MEMORANDUM

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Federal Highway Administration

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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:

1. AASHTO TP 98, *Standard Method of Test for Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By Method (SIP)*.
2. AASHTO TP 99, *Standard Method of Test for Determining the Influence of Road Surfaces on Traffic Noise Using the Continuous-Flow Traffic Time-Integrated Method (CTIM)*.

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.