall be conducted no earlier than 1 h before and no later than 1 h after the measurement period. Additional verification shall be conducted during the course of the measurements so that the maximum period between verification checks does not exceed 4 h.

11.3. The measurement system shall be adjusted for accuracy according to the manufacturer’s instructions. The results of all measurement system accuracy checks shall be recorded in the test report. If the results of any two consecutive verification checks during the measurement period differ by more than 0.5 dB, the testing between those checks shall be considered invalid.

12. **PROCEDURE**

12.1. *Sound Level Measurement*—During each vehicle pass-by, the maximum A-weighted sound pressure level shall be measured using fast time response. (Refer to ANSI S1.42 for weighting networks.) Audio recordings can allow for later analysis, but are not required.

12.2. *Frequency Spectrum Measurement (Recommended)*—It is recommended to measure one-third octave band frequency spectra. The averaging time shall correspond to “fast response.” The spectrum should correspond to when the overall A-weighted sound pressure level during a vehicle pass-by is at its maximum. Refer to IEC 61260.

12.3. *Vehicle Speed Measurement*—The vehicle speed representative of when the vehicle midpoint passes the microphone shall be measured. The intent of the measurement is to gather the speed of the vehicle as it passes the microphone. Alternative speed measuring positions up- or downstream of the microphone can be used if the vehicle speed at that position is representative of when it passes the microphone.

12.4. *Air Temperature Measurement*—The air temperature sensor shall be positioned in the vicinity of the microphone position(s), in such a way that it is exposed to the airflow, protected from direct solar radiation, and causes no influence on the measured sound levels. If continuous monitoring is not available, the air temperature shall be measured at a minimum of 1-h intervals.

12.5. *Wind Measurement*—The wind sensor shall be positioned in the vicinity of the microphone position(s), in such a way that it is exposed to the airflow and causes no influence on the measured sound levels. The wind shall be monitored to ensure that the wind speed at the microphone at the time of the pass-by event does not exceed 11 mph (5 m/s), regardless of wind direction.

13. **DATA SCREENING AND REDUCTION**

13.1. Measurements that are impacted by unusual or disruptive conditions such as background noise contamination (refer to Section 8.2.1), atypical vehicle noises (refer to Section 8.2.3), or environmental factors such as wind gusts (refer to Section 12.5) shall be discarded.
13.2. If the measured levels are expressed in one-third octave bands, these conditions shall also be met for each one-third octave.

13.3. Accelerating, rapidly decelerating, and vehicles that are outside of the speed range shall be excluded (refer to Section 8.2).

14. **CALCULATION OF RESULTS**

14.1. *Calculation of Statistical Isolated Pass-By Index (SIPI) (refer to Appendix X5 for an example):*

14.1.1. *Regression Analysis*—A linear regression analysis shall be made using data pairs consisting of the measured maximum A-weighted sound level as a function of the logarithm of speed (base 10) for the corresponding vehicle pass-by. A regression line shall be fit to the data points for each separate vehicle category, using a least squares method. (In Microsoft Excel, use the Analysis Regression Tool with the following input: x values = log of speed; y values = sound levels; check the confidence level box, 95 percent; check the residuals box.)

14.1.2. *Determination of Designated Speed*—The designated speed is the arithmetic average of all measured pass-by vehicle speeds for a single vehicle category. Designated speed shall be calculated to two or more decimal places and rounded to an integer for reporting. For reporting, include only speeds associated with pass-by events retained for the final regression analysis (the Designated Speed will need to be recalculated if data pairs are eliminated in step 14.1.4).

14.1.3. *Determination of Measured Vehicle Sound Level at Designated Speed*—The sound level from the regression line for each vehicle category at the data set’s Designated Speed is taken to be the Measured Vehicle Sound Level, \( L_{veh} \). All levels shall be calculated to two or more decimal places and rounded to one decimal place for reporting. For reporting, include only sound levels associated with pass-by events retained for the final regression analysis (\( L_{veh} \) will need to be recalculated if data pairs are eliminated in step 14.1.4).

14.1.4. *Data Outlier Check/Elimination*—All data points with sound levels outside 3 standard deviations from the regression line shall be excluded from the regression analysis. (This requires calculating the standard deviation of the residuals and eliminating any data pair whose sound level is outside the allowable standard deviations from \( L_{veh} \).)

All data points with associated speeds that are not within \( x \) times the standard deviation of the average shall be eliminated, where \( x = 3.5 \) for autos and 3.0 for heavy trucks. (This requires use of the Designated Speed and calculation of the standard deviation of the measured speeds.)

If data points are excluded, a regression analysis shall be recalculated for the revised data sets, in addition to recalculating the Designated Speed (14.1.2) and \( L_{veh} \) (14.1.3).

14.1.5. *Determination of the Regression Uncertainty at Designated Speed*

\[
\begin{align*}
\sigma^2 &= \frac{1}{N-2} \sum_{i=1}^{N} (\varepsilon_i)^2 \\
Y_i &= \varepsilon_i = Y_i - (Y_{reg})_i \\
u &= t_{0.05;N-2} \times \sqrt{\frac{\sigma^2}{N}}
\end{align*}
\]

where:
Appendix D

14.1.6. **Determination of Reference Vehicle Sound Level at Designated Speed**—The sound level from the reference regression line for each vehicle category at the data set’s designated speed is taken to be the Reference Vehicle Sound Level, $L_{veh,ref}$ (see Section 3.1.9 for regression line coefficients). All levels shall be calculated to two or more decimal places and rounded to one decimal place for reporting.

14.1.7. **Determination of Statistical Isolated Pass-by Index (SIPI)**—The SIPI is the difference between measured and reference sound levels for a single-vehicle category. So, for each vehicle category, $SIPI = L_{veh}(\text{designated speed}) - L_{veh,ref}(\text{designated speed})$. Care should be made that data acquired at a specified measurement position shall be compared to the appropriate reference line.

15. **REPORTED DATA**

15.1. The test report shall include the following general data:

15.1.1. Time of day and date of measurement period;

15.1.2. Organization and operators responsible for the measurement;

15.1.3. Components of the measurement system, including instrumentation used to collect acoustical, vehicle, and meteorological data;

15.1.4. Information related to location of the test site, including the route, designation, and direction of travel of the vehicles, and either the GPS coordinates for the microphone position(s) or a description of the location using the official agency mileage reference system and landmark indicators;

15.1.5. Information and photo documentation related to the measurement equipment setup and appearance of the test site, including geometry of the site plan (horizontal and vertical) with microphone location(s), tested road lane, documentation of the ground surface and any foliage located between...
the roadway and the microphone(s), and any acoustically reflective surfaces or other objects that could potentially affect the sound measurements; and

15.1.6. Information related to the surface type and treatment, the age and condition of the pavement section, and any notes regarding the homogeneity of the surface. Pavement texture and mixture information (e.g., maximum aggregate size, air voids) should be provided if available. Scaled photographs should be included if possible.

15.2. The test report shall include the following acoustical and vehicle speed data:

15.2.1. Results of sound level measurement system verification (using calibration device) conducted prior to, after, and during each measurement period;

15.2.2. Plot of the individual sound levels and the regression curve as a function of linear vehicle speed for vehicles within each vehicle category;

15.2.3. The calculated $L_{veh}$, $L_{veh,ref}$ and SIPI for each vehicle category measured; and

15.2.4. Statistical parameters including slope and intercept of regression line of noise versus (log) speed for measured data, standard deviation of the deltas between each data point, and the regression fit for each data set (standard deviation of residuals), maximum and minimum residuals, regression uncertainty.

15.3. The test report shall include the following vehicle data:

15.3.1. The number of vehicles measured in each category after screening per Section 13;

15.3.2. The designated speed for each vehicle category measured; and

15.3.3. The maximum and minimum speed for each vehicle category measured.

15.4. The test report shall include the following meteorological data:

15.4.1. The average air temperature for each data set shall be reported. Reporting of the air temperature occurring during each individual event is optional; and

15.4.2. Reporting of wind speed, wind direction, humidity, and sky condition is optional. When comparing between data sets, differences in average air temperature shall be reported.

15.5. The test report shall include the following additional data:

15.5.1. Details of any necessary modifications to the referenced standards; and

15.5.2. Measurement practice and SIP guidance shall be reported.

16. PRECISION AND BIAS

16.1. Precision—Not available at this time.

16.2. Bias—Not available at this time.

16.2-16.3. Additional information about precision and bias for this method is available in a memorandum to FHWA dated April 20, 2017, “Additional Considerations for AASHTO Standard Methods of Test TP 98 (SIP) and TP 99 (CTIM).”
17. **KEYWORDS**

17.1. Noise measurement; pass-by; pavement noise; statistical isolated; vehicle noise; wayside.

18. **REFERENCE**

18.1. *ISO Standard:*

APPENDIXES

(Nonmandatory Information)

X1. REFERENCED DOCUMENTS

X1.1. The following references were used or referred to in the preparation of this text:

X1.1.1. AASHTO Standards:
- TP 99, Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)

X1.1.2. FHWA Documents:
- FHWA-PD-96-008, Development of National Reference Energy Mean Emission Levels for the FHWA Traffic Noise Model (FHWA TNM®), Version 1.0
- FHWA-PD-96-046, Measurement of Highway-Related Noise, Section 4: Existing-Noise Measurements in the Vicinity of Highways
- FHWA-HEP-11-005, Temperature Effects Study

X1.1.3. TRB Documents:

X2. SELECTION OF PRIMARY MICROPHONE POSITION(S)

X2.1. As stated in Section 10 of the procedure, there are two primary microphone positions: (1) a position located at a horizontal distance of 25 ft (7.5 m) from and a height of 5 ft (1.5 m) above the center of the lane of travel for the vehicles to be measured, and/or (2) a position located at a horizontal distance of 50 ft (15 m) from and a height of 12 ft (3.7 m) above the center of the lane of travel for the vehicles to be measured, or placed at both locations. Selection of the primary microphone position(s) should be based on considerations described below.

X2.2. Benefits of Using the 25-ft (7.5-m) Microphone Position—The 25-ft (7.5-m) position will result in a higher signal-to-noise ratio between targeted events and background noise (see Appendix X4) and allow for smaller vehicle separation between acceptable events (Appendix X4). Additionally, ground surface requirements are easier to meet at this position and meteorological propagation effects are minimized.

X2.3. Benefits of Using the 50-ft (15-m) Microphone Position—The 50-ft (15-m) position is farther from the roadway, which can be less likely to affect driver behavior, results in the contribution of individual component sources on larger vehicles being more spatially integrated in the reported level, and minimizes air turbulence effects at the microphone due to passing traffic.
X2.4. **Use of Both Positions**—It is recommended that both positions be used when site conditions allow benefiting from the advantages of each position.

X3. **EXTENSIONS OF SIP METHOD**

X3.1. There are several possible extensions of the SIP measurement method that are not included in the SIP methodology. These include the use of additional measurement locations and the use of paired measurements, as described below.

X3.2. **Additional Measurement Location:**

An additional microphone position, located at a horizontal distance of 50 ft (15 m) from and a height of 5 ft (1.5 m) above the center of the travel lane, should be considered in addition to the two primary positions described in the SIP methodology. This position adheres to the FHWA 50-ft requirement (FHWA-PD-96-046) and is comparable to historical data. The data from this position would be compared with the results of the primary position(s), potentially to provide guidance for further research that might define the height needed to reduce or eliminate ground effects.

