# Guidelines for Obtaining AADT Estimates from Non-Traditional Sources

Publication No. FHWA-PL-21- 031

September 2021

U.S. Department of Transportation
Federal Highway Administration

## NOTICE

This document is disseminated under the sponsorship of the United States Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof. This report does not constitute a standard, specification, or regulation.

The United States Government does not endorse products or manufacturers. Trade and manufacturers' names appear in this report only because they are considered essential to the object of the document.

## QUALITY ASSURANCE STATEMENT

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

# TECHNICAL REPORT DOCUMENTATION PAGE

| | | |
|---|---|---|
| 1. Report No.<br>FHWA-PL-21-031 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle<br>Non-Traditional Methods to Obtain Annual Average Daily Traffic (AADT) | | 5. Report Date<br>September 2021<br>6. Performing Organization Code |
| 7. Author(s)<br>Laura Schewel, Sean Co, Christy Willoughby, Louis Yan, Nancy Clarke, Jon Wergin | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>StreetLight Data<br>677 Harrison Street<br>San Francisco, CA 94107 | | 10. Work Unit No. (TRAIS)<br>11. Contract or Grant No.<br>693JJ319C000015 |
| 12. Sponsoring Agency Name and Address<br>Federal Highway Administration<br>Office of Highway Policy Information<br>1200 New Jersey Avenue SE<br>Washington, DC 20590 | | 13. Type of Report and Period Covered<br>14. Sponsoring Agency Code |
| 15. Supplementary Notes<br>Project performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration and a Technical Advisory Committee (TAC) consisting of Alaska DOT, Caltrans, Colorado DOT, Georgia DOT, Idaho DOT, Illinois DOT, Maryland DOT, Minnesota DOT, Nebraska DOT, New Jersey DOT, North Carolina DOT, North Dakota DOT, Oregon DOT, Ohio DOT, Pennsylvania DOT, South Carolina DOT, Texas DOT, and Virginia DOT.<br>Steven Jessberger (Task Manager) | | |
| 16. Abstract<br>The use of passive data from location-based smartphone applications (LBS) and Global Positioning Services (GPS) to collect Annual Average Daily Traffic (AADT) has the potential to greatly reduce costs to State Department of Transportations (DOTs) and Metropolitan Planning Organizations (MPOs) and expand the coverage of up-to-date counts. This report evaluates the technical and statistical validity of traffic data derived from these sources using machine learning methods. Validity was determined by comparison to 4255 permanent counters, and a survey of recent publications about accuracy expectations.<br>The document covers the input data and the development of the machine learning models and model validation. The results include the error by road volume, roadway and regional characteristics compared to typical estimation. The effects of reduced trip sample, ping rate, spatial accuracy and reference counters were also tested. The applicability of Probe Data was tested for other factors including, day of week, month of year, directional and ramp AADT, work zones ADT, K and D factors, peak hour truck data, special events or unusual weather and AADT by vehicle type. | | |
| 17. Key Words<br>AADT, probe data, volume, Big Data, LBS, GPS, Machine Learning, MADT, Volume, AADTT, K-Factor, D-Factor, AAHT | 18. Distribution Statement<br>No restrictions. This document is available to the public. | |
| 19. Security Classif.(of this report)<br>Unclassified | 20. Security Classif. (of this page)<br>Unclassified | 21. No. of Pages<br>151 |
| | | 22. Price |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

# PREFACE

We would like to acknowledge the following Technical Advisory Committee members for their contributions, support and technical guidance during this project.

| | |
|---|---|
| Scott Vockeroth | Alaska DOT |
| Afrid Sarker | Caltrans |
| Steve Abeyta | Colorado DOT |
| Eric Conklin | Georgia DOT |
| John Phillips | Idaho DOT |
| William (Bill) Morgan | Illinois DOT |
| Lisa Shemer | Maryland DOT |
| Gene Hicks | Minnesota DOT |
| David Schoenmaker | Nebraska DOT |
| Chris Zajac | New Jersey DOT |
| Kent Taylor | North Carolina DOT |
| Terry Woehl | North Dakota DOT |
| Josh Roll | Oregon DOT |
| Sandie Mapel | Ohio DOT |
| Greg Dunmire | Pennsylvania DOT |
| Todd Anderson | South Carolina DOT |
| Chris Didear | Texas DOT |
| Hamlin Williams | Virginia DOT |

# Guidelines for Obtaining AADT Estimates from Non-Traditional Sources

## Table of Contents

# List of Tables



# List of Figures

# GUIDELINES FOR OBTAINING AADT ESTIMATES FROM NON-TRADITIONAL SOURCES

## INTRODUCTION

This document provides decision making guidance that highway agencies can use to purchase or acceptance test traffic volume estimates such as annual average daily traffic (AADT) from the private sector when those estimates are based on non-traditional data sources, such as vehicle probe or smartphone data.