X3.3. **Paired Measurements:**

In situations where multiple test surfaces occur along a continuous section of roadway, it may be possible to use a paired measurement technique. With paired measurements, acoustical and traffic data at two or more nearby contiguous sites can be collected simultaneously for comparison between sites of similar traffic and geometric conditions with different pavement types. In some situations, the use of the paired technique could reduce uncertainty when comparing multiple sites due to the elimination of differences in traffic composition and meteorological conditions.

In the case of paired measurements:
- All test sites should be largely similar in geometry, aside from roadway surface (e.g., numbers of lanes, median widths, shoulder widths, relative elevations of directional roadways and measurement locations, and microphone distances).
- The same vehicles from the traffic stream must be selected as they pass each measurement site.
- Speed and noise level measurements must be made at each test site.

X4. **MINIMIZING CONTAMINATION FROM NONTARGETED VEHICLES—VEHICLE SPACING AND MICROPHONE DISTANCE**

X4.1. As stated in Section 8.2.1 of the procedure, the measured level of the target vehicle shall be 10 dB greater than the background noise, including existing noise at the measurement site and noise from non-targeted vehicles. In regard to other vehicles, the criteria illustrated in Figure 2 is that the pass-by level of the target vehicle be at least 6 dB greater than the pass-by levels produced by other vehicles immediately before and after the maximum level of the target vehicle occurs. The purpose of this discussion is to provide additional information on the relationships between microphone distance, background noise from existing or other vehicle noises, and the typical spacing between potential target vehicles.

X4.2. **Effects of Microphone Distance on Background Noise**—As an example of background noise created by other vehicles on the roadway under test, the plot of Figure 2 is repeated in Figure X4.1 with values of sound pressure level and time shown based on a finite size vehicle model with wheelbase dimensions corresponding to a light vehicle (Vehicle #1), a heavy truck (Vehicle #2), and medium truck (Vehicle #3). These events correspond to vehicles measured at a distance of
25 ft from center of the lane of vehicle traveling at 60 mph. In this case, the maximum level produced by Vehicle #3 does not meet the 6-dB criteria due to adjacent vehicles and is rejected. This same case is represented in Figure X4.2 for the same vehicles, speeds, spacing, and existing background noise except as measured at a distance of 50 ft. For this distance, the peaks of the pass-by levels are not as well defined and two of the three pass-by events need to be rejected. In this case, the indicated pass-by levels are all more than 10 dB greater than the existing background noise.

Figure X4.1—Example Pass-By Time Histories for Three Vehicles Traveling at 60 mph Measured at 25 ft
Figure X4.2—Example Pass-By Time Histories for Three Vehicles Traveling at 60 mph Measured at 50 ft

X4.3. Although one of the pass-by events can accurately be determined for the case shown in Figure X4.2, if the spacing of these events were typical of the site, the conditions would not be conducive to collecting SIP data. Because of frequent contamination from other vehicles, only the vehicles producing the higher noise levels would be included in the reported data. This would bias the results to be dominated by noisier vehicles.

X4.4. Vehicle Spacing Considerations—The case illustrated in Figure X4.2 is further modified in Figure X4.3 by changing the spacing between the same vehicles, Vehicle #2 and #3, as measured at 50 ft. Comparing these figures, the separation between the vehicles would need to increase from 1.9 s to 5.9 s in order to generate an acceptable SIP data point for Vehicle #3. For 60 mph, this corresponds to an increase in spacing from 167 ft to 519 ft. For higher speeds, the required separation in time becomes smaller. Unfortunately, there are no “rules of thumb” that can be easily applied in the field without review of the data as the required separation is a function of the speed of individual vehicles, their respective noise level, and the distance between the roadway and measurement microphone.
Figure X4.3—Example Pass-By Time Histories for Three Vehicles Traveling at 60 mph
Measured at 50 ft with Vehicle #3 Spaced Sufficiently Far to Produce an Acceptable Pass-By Event

X4.5. Microphone Distance Selection—In general, if the selection of only one microphone distance is limited to either 25 ft or 50 ft, the selection will depend on a number of considerations that are specific to the site as well as the need for comparison to other existing data. The 25-ft distance should be considered if the spacing of the vehicles is smaller and/or the existing background noise levels are higher. From existing data at both distances but at a microphone height of 5 ft, there is no appreciable difference in propagation fall-off rate between light vehicles and heavy trucks as indicated by the data shown in Figure X4.4. This figure plots the difference in maximum levels between the 25- and 50-ft microphone locations for 1714 individual pass-by events (1208 light vehicles and 506 heavy trucks) measured at 9 different sites in Iowa and California (NCHRP Report 630). The slopes for the two regression lines are within 0.02 of each other and within 0.06 of unity. The scatter of the data for two vehicle types is essentially the same and average uncertainties are very small (±0.1 dB). The average difference between the 25- and 50-ft levels is 6.6 dB for the light vehicles and 6.4 dB for heavy vehicles. Based on these results, there should be no acoustic concerns in measuring the pass-by levels at the closer position.
EXAMPLE CALCULATION OF RESULTS

This Appendix provides an example of the calculation of results described in Section 14. Figure X5.1 provides an example of a spreadsheet used to calculate SIP results. In Figure X5.1, blue highlighting indicates cells where user input is needed and yellow highlighting indicates the calculated results. Figure X5.2 shows an example plot, as required to be reported in Section 15.2.2, of the individual sound levels and the regression curve as a function of linear vehicle speed for vehicles from the example described in this Appendix. The spreadsheet is available at: [http://downloads.transportation.org/TP98-TP99/CTIM_example_calculations.xls](http://downloads.transportation.org/TP98-TP99/CTIM_example_calculations.xls)

Regression Analysis—This set of data is for 136 automobiles (not all data shown in the figure below), where the vehicle speed and maximum A-weighted sound level ($L_{Amax}$) were measured for each pass-by event (sound level measurements taken at 50 ft). Before doing the regression analysis, speed was converted to log of speed (base 10), so that each data pair consists of $x = \log$ of speed and $y = L_{Amax}$. A linear regression analysis was then conducted using the MS Excel Data Analysis Regression Tool with the following input: $x$ values = log of speed; $y$ values = sound levels; check the confidence level box, 95 percent; check the residuals box.

In order to exclude outliers, the data were then checked for the following:
X5.1.1.1. All data points with sound levels outside 3 standard deviations from the regression line shall be excluded from the regression analysis. As can be seen in the example, the allowable residual range is −8.3 to 8.3 dBA, and none of the data points fall outside this range, so none were eliminated.
X5.1.1.2. All data points with associated speeds that are not within $x$ times the standard deviation of the average shall be eliminated, where $x = 3.5$ for autos and 3.0 for heavy trucks. As can be seen in the example, the allowable speed range is 47 to 85 mph, and none of the data points fall outside this range, so none were eliminated. If any of the data points had been eliminated, the entire regression analysis should be repeated until all data fall within the limits.

![Figure X5.1 Example of Spreadsheet Used to Calculate SIP Results](image-url)
X5.2.  

**Determination of Designated Speed**—The arithmetic average speed of the measured pass-by events was calculated and found to be 65.59 mph (reported as 66 mph). (See Figure X5.1.)

X5.3.  

**Determination of Measured Vehicle Sound Level at Designated Speed**—The sound level associated with the designated speed was then extracted using the regression equation determined in X5.1 (See the highlighted cells in Figure X5.1). For this example, \( L_{veh} = A \times \log_{10} \text{(speed in mph)} + B = 21.06461 \times \log_{10}(65.59) + 30.16341 = 68.43 \text{ dBA} \) (reported as 68.4 dBA). \( A \) = slope = cell to the right of “X Variable”; \( B \) = \( y \)-intercept = cell to the right of “Intercept,” both found on the Summary Output from the Excel regression analysis.

X5.4.  

**Determination of the Regression Uncertainty at Designated Speed**—The regression uncertainty at the designated speed was calculated for reporting purposes using the following equation and function in Excel:

\[
\text{Regression Uncertainty} = \sqrt{\frac{1}{\text{# pass-by events}} \times \text{(mean square of residuals)}} \times \text{TINV}(1-0.95, \text{# pass-by events} - 2) \\
= \text{TINV}(0.05,136-2)
\]

\( \text{Note 6} \)—The mean square of residuals is provided in the Output Summary of the regression analysis, as seen in the Figure X5.1 as ANOVA MS in the Residual row.

X5.5.  

**Determination of Reference Vehicle Sound Level at Designated Speed**—Using the coefficients found in Section 3.1.9, Table 1 for automobiles at 50 ft, the reference vehicle sound level at the designated speed was calculated: \( L_{veh,ref} = A \times \log_{10} \text{(speed in mph)} + B = 41.740807 \times \log_{10}(65.59) + 0.223836 = 76.06 \text{ dBA} \) (reported as 76.1 dBA).

X5.6.  

**Determination of Statistical Isolated Pass-by Index (SIPI)**—The SIPI was then calculated:

\( \text{SIPI} = L_{veh} \text{ (designated speed)} - L_{veh,ref} \text{ (designated speed)} = 68.43 - 76.06 = -7.63 \text{ dBA} \) (reported as \(-7.6 \text{ dBA}\)). This indicates that the pavement tested was 7.6 dBA quieter than the REMEL (FHWA-PD-96-008) sound level for TNM average pavement.
Figure X5.2—Example Plot of the Individual Sound Levels and the Regression Curve as a Function of Linear Vehicle Speed

\[ L_{A,\text{max}} \text{(dBA)} \]

1 This provisional standard was first published in 2011.
Standard Method of Test for

Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)

AASHTO Designation: TP 99-13 (2015)\textsuperscript{1}

Technical Section: 5a, Pavement Measurement Technologies

AASHTO
American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001
Standard Method of Test for

Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)

AASHTO Designation: TP 99-13 (2015)\(^1\)

Technical Section: 5a, Pavement Measurement Technologies

1. SCOPE

1.1. The Continuous-Flow Traffic Time-Integrated Method (CTIM) describes the procedures for measuring the influence of road surfaces on highway traffic noise at a specific site. It provides a quantitative measure of the sound pressure level at locations adjacent to a roadway. Measurements capture the sound from existing traffic for all vehicles on all roadway lanes. Measurements also include propagation effects over the roadway pavement and adjacent terrain to the nearby measurement location.

1.2. CTIM is to be applied on roadways where measuring single-vehicle pass-by events would be difficult due to continuously flowing, relatively dense traffic (sound levels from single vehicles cannot be properly captured due to contamination from sound from other vehicles).

1.3. This standard is intended for use by acoustic professionals. Competency with acoustical measurement, modeling, and analysis techniques is assumed.

1.4. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- T 360, Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method
- TP 98, Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method

2.2. ASTM Standard:

- F2493, Standard Specification for P225/60R16 97S Radial Standard Reference Test Tire

2.3. FHWA Reports:

- FHWA-PD-96-008, Development of National Reference Energy Mean Emission Levels for the FHWA Traffic Noise Model (FHWA TNM\(^5\)), Version 1.0
2.4. **IEC Standards:**
- IEC 60942: 2003, Electroacoustics—Sound Calibrators

2.5. **ANSI Standards:**

3. **TERMINOLOGY**

3.1. **Definitions:**

3.1.1. *analysis time block*—the shortest length time block for which all sound level, traffic, and meteorological data are analyzed. The analysis time block length shall range from 5 to 15 min. The length of the analysis time block should be long enough to minimize variation in sound levels from one analysis time block to the next, but short enough to facilitate the elimination of periods of time where the measurements were contaminated by nonhighway source noise. (For example, if measuring 15 min analysis time blocks, it would be undesirable to eliminate the entire 15 min because 5 min of the time period had noise contamination from jets flying overhead; in this case, shorter time blocks would minimize the amount of data lost to contamination.)

3.1.2. *control block*—the calculated energy average, \( L_{eq} \), of all modeled analysis time blocks over the first measurement period that meets the data quality criteria specified in this standard. This control block is used for normalization of the remaining analysis data blocks for all data sets.

3.1.3. *data set*—the acoustical, traffic, and meteorological data collected over a measurement period during one site visit.

3.1.4. *measurement period*—a period of time selected to capture enough data to properly represent the site. A minimum of three reporting time blocks or data points are required; additional data are desirable.

3.1.5. *On-Board Sound Intensity (OBSI) method*—a measurement procedure to evaluate the tire/pavement noise component resulting from the interaction of an ASTM F2493 Standard Reference Test Tire (SRTT) on a pavement surface. Sound intensity measurements are taken at defined locations near the tire/pavement interface.

3.1.6. *powertrain noise*—the noise generated from the powertrain, including the vehicle engine, exhaust system, air intake, fans, transmission, differential, and axles.

3.1.7. *reporting time block*—a time block comprised of 15-min \( L_{eq} \) sound levels for which sound level, traffic, and meteorological data shall be reported. The reporting time block shall be comprised of one or more analysis time blocks.
3.1.8. **sampling period**—the period of time over which data are collected during data acquisition. The sampling period must be shorter than or equal to the analysis time block.

3.1.9. **Statistical Isolated Pass-By (SIP) method**—a test method for measuring the influence of road surfaces on highway traffic noise. The SIP method captures the sound pressure level from isolated vehicles in existing traffic and allows for the comparison of vehicle noise on roadways of varying surfaces and across studies by comparing measured sound levels to a reference noise curve.

3.1.10. **tire/pavement noise**—the sound generated by the interaction of the tire with the pavement surface as it traverses the pavement.

3.1.11. **traffic noise**—the overall noise emitted by multiple vehicles running over the road being evaluated.

3.1.12. **vehicle categories**—a vehicle category consists of vehicles that have certain common features easy to identify in the traffic stream, such as the number of axles and the size. The common features are assumed to correspond to similarities in sound emission when driven under the same operating conditions. The following vehicle categories are considered to be sufficient to describe the noise characteristics of road surfaces and are used in this part of the CTIM procedure:

### Table 1—Vehicle Categories

<table>
<thead>
<tr>
<th>Vehicle Category</th>
<th>Number of Axles, Number of Tires, Gross Vehicle Weight (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobiles</td>
<td>2 axles, 4 tires, and generally &lt;9,900 lb (4,500 kg) (designated primarily for transportation of 9 or fewer passengers or for transportation of cargo—cars, pickup trucks, and sports utility vehicles)</td>
</tr>
<tr>
<td>Medium Trucks</td>
<td>2 axles, more than 4 tires, and generally &gt;9,900 lb (4,500 kg) and &lt;26,400 lb (12,000 kg)</td>
</tr>
<tr>
<td>Heavy Trucks</td>
<td>3 or more axles and generally &gt;26,400 lb (12,000 kg)</td>
</tr>
<tr>
<td>Buses</td>
<td>2 or 3 axles (designated for transportation of 9 or more passengers)</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>2 or 3 tires (with an open-air driver and/or passenger compartment)</td>
</tr>
</tbody>
</table>

Notes:
1. The definitions for these vehicle categories are intended for U.S. applications, including the FHWA Traffic Noise Model (FHWA-PD-96-009, FHWA-PD-96-010) and its vehicle noise emission database (FHWA-PD-96-008). The vehicle category definitions can be found in those references as well as the FHWA highway noise measurement manual (FHWA-PD-96-046).
2. Only vehicles that clearly fall within any of the types described in this Section shall be measured. Where there is any doubt in classifying a vehicle, the measurement for that vehicle shall be discarded from the study.

3.1.13. **vehicle noise**—the total noise from a vehicle, including a combination of noise generated by the tire/road interaction (tire/pavement noise), air turbulence, and the powertrain.

### 4. SUMMARY OF TEST METHOD

4.1. A-weighted, time-integrated sound pressure levels, traffic volumes, speeds, and vehicle categories, and meteorological data are measured continuously on the side of a roadway for a period of time that captures enough data to properly represent the site.

4.2. The acoustical, traffic, and meteorological data measurements are repeated at the same site at a later time to determine either: (1) the difference in sound levels before and after the application of a new surface on the highway; or (2) the difference in sound levels as the pavement on a highway ages. For comparison purposes, traffic and site conditions between data sets should be similar; for example, measuring at the same time of day, weekday or weekend, and the same time of year all help to minimize variation.

4.3. To allow for comparisons between data sets, the measured sound levels are normalized for differences due to variations in traffic using the FHWA Traffic Noise Model (TNM) (FHWA-PD-96-009 and FHWA-PD-96-010), or another model. Traffic data are input into the
model to predict the sound levels for the same period of time that the acoustical data were captured and to determine any sound level adjustments necessary to remove traffic variation influences.

Note 1—This procedure does not currently allow for site-to-site comparison.

4.4. The method is detailed below, and additional CTIM considerations are available in a memorandum to FHWA dated April 20, 2017, “Additional Considerations for AASHTO Standard Methods of Test TP 98 (SIP) and TP 99 (CTIM).” The memorandum is available at: http://downloads.transportation.org/TP98-TP99/SIP_CTIM_Considerations_Memo.pdf

5. SIGNIFICANCE AND USE

5.1. This CTIM procedure provides a measure of the influence of road surfaces on traffic noise at a specific site adjacent to a roadway and allows for the comparison of different pavement conditions at a specific site, either due to changes over time or through the application of a new pavement surface.

5.2. CTIM measurements capture the sound from existing traffic for all vehicles on all roadway lanes and include propagation effects over the roadway pavement and adjacent terrain to the nearby measurement location. Although it may be possible to compare results across studies through the use of noise modeling to reduce site and traffic differences, the procedure for such comparisons is not included in this standard at this time.

5.3. The CTIM procedure reports broadband A-weighted, time-integrated sound pressure levels. While it is possible to measure one-third octave band levels in conjunction with the broadband levels, methods to analyze the one-third octave band data are not included in this procedure.

5.4. CTIM should be applied on roadways with continuously flowing and sufficiently dense traffic that sound levels from single vehicles cannot easily be captured due to sound contamination from other vehicles. In situations where lower traffic volumes allow for the measurement of single vehicle pass-by events without contamination from other vehicles, TP 98, Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method, or other similar method should be applied. The appropriate measurement technique should be selected based on site and traffic conditions.

5.5. The CTIM test procedure may be used in conjunction with the on-board sound intensity (OBSI) method described in T 360 that measures the tire/pavement component of vehicle noise exclusively.

6. APPARATUS

6.1. Sound Level Instrumentation—The sound level meter (or equivalent measuring system) shall meet the requirements of a Class 1 instrument according to IEC 61672-1.

Note 2—It is recommended to use a pressure response/random incidence microphone at grazing incidence (i.e., vertical orientation); see Figure 1. Microphone positions are discussed in Section 10.
6.2. **Windscreens**—A windscreen that does not detectably influence the measured sound levels shall be used.

6.3. **Frequency Analysis Instrumentation**—Frequency analysis of the measured sound using one-third octave-band resolution is recommended, but not mandatory. The frequency range of 50 to 10,000 Hz (center frequencies of one-third octave bands) shall be covered. The one-third octave-band filters shall conform to IEC 61260.

6.4. **Calibration Instrumentation**—The acoustic calibration device used shall meet the requirements of a Class 1 instrument according to IEC 60942. (Note that some calibrators require correction for environmental conditions. The manufacturer’s specifications should be consulted.)

6.5. **Vehicle Speed Measurement Instrumentation**—The average vehicle speed for each lane of travel shall be determined. A list of measuring devices/methods is found in *Measurement of Highway-Related Noise* (FHWA-PD-96-046) and includes radar gun, stopwatch, light sensors, and pneumatic tubes. Care must be taken to avoid interfering with the sound level measurements, including actions that could influence driver behavior and/or generating any intrusive noise caused by a measurement device. The vehicle speed measuring instrument(s) shall have an accuracy of ±1 mph (±1.6 km/h) for the range of speeds of interest.

6.6. **Temperature Measurement Instrumentation**—The air temperature measuring instrument(s) shall have an accuracy of ±2°F (±1.2°C). Meters using an infrared technique shall not be used to measure air temperature.

6.7. **Traffic Counting Instrumentation**—Traffic volumes shall be collected. Traffic-counting instrumentation or methods shall not interfere with noise measurements.

6.8. **Wind Measurement Instrumentation**—The wind speed measuring instrument(s) shall have an accuracy of ±2 mph (±0.9 m/s). The wind direction measuring instrument(s) shall have an accuracy of ±10 degrees.

7. **SELECTION OF TEST SITES**

7.1. The following considerations apply for site selection:

7.1.1. Each road test section shall extend for a distance of at least four times the distance from the center of the near travel lane to the microphone location in both the up- and down-stream directions from the microphone location. For example, for a microphone located at a distance of 50 ft (15.2 m)
from the center of the near travel lane, the road test section must extend 200 ft (61 m) in each direction.

7.1.2. The road shall be essentially level and straight. Horizontal curves should be avoided when possible. Roadway geometry and approximate grade shall be noted.

7.1.3. A test section shall have the same nominal material and surfacing for its length. The road surface should be homogeneous over the entire test section and the test section should be representative of the road under study. The condition of the road should be documented with pictures of the typical surface included when possible.

For example, if the pavement is generally free of distress, the test section should be selected to exclude any portion of pavement that exhibits surface cracking, bleeding, or excessive stone loss. If, however, pavement distress is prevalent, then the test section should include these same distresses.

7.1.4. It is recommended that the On-Board Sound Intensity (OBSI) Method (AASHTO T 360) be applied to help determine potential CTIM locations to represent a roadway section; the best locations would be those with OBSI levels most prevalent in the roadway section of interest. OBSI testing may reveal variations in pavements that appear homogeneous from visual inspection. **Note 3**—The noise characteristics of some road surfaces change quickly after opening for traffic. Changes in noise characteristics of newly constructed surfaces (aged less than 2 to 6 months) may not represent aging effects over the lifespan of the pavement.

7.1.5. The road surface shall be free of extraneous material, such as gravel or road debris to the extent practical.

7.1.6. The site shall consist of an open space free of large sound reflecting surfaces that could affect the CTIM measurements, such as parked vehicles, signboards, buildings, hillsides, safety barriers (or any other type of barrier), and guardrails. The line-of-sight from the microphone(s) to the roadway shall not be obscured within an arc of 120 degrees.

7.1.7. The ground surface between the roadway and the microphone(s) should consist of relatively flat and acoustically hard terrain (e.g., pavement, hard ground). The ground surface and any foliage located between the roadway and the microphone(s) shall be documented, and foliage should be consistent from one data set to the next.

7.1.8. The site shall be located away from intersections, lane merges, or any other features that would cause traffic to accelerate or decelerate, so that measured vehicles are operating under cruise conditions.

7.1.9. The site should be located away from known intrusive noise sources that could influence the noise measurements, such as airports, construction sites, rail yards, or other heavily traveled roadways.

7.2. **Additional considerations for site selection:**

7.2.1. The availability of a nearby overpass (or side-of-the-road alternative) can be useful for traffic counting purposes.

7.2.2. For long-term pavement studies, it is beneficial to select a site that is expected to have minimal physical or operational changes that could bias the results. (Refer to Appendix X2.)

7.2.3. It may be possible to use the paired measurement technique by collecting data simultaneously at two or more contiguous sites, which could reduce uncertainty when comparing multiple sites due to the elimination of differences in traffic composition and meteorological conditions. (Refer to Appendix X3.)
8. TRAFFIC CONDITIONS

8.1. Measurements should be conducted for continuous and freely flowing traffic at a constant speed. For sparsely trafficked roadways, where traffic can be infrequent and/or inconsistent, another measurement method, such as TP 98, Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method, may be more appropriate.

9. METEOROLOGICAL CONDITIONS AND INFLUENCES

9.1. Wind—Acoustical measurements shall not be made when the wind speed at the primary microphone position exceeds 11 mph (5 m/s), regardless of wind direction. It may be useful to monitor and record the wind velocity (direction and speed) to help explain discrepancies between data, e.g., due to propagation effects. Measured sound levels shall not be adjusted for possible variations caused by wind. If examining wind direction, it must be noted in relation to the roadway orientation in order to understand its effects on sound levels.

9.2. Air Temperature—The air temperature shall be recorded at least once for each analysis time block. For pavement comparison studies, average air temperatures for the time blocks included in the measurement period should be within ±7°F (±4°C) from one data set to the next in order to increase precision and minimize the influence of temperature on sound levels. Measured sound levels shall not be adjusted for possible variations caused by temperature.

9.3. Sky Condition—The sky condition (for example, clear, scattered clouds, partly cloudy, mostly cloudy, or overcast) during the measurement period should be recorded at least once per hour.

9.4. Pavement Moisture—Measurements shall only be made when the road surface is visibly dry.

10. MICROPHONE POSITIONS

10.1. The same measurement position shall be used during all site visits.

10.2. Preferred Measured Location—The preferred measurement location is 50 ft (15 m) from the center of the near travel lane, 12 ft (3.7 m) above the center of the near travel lane, and at least 5 ft (1.5 m) above the elevation of the ground surface.

10.3. Alternate Measurement Location—In situations where the 50 ft (15 m) position would not be feasible due to site or other considerations, another location could be used. The alternate primary measurement location shall be between 50 and 100 ft (15 and 30 m) from the center of the near travel lane, at least 5 ft (1.5 m) above the elevation of the ground surface, and at least 12 ft (3.7 m) above the center of the near travel lane.

10.4. Additional Microphones—Additional microphones can be placed at distances farther from the roadway in order to capture the pavement influences at those locations; additional microphones are encouraged since it is known that propagation effects change the influence of pavements, especially at higher frequencies (1000 to 5000 Hz).

10.5. Meteorological Conditions—Meteorological conditions can significantly affect sound levels and sound propagation at positions beyond 50 ft (ANSI S12.8).
11. **CALIBRATION AND STANDARDIZATION**

11.1. At the beginning of the measurements, and following all warm-up procedures specified by the manufacturer, the sound level measurement system shall be field calibrated using an acoustic calibrator or piston phone.

11.2. At a minimum, verification shall be conducted no earlier than 1 h before and no later than 1 h after the measurement period. Additional verification shall be conducted during the course of the measurements so that the maximum period between verification checks does not exceed 4 h.

11.3. The measurement system shall be adjusted for accuracy according to the manufacturer’s instructions. The results of all measurement system accuracy checks shall be recorded in the test report. If the results of any two consecutive verification checks during the measurement period differ by more than 0.5 dB, the testing between those checks shall be considered invalid.

12. **PROCEDURE**

12.1. **Sound Level Measurement**—A-weighted sound levels are measured continuously using sound level meters or spectrum analyzers. (Refer to ANSI S1.42 for weighting networks.) Audio recordings can allow for later analysis, but are not required. The sound levels will be used to calculate equivalent sound levels in the specified analysis time blocks, either directly from field measurements or constructed after measurement from measured levels corresponding to sample periods.

12.2. **Frequency Spectrum Measurement (Recommended)**—It is recommended to measure A-weighted one-third octave-band frequency spectra. Refer to IEC 61260.

12.3. **Incident Noise Log**—During highway traffic noise data collection, a log shall be kept by a listener/observer noting any noise that could potentially contaminate the targeted highway noise data. Potential contaminating noise sources include aircraft flying overhead, train pass-bys, nearby construction, loud noises near the microphone such as talking or birds, extremely loud or unusual highway vehicles, etc. The start and stop time of any extraneous noise sources shall be logged and documented in the incident noise log.

12.4. **Traffic Measurement**—Traffic counts, vehicle types and speed data must be collected in such a way as to obtain the proper data for input in a highway noise prediction model. For the most accuracy, this includes knowing the vehicle counts and types and speeds for each lane of traffic. This can be accomplished through use of traffic counters, video cameras, and postprocessing systems and procedures. Traffic data shall be collected in time blocks that are shorter or equal to the length of the analysis time block, with a minimum sampling period for traffic data of 1 min. The traffic speed shall be reported as an average per traffic lane. In addition to traffic composition, the percentage of heavy trucks, as compared to the total volume of all vehicle categories, shall be noted. Refer to FHWA-PD-96-009 and FHWA-PD-96-010.

12.5. **Air Temperature Measurement**—The air temperature sensor shall be positioned in the vicinity of the microphone position(s), in such a way that it is exposed to the airflow, protected from direct solar radiation, and causes no influence on the measured sound levels. If continuous monitoring is not available, the air temperature shall be measured at a minimum time block that is shorter than or equal to the length of the analysis time block. Limitations on temperature are equipment specific, and manufacturer’s specifications should be followed.

12.6. **Wind Measurement**—The wind sensor shall be positioned in the vicinity of the microphone position(s), in such a way that it is exposed to the airflow and causes no influence on the measured
sound levels. The wind shall be monitored to ensure that the wind speed at the microphone during sound level data collection does not exceed 11 mph (5 m/s), regardless of wind direction.

12.7. Additional Meteorological Data Measurement—If documented, sky condition, relative humidity, and wind direction should be collected in time blocks that are shorter than or equal to the length of the analysis time block.

13. CALCULATION OF RESULTS

13.1. Summary of Analysis Method:

13.1.1. The measured acoustical, traffic, and meteorological data are combined into analysis time blocks. Analysis time blocks that were observed to include contamination from nonhighway noise sources, slowed or unusual traffic conditions, or wind speeds in excess of 11 mph (5 m/s) are eliminated. Traffic noise levels for the remaining analysis time blocks are then modeled using an appropriate traffic noise model. Deltas between the measured and modeled noise levels for each analysis time block are compared to the average delta for the associated measurement period, and data that do not fall within the given tolerances are eliminated from the data set.

Note 4—The measurement period should be selected based on site factors including uniformity and flow of traffic, stability of meteorological conditions, and the amount of contamination from nonhighway noise sources.

13.1.2. Normalization values for each analysis time block are determined by modeling traffic data for each analysis time block. For each measurement site, a “control” data block is selected as the average $L_{eq}$ of all modeled analysis blocks for the first measurement period. All analysis time blocks for all data sets are then normalized to this “control” data block by first calculating the differences, or normalization values, between the “control” data block and every other analysis time block and then applying each calculated normalization value to each corresponding analysis time block. This same “control” data block is used for data collected in all measurement periods conducted over time.

13.1.3. Once normalization is complete for each analysis time block within a data set, reporting time blocks are constructed. The (arithmetic) average sound levels (average of reporting time blocks) for each data set are calculated. The averages from one data set to the next are then compared. Both the normalized sound levels and the differences, or deltas, between data sets are reported.

13.2. Detailed Analysis Process—Refer to Appendix X4 for an example and see Figure 2 for guidance.

13.2.1. Construction of Analysis Time Blocks from Data Samples (Step 1)—Once acoustical, traffic, and meteorological data have been collected in their respective sampling periods, the data shall be organized into time blocks of equivalent length, called analysis time blocks. Acoustical data shall be combined into analysis time blocks through computation of the energy average sound pressure level, $L_{eq}$, occurring over the assigned analysis time block. Traffic volumes shall be summed arithmetically over the analysis time block. Traffic speed, wind speed, and air temperature shall be arithmetically averaged. Sky condition noted should be the one dominant during the analysis time block (if dominance cannot be determined, it should be noted as “variable”). If the selected sample period coincides with the selected length of the analysis time block, this step is not needed.

13.2.2. Elimination of Contaminated Noise Level Data (Step 2)—Based on review of the incident noise log, any analysis time blocks in which sound sources other than the targeted highway may have contaminated the sound levels shall be eliminated from the data set. Analysis time blocks that include periods of time where reduced travel speeds occurred, when traffic would not be considered free flowing, or when peak wind speeds exceed 11 mph (5 m/s) shall also be eliminated. (Refer to Appendix X5.)
13.2.3. Traffic Noise Modeling (Step 3)—In order to compare two sets of data, it is necessary to model the site and traffic and predict the sound level at each of the measurement locations. The modeling can be accomplished using the FHWA Traffic Noise Model with Average pavement (FHWA-PD-96-009 and FHWA-PD-96-010).

13.2.3.1. Traffic noise modeling is done for each analysis time block, excluding any that were eliminated in the previous steps. All features that could affect modeled sound levels should be included in the model. For the near direction of travel, individual lanes and a roadway shoulder should be included in the model to maximize accuracy. (Note: Modeling practices may affect differences between modeled and measured noise levels.)

13.2.4. Elimination of Noise Level Data Outliers (Step 4)—The difference between the measured and modeled $L_{eq}$ noise levels for each analysis time block shall be calculated by subtracting the measured noise level from the modeled level. These differences shall be known as “deltas.” In addition to calculating the delta for each analysis time block, the arithmetic average delta for each measurement period of the analysis time block deltas shall also be calculated.

13.2.4.1. Any analysis time block in which the difference between the delta and the average delta for the associated measurement period exceeds a tolerance of $\pm 1.5$ dB, based on a 15-min analysis time block length, or $\pm 2$ dB, based on a 5-min analysis time block length, shall be eliminated from the data set. If analysis time blocks are removed based on this assessment, the average delta will need to be recalculated, using only the accepted analysis time block data.

13.2.5. Definition of Control Block (Step 5)—The average modeled $L_{eq}$ of all analysis blocks occurring over the first measurement period or data set that meet the data quality criteria specified in Sections 13.2.2 and 13.2.5 shall be calculated using an arithmetic average computation method. This average modeled $L_{eq}$ will be defined as the “control block.” This control block is used for normalization of the remaining analysis data blocks for all data sets.

13.2.6. Calculation of Traffic Normalization Values from Control Block (Step 6)—The difference between the modeled control block and modeled $L_{eq}$ noise levels for each analysis time block shall be calculated by subtracting the modeled noise level from the modeled control block. These sound level differences account for differences in traffic between the control block and each analysis time block and will be used to normalize the data for variations in traffic.

13.2.7. Calculation of Normalized Measured Leq Sound Levels (Step 7)—The normalized measured $L_{eq}$ sound level for each analysis time block shall be calculated by adding the calculated normalization value (as calculated in Section 13.2.6) to the measured $L_{eq}$ for that time block.

13.2.8. Construction of Reporting Time Blocks from Analysis Time Blocks (Step 8)—Analysis time blocks of acoustical, traffic, and meteorological data shall be combined into reporting time blocks. Acoustical data, including measured, modeled, and normalized (measured) $L_{eq}$ sound levels, shall be combined into reporting time blocks through computation of the energy average sound pressure level, $L_{eq}$, occurring over the assigned reporting time block. In addition, the deltas between modeled and measured (modeled minus un-normalized measured) shall be calculated for each reporting block. Traffic volumes shall be summed arithmetically over the reporting time block. Traffic speed, wind speed, and air temperature shall be arithmetically averaged, and sky condition should be noted as the one dominant during the reporting time block (if dominance cannot be determined, it should be noted as “variable”). If the length of the analysis time block coincides with the length of the reporting time block, this step is eliminated.

13.2.9. Calculation of Averages for a Data Set (Step 9)—Using all valid reporting data blocks for a measurement period, data set, or both, calculate the arithmetic average for the following parameters: measured $L_{eq}$ sound level, modeled $L_{eq}$ sound level, delta between measured and modeled sound levels, normalized measured $L_{eq}$ sound level, wind speed, air temperature, all-lanes
traffic speed, and all-lanes percentage heavy trucks. In addition, the “average” sky condition is determined by the dominant condition or noted as “variable” if dominance cannot be determined.

13.2.10. Calculation of Sound Level Differences between Data Sets (Step 10)—The difference between the average normalized measured data for this data set and the average normalized measured data for the first data set shall be calculated using the average normalized measured $L_{eq}$ sound level calculated in Section 13.2.9 from each data set. (This step applies to all but the first data set.)

13.2.11. Comparing Percentage of Heavy Trucks between Data Sets (Step 11)—Calculate the percentage heavy trucks for all lanes of traffic for each valid reporting time block. Using the calculated percentage of heavy trucks for average traffic of each data set from Section 13.2.10, compare heavy truck percentages to previous data sets (where applicable). If the difference in the percentage of trucks between data sets exceeds 5 percent, it shall be noted and reported.

**Note 5**—Differences in truck percentages may affect the comparability of the results.

13.2.12. Comparing Vehicle Speeds between Data Sets (Step 12)—Calculate the average vehicle speed for all lanes of traffic for each valid reporting time block. Using the calculated average vehicle speed for each data set from Section 13.2.9, compare average vehicle speed to previous data sets (where applicable). If the difference in the average vehicle speed between data sets exceeds 10 mph (16 km/h), it shall be noted and reported.

**Note 6**—Differences in vehicle speeds may affect the comparability of the results.

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**Figure 2**—Summary of Data Analysis for CTIM Analysis Process

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**Comment [j1]:** Updated shape of steps 11 and 12 to “calculation.” Note this is the color version – can be modified to grey scale if needed.
14. REPORTED DATA

14.1. The test report shall include the following general data:

14.1.1. Time of day and date of measurement period;

14.1.2. Organization and operators responsible for the measurement;

14.1.3. Components of the measurement system, including instrumentation used to collect acoustical, traffic, and meteorological data;

14.1.4. Information related to location of the test site, including the route, designation, and direction of travel of the vehicles, and either the GPS coordinates for the microphone position(s) or a description of the location using the official agency mileage reference system and landmark indicators;

14.1.5. Information and photo documentation related to the measurement equipment set up and appearance of the test site, including geometry of the site plan (horizontal and vertical) with microphone location(s), documentation of the ground surface and any foliage located between the roadway and the microphone(s), and any acoustically reflective surfaces or other objects that could potentially affect the sound measurements; and

14.1.6. Information related to the surface type and treatment, the age and condition of the pavement section, and any notes regarding the homogeneity of the surface. Pavement texture and mixture information (e.g., maximum aggregate size, air voids) should be provided if available. Scaled photographs should be included if possible.

14.2. The test report shall include the following acoustical data:

14.2.1. Results of sound level measurement system verification (using calibration device) conducted prior to, after, and during each measurement period;

14.2.2. For each reporting time block for each data set: measured $L_{eq}$ sound level, delta between measured and modeled sound levels, and normalized measured $L_{eq}$ sound level. Values shall be reported in both broadband (A-weighted) and one-third octave-band level, when captured;

14.2.3. Data averages for each data set: measured $L_{eq}$ sound level, delta between measured and modeled sound levels, normalized measured $L_{eq}$ sound level; and

14.2.4. Difference between data sets: when comparing data sets, report the difference in normalized measured $L_{eq}$ sound levels.

14.3. The test report shall include the following traffic data—The number of vehicles measured in each type, percentage of heavy trucks, and the average traffic speed for each lane for each reporting time block. When comparing between data sets, differences in the percentage of heavy trucks and vehicle speed for the average traffic data shall be reported.

14.4. The test report shall include the following meteorological data—The average air temperature for each reporting time block and for each data set shall be reported. Reporting of wind speed, wind direction, humidity, and sky condition is optional. When comparing between data sets, differences in average air temperature shall be reported.

14.5. The test report shall include the following—The model or methodology, or both, that was used to do the normalization, including descriptions of the emission levels database and the modeled
geometry (number of lanes and terrain features, along with the site model plan view and skew view in line with the microphone position(s), if available).

15. PRECISION AND BIAS

15.1. Precision—Not available at this time.

15.2. Bias—Not available at this time.

15.2.15.3. Additional information about precision and bias for this method is available in a memorandum to FHWA dated April 20, 2017, “Additional Considerations for AASHTO Standard Methods of Test TP 98 (SIP) and TP 99 (CTIM).”

16. KEYWORDS

16.1. Noise measurement; pavement noise; vehicle noise; traffic noise; wayside.
APPENDIXES

(Nonmandatory Information)

X1. REFERENCED DOCUMENTS

The following references were used or referred to in the preparation of this text:

X1.1.1. AASHTO Standards:
- T 360, Measurement of Tire/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method
- TP 98, Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method

X1.1.2. FHWA Documents:
- FHWA-PD-96-008, Development of National Reference Energy Mean Emission Levels for the FHWA Traffic Noise Model (FHWA TNM®), Version 1.0
- FHWA-HEP-11-005, Temperature Effects Study

X1.1.3. TRB Documents:

X2. HOW TO ADDRESS SITE CHANGES

X2.1. For measurements over time at the same site, it is ideal that no site changes occur, such as the addition of traffic lanes or changes in the terrain between the highway and microphone location. Such changes complicate the comparison of one set of data to the next. Depending on the type of site change, it may be possible to continue data comparisons through the use of modeling techniques or alternate measurement locations. Two methods have been used historically to adjust the data with the site change to that prior to the site change.

X2.2. If advance notice of the site change is given, monitoring at the site prior to and after the site change at dates, times, weather conditions, and traffic conditions that are as similar as practical should be taken. If available, measurements at an alternate nearby site (same highway, same pavement, same pavement age, almost identical traffic, etc.) should be taken simultaneously to the measurements at the original site. Measurements and noise modeling would be done in accordance with the standard method of test to normalize the data for variations in traffic. Depending on the calculated sound level differences between data sets, this difference should be applied to all future data made after the site change to adjust that data to the original site data or, if the difference was found to be negligible, simply noted in the project file.
Depending on the noise model selected and the type of site change, it may be possible to simply model the site difference using the model with all other inputs to the model being identical. The resulting modeled difference could then be applied to all future data made after the site change to adjust that data to the original site data or, if the difference was found to be negligible, simply noted in the project file. Note that adjusting the data for site changes will reduce the accuracy of the results and that these types of adjustments should be made only for small changes in the site, as determined by the experience of the noise professional conducting the study. All adjustments need to be well documented in the project file, test report, and in any project documentation.

X3. PAIRED MEASUREMENTS

X3.1. In the traditional CTIM procedure, measurements are made on a single section of pavement over time and/or before and after the application of a new pavement. In situations where multiple test surfaces occur along a continuous section of roadway, it may be possible to use a “paired” measurement technique in place of the traditional measurement method. With “paired” measurements, acoustical and traffic data at two or more nearby contiguous sites can be collected simultaneously to allow for comparison between sites of similar traffic and geometric conditions with different pavement types.

X3.2. In the case of “paired” measurements:

X3.2.1. All test sites should be largely similar in geometry, aside from roadway surface (e.g., numbers of lanes, median widths, shoulder widths, relative elevations of directional roadways and measurement locations, and microphone distances).

X3.2.2. Speed and noise level measurements must be made at or near each microphone location.
X4. EXAMPLE OF DATA ANALYSIS PROCESS

X4.1. This appendix provides an example of the data analysis process described in Section 13 of the CTIM specification, Steps 1–9 (this is the process for a single data set; Steps 10–12 compare data sets, not shown in example). An Excel spreadsheet that includes these calculations is available at: http://downloads.transportation.org/TP98-TP99/CTIM_example_calculations.xls on request from AASHTO.

X4.2. CTIM Data Analysis Process, Steps 1–9:

X4.2.1. Construction of Analysis Time Blocks from Data Samples—This example shows 12 analysis data blocks. One-minute contiguous acoustical samples, $L_{eq}$s, were combined to form 5-min analysis data blocks. Wind speed, air temperature, and traffic data were also combined into corresponding 5-min analysis data blocks. Note that only one lane of traffic is shown in this table; the “etc.” in the last column represents the other lanes of traffic.

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<th>Air Temperature</th>
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<td>87</td>
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<td>19</td>
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<td>87</td>
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<td>77</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>67</td>
</tr>
</tbody>
</table>

X4.2.2.
Elimination of Contaminated Noise Level Data—The data block from 8:45 to 8:50 is eliminated because there was extraneous noise during this analysis data block that contaminated the highway traffic noise (an aircraft flew overhead). The data block from 8:50 to 8:55 is eliminated because the wind speed exceeded 11 mph. (See highlighted rows.)

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Stop Time</th>
<th>$LA_{eq}$, 5 min</th>
<th>Wind Speed</th>
<th>Air Temperature</th>
<th>Sky Condition</th>
<th>Counts</th>
<th>Speed</th>
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<tbody>
<tr>
<td>8:00:00</td>
<td>8:05:00</td>
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<td>1.7</td>
<td>86</td>
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<td>70</td>
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<td>1.1</td>
<td>86</td>
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<td>7</td>
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<td>1.5</td>
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<td>Scattered clouds</td>
<td>77</td>
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</tbody>
</table>
**Traffic Noise Modeling**—Using the FHWA Traffic Noise Model (TNM), the 5-min A-weighted $L_{eq}$ is predicted for each of the remaining analysis data blocks (sound levels shown in the “modeled” column). Note: Since TNM predicts 1-h A-weighted $L_{eq}$, the 5-min traffic data needs to be multiplied by 12 when entering the data into TNM in order to get the proper predictions. (See highlighted column.)

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Stop Time</th>
<th>$L_{eq}$, 5 min</th>
<th>Wind Speed</th>
<th>Air Temperature</th>
<th>Sky Condition</th>
<th>Autos</th>
<th>Medium Trucks</th>
<th>Heavy Trucks</th>
<th>Buses</th>
<th>Motorcycles</th>
<th>Speed</th>
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<tbody>
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<td>85</td>
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<td>79</td>
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<tr>
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<td>8:15:00</td>
<td>75.8</td>
<td>1.3</td>
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</tr>
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<td>8</td>
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<td>0</td>
<td>67</td>
</tr>
</tbody>
</table>

X4.2.4.
Elimination of Noise Level Data Outliers—The delta (modeled minus measured) sound level is calculated for each analysis data block, then the arithmetic average delta is calculated (last row of table). Following that, the difference between each delta and the average delta is calculated. Since 5-min analysis data blocks are being examined, and none of the differences between the delta and the average delta exceeds 2 dBA, no data blocks are eliminated in this step. (See highlighted columns.)

### Microphone Position: 50 ft

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Stop Time</th>
<th>$L_{A_{eq}}$ 5 min (dBA)</th>
<th>Wind Speed (mph)</th>
<th>Air Temperature (°F)</th>
<th>Sky Condition</th>
<th>Counts Autos</th>
<th>Counts Medium Trucks</th>
<th>Counts Heavy Trucks</th>
<th>Counts Buses</th>
<th>Counts Motorcycles (mph)</th>
<th>etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00:00</td>
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<td>5.7</td>
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<td>9</td>
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<tr>
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</tbody>
</table>

X4.2.5. **Definition of Control Block**—The control block is defined as the average modeled sound level, which is shown in the last row of the table in Step 4, highlighted in blue.

X4.2.6.
Calculation of Traffic Normalization Values from Control Block—For each of the valid analysis data blocks, the modeled sound level is subtracted from the control block sound level (calculated in Step 5) to determine the normalization value for each analysis data block. (See yellow-highlighted column.)

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Stop Time</th>
<th>LA&lt;sub&gt;eq&lt;/sub&gt;, 5 min (dBA)</th>
<th>Wind Speed (mph)</th>
<th>Air Temperature (°F)</th>
<th>Sky Condition</th>
<th>Counts</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Modeled</td>
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<td>Normalized</td>
<td>Measured</td>
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<td>86</td>
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<td>80.9</td>
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<td>75.1</td>
<td>1.1</td>
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<td>8:35:00</td>
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<td>81.5</td>
<td>-0.7</td>
<td>74.9</td>
<td>1.5</td>
<td>87</td>
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<td>75.5</td>
<td>2.3</td>
<td>87</td>
</tr>
</tbody>
</table>

X4.2.7. Calculation of Normalized Measured L<sub>eq</sub> Sound Levels—The normalized measured L<sub>eq</sub> sound levels are then calculated for each analysis time block by adding the normalization values to the measured L<sub>eq</sub> sound levels. (See the blue-highlighted column in the table in Step 6.)

X4.2.8. Construction of Reporting Time Blocks from Analysis Time Blocks—Fifteen-minute analysis data blocks are then constructed from the 5-min data blocks using an energy average for the measured, modeled, and normalized sound levels, an arithmetic average for the meteorological data (except sky condition, where dominance is applied) and traffic speeds, and addition of volumes for the traffic. For all lanes of traffic, an average speed and percentage heavy trucks are also calculated and appended for each reporting time block (not shown). The measured sound level is then subtracted from the modeled sound level to determine the delta for each reporting time block. Note that since there was only one 5-min analysis time block remaining from 8:45 to 9:00, that 15-min data block is not constructed or reported.
## Appendix D

### Traffic Data Measurement Side—Lane 1 etc.

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Stop Time</th>
<th>$L_{A_{eq}}$ 5 min (dBA)</th>
<th>Wind Speed (mph)</th>
<th>Air Temperature ($^\circ$F)</th>
<th>Sky Condition</th>
<th>Counts</th>
<th>Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>79.9</td>
<td>5.5</td>
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<td>75.8</td>
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<td>5.2</td>
<td>75.7</td>
<td>86</td>
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</tr>
<tr>
<td>8:30:00</td>
<td>8:45:00</td>
<td>75.7</td>
<td>81.6</td>
<td>5.9</td>
<td>75.0</td>
<td>87</td>
<td>Scattered clouds</td>
</tr>
</tbody>
</table>

| Average   | 75.3      | 80.8                     | 5.5              | 75.3                        | 86            | Clear  |

### Calculation of Averages for a Data Set

Arithmetic averages are calculated for each of the following: measured $L_{A_{eq}}$ sound levels, modeled $L_{A_{eq}}$ sound levels, delta between measured and modeled $L_{A_{eq}}$ sound levels, normalized measured $L_{A_{eq}}$ sound levels, wind speed, air temperature, average traffic speed, and percentage heavy trucks. In addition, the “average” sky condition is determined by the dominant condition or noted as “variable” if dominance cannot be determined; in this case the dominant condition was “clear.” (Averages are shown in highlighted cells in the previous table; averages for traffic speed and percentage of heavy trucks are not shown.) Note that the delta sound level in this example indicates that the road tested is 5.5 dBA quieter than TNM average pavement. The normalized measured sound level of 75.3 dBA would be compared to other data sets to determine sound level differences with different pavements at the site tested or aging pavement over time.

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**X4.2.9.**

Calculation of Averages for a Data Set—Arithmetic averages are calculated for each of the following: measured $L_{A_{eq}}$ sound levels, modeled $L_{A_{eq}}$ sound levels, delta between measured and modeled $L_{A_{eq}}$ sound levels, normalized measured $L_{A_{eq}}$ sound levels, wind speed, air temperature, average traffic speed, and percentage heavy trucks. In addition, the “average” sky condition is determined by the dominant condition or noted as “variable” if dominance cannot be determined; in this case the dominant condition was “clear.” (Averages are shown in highlighted cells in the previous table; averages for traffic speed and percentage of heavy trucks are not shown.) Note that the delta sound level in this example indicates that the road tested is 5.5 dBA quieter than TNM average pavement. The normalized measured sound level of 75.3 dBA would be compared to other data sets to determine sound level differences with different pavements at the site tested or aging pavement over time.
X5. EXAMPLES OF HOW TO ELIMINATE ANALYSIS DATA BLOCKS DUE TO CONTAMINATION FROM ATYPICAL HIGHWAY NOISE SOURCES OR OTHER NONHIGHWAY NOISE SOURCES

X5.1. To ensure that highway noise measurements represent typical traffic, it is important to identify noise events that could potentially adversely influence measured sound levels. As such, listener/observer logs are used during measurements to help determine if any data need to be eliminated due to contamination. The CTIM procedure and calculation of results sections of the main text describes the necessary information to log, and this appendix describes the data analysis process to determine if contamination may have occurred. (Potential contaminating noise sources include aircraft flying overhead, nearby construction, loud noises near the microphone such as talking or birds, extremely loud or unusual highway vehicles, etc.)

X5.2. For an extraneous noise source to be considered to contaminate an analysis time block, the noise level of the extraneous event must be of a level that is high enough above typical noise generated for the roadway of interest and for a length of time that is long enough that the average traffic noise level over the analysis time block could be affected. Contamination is determined by comparing the noise level during an extraneous noise event to typical noise for the highway of interest, including noise just before and after the extraneous event. Both noise level and duration of the extraneous event are important, as a louder extraneous noise source would require a shorter duration of time to contaminate the analysis time block. For example, if a car honks its horn for 1 s during a 5-min analysis time block, it is highly unlikely that the average highway traffic noise level over 5 min will be affected, so it is unnecessary to log the 1-s honking as a potentially contaminating extraneous noise event. However, if a train horn sounded near the microphone location for 1 s during a 5-min analysis time block, it may be at a level high enough to potentially contaminate the data and should be logged.

X5.3. Based on real-time display on sound measurement equipment, typical highway traffic noise levels, as well as noise levels generated during extraneous noise events, are observed and recorded. Determination can be made as to whether or not an extraneous noise source may have contaminated an analysis time block either in real time while conducting measurements or during postprocessing. Following are some examples of how contamination can be identified and eliminated. One or more of these methods can be used for any noise measurement data set.

X5.4. Identification of Contamination Based on Analysis Time Block Noise Levels—Sound levels of the analysis time block in which the extraneous noise occurred are compared to typical noncontaminated analysis time block sound levels, as well as to the analysis time blocks immediately preceding and following the analysis time block of question, during either postprocessing or in real time. If an analysis time block in which an extraneous noise event occurred is found to be 1 dB or more above the typical analysis time block sound levels and 1 dB or more above the sound levels of the analysis time blocks immediately preceding and following the analysis time block of question, the entire analysis time block in which the extraneous noise event occurred is eliminated.

X5.5. Postprocessing Identification of Contamination Based on Noise Level of Extraneous Event—First, the equivalent sound level for the extraneous noise event is calculated, then the equivalent sound level 30 s before and after the extraneous noise event is calculated. The extraneous event sound level is compared to the surrounding sound level, and if the difference is 3 dB or greater, the entire analysis time block in which the extraneous noise event occurred is eliminated.

1 This provisional standard was first published in 2011.
MEMORANDUM

To: Mark Ferroni, Adam Alexander, Aileen Varela-Margolles
Federal Highway Administration

From: Judy Rochat, ATS Consulting
Paul Donavan, Illingworth & Rodkin
Darlene Reiter, Bowlby & Associates

Date: April 20, 2017

Subject: Additional Considerations for AASHTO Standard Methods of Test TP 98 (SIP) and TP 99 (CTIM)

1. Introduction

As part of Task Order FHWA 23 CFR 772 Accelerated Process: Measurement and Modeling Techniques (DTFH61-11-D-00028 T5009), two AASHTO noise specifications were updated, and a summary of these test methods will be included in the updated FHWA measurement guidance document. Practitioners apply the test methods to determine the effects of pavement or road surfaces on vehicle noise (TP 98, also known as SIP) and traffic noise (TP 99, also known as CTIM). The full reference for each method is provided below:


There are additional considerations for both the SIP and CTIM methods that are not included in the formal test method documents. These considerations as provided below in Section 2 for SIP and Section 3 for CTIM. The information in each section includes suggestions for further development of the SIP and CTIM methods.

2. Considerations for SIP

The considerations discussed in this section would help to further define the SIP test method.

2.1 Precision and Bias Statements

Validated, comprehensive precision and bias statements are not available at this time for the SIP method.

National Cooperative Highway Research Program (NCHRP) Web-Only Document 217: Precision and Bias Statements for AASHTO Standard Methods of Test TP 98 and TP 99 describes a study conducted to develop precision and bias statements for SIP. The study describes that precision and bias are products of measurement variability due to different factors. The precision of a method is defined as the
closeness of agreement between individual test results. For the study, precision was examined in terms of repeatability and reproducibility. The bias of the method is defined as the difference between expected test results and an accepted reference value; for SIP, there is no accepted reference value since results are defined only in terms of the test method. In lieu of comparing to a reference value, the research team was able to estimate some limited components of bias in terms of the measurement environment. Although the study was able to produce precision and bias statements, the validity of the conclusions is compromised by three factors: 1) not all key sources of uncertainty were included in the analysis; 2) it is not clear if all the requirements of the procedures were followed; and 3) there is insufficient data available in the NCHRP report or its appendices to make a proper assessment of results for the sources of uncertainty that were examined. Therefore, the precision and bias statements in the report are not included as part of this method.

Further study is required to develop valid, comprehensive precision and bias statements. This could include further evaluation of the NCHRP study, obtaining more details from the researchers, and possible inclusion of results as part of a comprehensive evaluation. Further study would also need to include evaluation of more sources of uncertainty for a comprehensive examination. In addition to combined uncertainty, elements should be isolated to the extent possible to determine the cause (and possibly solution to) variations in the results. The sources of uncertainty that need to be included are listed below, with bolded items being highest priority to examine:

*Environmental effects*—Are the stated limits enough to minimize meteorological effects? Effects include **air temperature, wind speed and direction**, pavement moisture content, **temperature inversions**, and air density and humidity.

*Site geometry/other site factors*—**Ground effects**: is the ground similar enough site-to-site or over time?; are the limits adequate for site flatness, road grade, reflecting surfaces?

*Pavement within test section*—Are recommendations enough for a practitioner to choose a site that minimizes **effects due to variability of pavement for the roadway section under study**; how do lane-to-lane source level differences affect results?

*Microphone set-up*—Height and distance.

*Instrumentation differences*—Includes analyzers/sound level meters, microphone and preamplifiers, calibrators, and recording devices.

*Vehicle operations and identification*—Includes vehicle speed and vehicle type identification.

*Data elimination due to contamination or outliers.*

*Number of data points*—Effect of applying minimum versus greater numbers.

*Daily variation*—The range in reported values due to day-to-day variation of all parameters including environmental conditions, traffic mix, vehicle fleet, vehicle speeds, and set-up variation.

*Reproducibility for different measurement teams*—establish the bounds on reproducibility for independent teams making SIP measurements at the same site

Investigations for some of the above sources of uncertainty are included in other considerations listed in this section.
2.2 Microphone Position Sensitivity
There are currently two primary microphone positions for SIP, both being recommended but only one being required. A study should be done to determine: 1) results variation when using one, the other, or both of the primary positions; 2) how the REMEL (FHWA-PD-96-008) reference microphone position relates to the two primary positions, since the data collected are being compared to the reference; and 3) if the primary positions are ideally located [note: need to consider ground effects, practicality of achieving the position, and source proximity (for purposes of near-field effects and turbulence)]. Variations and recommendations can be included in the precision and bias analysis.

2.3 Data Processing Sensitivity
SIP data sets should be used to evaluate sensitivities due to the sound pressure level/speed pair selection, determination of designated speed, and background noise. Pair selection should be considered by adding and removing data pairs and recalculating the SIPI. The designated speed should be evaluated comparing the SIP data regression curve to the REMELs (TNM noise emission database, FHWA-PD-96-008) reference curve for a range of pavements and various vehicle categories. The variation based on number of events should be determined (as necessary for establishing precision and bias) and best practices to minimize variations should be developed. Variation in relation any other sensitivities should also be determined.

2.4 Temperature Sensitivity
The SIP method currently restricts data sets to have an average temperature within a particular range in order to minimize temperature influences when comparing results. This restriction is based on conclusions from the FHWA report Temperature Effects Study (FHWA-HEP-11-005). The range of variation applying the restriction should be formalized as necessary for establishing precision and bias. In addition, restrictions on absolute temperatures, 40 and 100°F (4 and 38°C), are listed. It should be investigated if this range of temperatures is too broad since the reference levels (FHWA-PD-96-008) were measured in a narrower range. Another element to consider is adding temperature corrections.

2.5 Spectral Analysis Details
Several alternatives for doing spectral analysis of SIP should be considered. These will likely include averaging spectra of vehicles with overall levels near the average speed, adjusting the spectra up or down using the regression of the level versus speed or the slope of the reference curve for the vehicle type, or patterning a method based on the methods used for the reference database. These and any other candidate methodologies could be applied to existing data and the results evaluated. Based on this evaluation, a method for inclusion in SIP could be developed.

2.6 Field Practice
A discussion of best practices to be used in the field for data collection in preparation of data analysis could be included as part of the method. The practices could include aspects of noise data collection, vehicle speed measurement, data synchronization, and considerations influencing driver behavior.

2.7 Field Form Examples
Examples of field forms for use in acquiring SIP data should be included. Several practitioners have applied SIP, and examples should be solicited, reviewed for SIP requirements, and included as examples for the method as appropriate.
2.8 Measurement Method Comparison
The “Significance and Use” section could be expanded to provide further guidance on when to use the different procedures for determining the influence of pavements, particularly the use of either SIP or CTIM. More explicit guidance could be provided on the limits of both procedures in terms of traffic volumes. Lower limit guidelines for CTIM and upper limits for SIP could be recommended and included in the methods.

2.9 Measurement Comparison between Teams
Ultimately, the overall certainty in the procedure is the ability of different teams to get the same result at the same site. For the finalization of AASHTO T 360 OBSI, this was done with OBSI “rodeos” where different teams with their own equipment made measurements on the same pavements and compared results. This draws in all the possible sources of variation discussed above. In the absence of a reference level, this at least establishes a mean expected level of uncertainty and provides insight into additional parameters that may need to be addressed.

3. Considerations for CTIM
The considerations discussed in this section would help to further define the CTIM test method.

3.1 Precision and Bias Statements
Validated, comprehensive precision and bias statements are not available at this time for CTIM.

National Cooperative Highway Research Program (NCHRP) Web-Only Document 217: Precision and Bias Statements for AASHTO Standard Methods of Test TP 98 and TP 99 describes a study conducted to develop precision and bias statements for CTIM. The study describes that precision and bias are products of measurement variability due to different factors. The precision of a method is defined as the closeness of agreement between individual test results. For the study, precision was examined in terms of repeatability and reproducibility. The bias of the method is defined as the difference between expected test results and an accepted reference value; for CTIM, there is no accepted reference value since results are defined only in terms of the test method. In lieu of comparing to a reference value, the research team was able to estimate some limited components of bias in terms of the measurement environment. Although the study was able to produce precision and bias statements, the validity of the conclusions is compromised by three factors: 1) not all key sources of uncertainty were included in the analysis; 2) it is not clear if all the requirements of the procedure were followed; and 3) there is insufficient data available in the NCHRP report or its appendices to make a proper assessment of results for the sources of uncertainty that were examined. Therefore, the precision and bias statements in the report are not included as part of this method.

Further study is required to develop valid, comprehensive precision and bias statements. This could include further evaluation of the NCHRP study, obtaining more details from the researchers, and possible inclusion of results as part of a comprehensive evaluation. Further study would also need to include evaluation of more sources of uncertainty for a comprehensive examination. In addition to combined uncertainty, elements should be isolated to the extent possible to determine the cause (and possibly solution to) variations in the results. The sources of uncertainty that need to be included are listed below, with bolded items being highest priority to examine:
Environmental effects—Are the stated limits enough to minimize meteorological effects? Effects include air temperature, wind speed and direction, pavement moisture content, temperature inversions, and air density and humidity.

Site geometry/other site factors—Ground effects: is the ground similar enough over time?; are the limits adequate for site flatness, road grade, reflecting surfaces?

Pavement within test section—Are recommendations enough for a practitioner to choose a site that minimizes effects due to variability of pavement for the roadway section under study?; how do lane-to-lane source level differences affect results?

Microphone set-up—Height and distance.

Instrumentation differences—Includes analyzers/sound level meters, microphone and preamplifiers, calibrators, and recording devices.

Vehicle operations and identification—Includes vehicle speed, vehicle volume, and vehicle type identification.

Data elimination due to contamination or outliers.

Number of data points—Effect of applying minimum versus greater numbers.

TNM or other modeling—Variation due to techniques.

Processing methodology—Sensitivity due to sampling period, analysis period, and reporting period.

Daily variation—The range in reported values due to day-to-day variation of all parameters including environmental conditions, traffic mix, vehicle fleet, vehicle speeds, and set-up variation.

Reproducibility for different measurement teams – establish the bounds on reproducibility for independent teams making SIP measurements at the same site.

Investigations for some of the above sources of uncertainty are included in other considerations listed in this section.

3.2 Noise Modeling Study

The FHWA Traffic Noise Model (TNM) inputs such as ground type, traffic data, and other modeling parameters should be varied and the normalizing values recalculated using several CTIM data sets. The sensitivity of the TNM normalization values to these variables should be determined. If parameters create variations on the order of 0.5 dB or more, guidance for TNM with respect to those parameters should be included in the method. Determining the variations as part of this study could be included as part of determining precision and bias statements.

3.3 Data Processing Sensitivity

A number of variables associated with the processing of measured sound levels into normalized reporting time blocks should be examined. Several data sets should be processed and re-processed using different methods nominally allowed in the CTIM procedure. This should include factors such as different lengths of time for analysis time blocks, the use of different control blocks, elimination of contaminated analysis time blocks, and removal of data outliers. The range of variation should be
determined (as necessary for establishing precision and bias) and best practices to minimize variations should be developed.

3.4 Temperature Sensitivity
CTIM currently restricts data sets to have an average temperature within a particular range in order to minimize temperature influences when comparing results. This restriction is based on conclusions from the FHWA report *Temperature Effects Study* (FHWA-HEP-11-005). The range of variation applying the restriction should be formalized as necessary for establishing precision and bias. In addition, restrictions on absolute temperatures should be investigated, since TNM is used for the normalization process, and the vehicle noise emissions database (FHWA-PD-96-008) within TNM was mostly measured in a fairly narrow range of temperatures. Another element to consider is adding temperature corrections.

3.5 Spectral Analysis Details
The basic process for normalizing results in terms of the overall A-weighted levels could be extended to individual 1/3-octave bands and validated.

3.6 Field Practice
A discussion of best practices to be used in the field for data collection in preparation of data analysis could be included as part of the method. The practices could include aspects of noise data collection, traffic data collection, data synchronization, and considerations for not influencing the traffic flow.

3.7 Field Form Examples
Examples of field forms for use in acquiring CTIM data should be included. Several practitioners have applied CTIM, and examples should be solicited, reviewed for CTIM requirements, and included as examples for the method as appropriate.

Note that part of this study could examine the effect of site changes over time and how to account for that in order to compare data sets.

3.8 Extend CTIM to Site Comparison
CTIM is currently restricted to comparing pavement changes at one site, either when new pavement is installed or for monitoring the influence of pavement aging. FHWA TNM is only used for the purposes of normalizing the measured noise to the same traffic conditions at one site and within constraints on how much the traffic can change from measurement to measurement. TNM is not used to quantify absolute traffic noise levels, but to predict the relative changes due to traffic. For site-to-site comparisons, TNM could be used for absolute noise predictions, and the site-to-site comparisons could be done relative to TNM Average Pavement and/or OBSI measurements taken at each site. Traffic mix, highway geometry, vehicle speeds, etc., could be quite different between sites. The feasibility of quantifying the effect of pavement on traffic noise from site-to-site should be investigated starting with the Noise Modeling Study as previously discussed. Data sets for different measurement sites should be compared and contrasted relative to the results of AASHTO OBSI measurements and/or AASHTO SIP measurements. Based on the analysis, a recommendation to proceed further with the extension of CTIM to site-to-site comparison could be made.
3.9 Measurement Method Comparison
The “Significance and Use” section could be expanded to provide further guidance on when to use the different procedures for determining the influence of pavements, particularly the use of either SIP or CTIM. More explicit guidance could be provided on the limits of both procedures in terms of traffic volumes. Lower limit guidelines for CTIM and upper limits for SIP could be recommended and included in the methods.

3.10 Expanded Definitions
Some terms or requirements in CTIM may benefit from expanding their definitions. These include: continuous-flow traffic, traffic speeds (e.g., obtaining, averaging, limits when traffic slows), foliage consistency, and percentage of heavy trucks (explain effect of percent differences when comparing data sets – may require study with TNM).

3.11 Measurement Comparison between Teams
Ultimately, the overall certainty in the procedure is the ability of different teams to get the same result at the same site. For the finalization of AASHTO T 360 OBSI, this was done with OBSI “rodeos” where different teams with their own equipment made measurements on the same pavements and compared results. This draws in all the possible sources of variation discussed above. In the absence of a reference level, this at least establishes a mean expected level of uncertainty and provides insight into additional parameters that may need to be addressed.
Appendix D

Comparison for ASTM E501-08(2015) and AASHTO M261

Update ASTM reference

AASHTO Fig 2 Tire groove depth is 5.10 mm (0.20 in). ASTM the dimension is 0.20 in. (5.08 mm)
AASHTO Fig 2 Friction test depth 9.78 mm (0.385 in.). ASTM 0.385 in. (9.8 mm)
AASHTO Fig 2 outer diameter 703.1 mm (27.68 in.). ASTM 27.68 in. (703 mm)
AASHTO Fig. 2 cross section width 212 mm (8.35 in.) ASTM 8.35 in (212.1 mm)

AASHTO 6.1.1 149 mm (5.85 in.). This doesn’t agree with Figure 1 dimension which shows 148.6 mm.
Also, the cross-sectional tread radius 394 mm doesn’t match with Figure 1 393.7 mm.

AASHTO 6.1.3 under-tread instead of undertread

AASHTO 10.1 temperature range is 21 +/- 14 degrees C (70 +/- 2 degrees F). ASTM the temperature range is 70 +/- 2 degrees F (21 +/- 13.8 degrees C).

AASHTO 11.4 static test load is 4825 N (1085 lbf). ASTM 1085 lbf (4826 N) also, loading to a max of 6150 N (1380 psi) ASTM 1380 psi (6138 N).

Comparison for ASTM E524-08(2015) and AASHTO M286

Update ASTM reference

AASHTO Fig 2 outer diameter 703.1 mm (27.68 in.). ASTM 27.68 in. (703 mm)
AASHTO Fig 2 tread radius 394 mm +/- 51 mm (15.5 in. +/- 2.0 in.) ASTM 15.50 in +/- 2.0 in. (393.7 mm +/- 50.8 mm)
AASHTO Fig. 2 cross section width 212 mm (8.35 in.) ASTM 8.35 in (212.1 mm)

AASHTO 6.1.1 149 mm (5.85 in.). This doesn’t agree with ASTM Figure 1 dimension which shows 148.6 mm.

AASHTO 10.1 temperature range is 21 +/- 14 degrees C (70 +/- 2 degrees F). ASTM the temperature range is 70 +/- 2 degrees F (21 +/- 13.8 degrees C).

AASHTO 11.4 static test load is 4825 N (1085 lbf). ASTM 1085 lbf (4826 N) also, loading to a max of 6150 N (1380 psi) ASTM 1380 psi (6138 N).

Comparison for ASTM E274/E274M-15 and AASHTO T242

Update ASTM reference

ASTM the last sentence of 4.4 references the E1136. Change last sentence of AASHTO 4.4 by deleting “standard rib tire for pavement skid resistance of M261 or E501” and adding “ASTM E1136”. Add ASTM E1136 to section 2 References.
AASHTO Figure 1 See marked up figure.

AASHTO section 7.5.1 FN80 should be FN(80). When referencing the test speed and SI units are used the test speed should be in parentheses.

**Comparison for ASTM D3319-11(2017) and AASHTO T279**

Update ASTM reference

Section 5.1.1 ASTM dimensions are 1 ¾” (44.45 mm) AASHTO dimensions are 44.5 mm (1 ¾”).

AASHTO Note 2 doesn’t have SI units as primary. Should be 101.6 mm (4 in.) & 2.54 mm (0.10 in.)

AASHTO 5.1.3.3 is missing the SI units. Should be 4.76 mm (3/16 in.)

AASHTO 5.3.1 contact path 76.20+/- 1.60 mm. ASTM 5.3.1 76.20+/-1.59 mm.

AASHTO 5.3.2 slider width 71.8 mm. ASTM 5.3.2 31.75 mm.

AASHTO 5.3.3 rubber dimensions 6.4 by 25.4 by 31.8 mm. ASTM 5.3.3 635 by 25.4 by 31.75 mm.

AASHTO 5.4 sanding block radius of curvature 190 mm (7.5 in.). ASTM 5.4 7.5 in. (190.5 mm)

AASHTO 7.3 12.7 mm sieve. ASTM 7.3 12.5 mm sieve.

AASHTO note 6 12.7 mm sieve & 6.4 mm sieve. ASTM note 7 12.5 mm sieve & 6.3 mm sieve.

AASHTO doesn’t have a note similar to ASTM Note 10. Add a new note 9 after section 7.11 and before 7.12 as follows “Note 9—When warping of the test specimens occurs due to shrinkage of the polyester resin, this can cause poor fit on the road wheel and bouncing and slipping of the polishing tire. The hardened polyester resin may be heated while remaining in the mold in a 100 °C oven for 2 to 4 h to allow the specimens to be re-conformed to the specified curvature through the use of mechanical clamping and through a cool-down period. “

Then change existing notes 9 and 10 to notes 10 and 11, respectively.

AASHTO note 9 the word “grade” is missing after 20-30
Appendix D

Notes:
1. Dimensions shown are for M 261 and M 286 Standard Tapes.
2. All dimensions are in mm.
3. Surface C must be milled flat and perpendicular to pipe centerline.

Figure 1—Nozzle
Proposed Research Needs Statement

PROBLEM TITLE
ENHANCEMENT OF JOINTED CONCRETE PAVEMENT FAULTING COLLECTION AND ANALYSIS STANDARDS

RESEARCH PROBLEM STATEMENT

In the last few decades, state DOTs and other agencies have measured faulting of transverse concrete joints manually (either measuring joint height differences or with a device such as the Georgia fault meter), or in automated fashion (for example, point lasers or 3D technology). Many highway agencies have shifted from manual methods to automated methods since other pavement management system (PMS) data are also being collected in an automated fashion. However, the accuracy of automated means of network-level faulting measurement has been mixed. An accurate network-level faulting detection method is crucial to a maintenance program. The analysis of faulting data is also crucial to select proper maintenance projects. If accurate faulting data is not available or properly analyzed, treatments such as pavement grinding might not be triggered at the appropriate time or location in a pavement’s life cycle. Faulting is also one of the MAP-21 national pavement performance metrics proposed by FHWA. In addition, automated methods, as opposed to manual, keep personnel off the roads, resulting in greater worker safety.

This RNS supports the AASHTO Subcommittee on Materials and Pavements which is charged with preparing and keeping current testing methods for highway facilities.

LITERATURE SEARCH SUMMARY

Some methods of automated faulting detection and data processing have been developed in recent years; such as the FDOT and MDOT methods, and the TxDOT 3D line laser sensor method., AASHTO R36, the standard practice for measuring joint faulting, outlines fault measurement concepts and references both the FDOT and MDOT methods. The TPF-5(354) pooled fund has a current study on longitudinal profiles. The TPF-5(299) pooled fund wishes to investigate the accuracy of automated faulting collection methods and consider ways to analyze faulting data, possibly coordinating with TPF-5(354).
Appendix E

AASHTO R 36-13—STANDARD PRACTICE FOR EVALUATING FAULTING OF CONCRETE PAVEMENTS

AASHTO M 328—INERTIAL PROFILER

AASHTO R 56—CERTIFICATION OF INERTIAL PROFILING SYSTEMS

AASHTO R 57—OPERATION OF INERTIAL PROFILING SYSTEMS

ASTM E867—STANDARD TERMINOLOGY RELATING TO VEHICLE-PAVEMENT SYSTEMS


FEDERAL HIGHWAY ADMINISTRATION, PROVAL SOFTWARE AUTOMATED FAULTING MODULE MISSISSIPPI DOT. (JAMES C. WATKINS, P.E.) BATCHCALCFAULT SOFTWARE USER GUIDE 3.00, MARCH 2010.


RESEARCH OBJECTIVE

The objective of this study is to improve the faulting data collection and analysis methods by identifying current methods of faulting data collection and processing and assess their appropriateness and accuracy and recommending an improvement to AASHTO 36. In addition to collection and processing of faulting data, this study also will focus on faulting analysis as well. Most of the automated faulting methods were developed when point lasers were the standard of practice. Nowadays 3D technology may provide more accurate methods for detecting, locating, and measuring faulting. Ideally, a detection and processing algorithm would be technology-independent. This study should also investigate the following:

1) The impact of surface texture to current faulting measurement.
2) The effect of data collection and analysis due to sensor type (3D, line or point).
3) Methods/algorithms to processing and analyzing faulting data.

The deliverable will be a final report detailing the information found and a recommended improvement to existing faulting data collection and analysis method, AASHTO R 36.

WORK TASKS

1. Summarize the existing methods of automated faulting data collection and processing, as well as the effects of surface texture, travel speed and sensor type (3D, line or point).
2. Review how faulting data is aggregated and used to make decisions regarding project selection.
3. Survey of DOTs’ and other agencies’ current faulting data collection and analysis practices
4. Propose and validate new data collection and analysis standards.
5. Final report outlining findings and improved AASTHO R 36.
ESTIMATED FUNDING REQUIREMENTS
It is estimated that this research will take 36 months to complete and will require $450,000.

URGENCY AND POTENTIAL BENEFITS
It is crucial to perform this study now as faulting is an important component of MAP-21 requirements. This study will result in the following anticipated benefits:

- Triggering of faulting-related projects the appropriate time, which enables DOTs to enhance pavement performance and save repair costs.
- Increase in automated faulting collection, keeping agency and vendor personnel off roads, resulting in greater safety.
- Ability to compare faulting data state-to-state.

IMPLEMENTATION PLANNING
Improvement to AASHTO R36, Faulting Standard, will result in use by AASHTO agencies to assist in meeting performance management requirements and agency business practices.

PERSONS DEVELOPING PROBLEM STATEMENT
TPF-5(299) pooled fund study that includes 21 state highway agencies. Point of contact is: Andy Mergenmeier  
FHWA Senior Pavement and Materials Engineer  
Phone # 667.239.0879  
e-mail: andy.mergenmeier@dot.gov

AASHTO MONITOR
AASHTO Subcommittee on Materials and Pavements TS 5a vice-Chair Scott George, AL DOT and member of TPF-5(299).

SUBMITTED BY
AASHTO Subcommittee on Materials and Pavements TS 5a Chair Greg Stellmach, OR DOT.