This guidance is the outcome of a Federal Highway Administration (FHWA) led pooled fund study that included nineteen state highway agencies, representing the states of Alaska, California, Colorado, Idaho, Illinois, Georgia, Maryland, Minnesota, Nebraska, New Jersey, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, South Carolina, Texas, and Virginia.

The guide provides material designed to help agencies

- prepare for purchasing data,
- interact with potential providers of those data,
- determine the quality and accuracy of the data being offered, and
- evaluate the value of those offerings.

Four checklists are provided.

- The first (A) is designed to help an agency clarify their requirements prior to requesting bids.
- The second (B) is designed to make sure those bids include the data required to compare different offers.
- The third (C) is designed to help judge the quality of the data being supplied and then select between offers.
- The fourth (D) is designed to help the agency understand the technical procedures of the vendor providing AADT estimates.

Copies of these four checklists are found in Appendix A of this document.

## A. PREPARING TO PURCHASE AADT ESTIMATES

### A.1) How do you intend to use the data?

Before starting the purchase of non-traditional AADT estimates from the private sector, your agency needs to ensure that it fully understands which analyses the data are needed for.

This understanding will help your agency

- set the accuracy standards the data need to meet,
- determine the timeliness and frequency of data delivery to the agency,
- determine what data items, in addition to AADT, are required to meet those user needs,
- identify the number and type of staff that are expected to access those data,
- determine the frequency with which, and process by which, the data will be accessed,
- determine the geographic resolution required of the data (e.g., Highway Performance Monitoring System (HPMS) segment data? Higher geographic resolution? Flexible geographic resolution?)
- define the degree to which the data will need to be integrated with existing agency data systems.

All of these factors, the prices bid, and the way the attributes of each bid relates to these factors will affect which vendor's offer is preferred.

When answering question A.1, your agency should know where the data will be used. Some examples are listed below.

1) Meet very specific project analysis needs (e.g., validate/calibrate link volumes for traffic demand models; determine existing traffic volumes for design purposes; estimate turning movements or other data required for operational analysis; perform safety analysis on specific road segments),
2) Replace and/or complement existing short term traffic counts, allowing the agency to reduce the number of short term counts they perform,
3) Provide AADT values on road segments for which recent short duration counts are not available in order to supply vehicle miles traveled (VMT) estimates as part of PM3 reporting
4) Trend analysis for a given segment of roadway and determination of growth or seasonal factors.

The data being purchased may be needed for more than one of these reasons. The purchasing agency then needs to understand how the "controlling" requirements from these uses affect its purchasing decisions.

The first and most important outcome from this understanding is that your agency can define the quality of the data it requires from the private sector. If the data are being purchased to replace all, a significant part of, or a limited number of the agency's current short term count program, then the AADT estimates should meet or have better accuracy and precision levels as those of the current annualized short term counts. Table 1 describes the accuracy of AADT estimates computed from short term count programs as determined by a previously led FHWA pooled fund study.[1] Guidance for the calculation of Traffic Count Error is found later in this document.

**Table 1: AADT Estimation Accuracy and Precision Based on Historical Short Term Counts**

| AADT Volume Range | Minimally 95% Probability, Median Traffic Count Error (Bias) (%) | Minimally 95% Probability, 95% Traffic Count Error Population Error Range (%) |
|---|---|---|
| Less than 500 | (see footnote)[2] | (see footnote)[2] |
| 500 – 4,999 (low) | ± 2.0 | ± 34.0 |
| 5,000 – 54,999 (medium) | ± 1.5 | ± 28.0 |
| 55,000 + (high) | ± 2.5 | ± 24.0 |

If the plan is to significantly reduce or replace the current data collection program, then your agency may need to ensure that the successful vendor can provide the variables needed by users that would otherwise be provided by the short term count data (e.g., time of day volumes, truck volumes, percent peak trucks and/or directional factors). The need for traffic volume variables besides AADT should be discussed with the intended users of the data (see question A.2) and that list of variables must be included in the request for proposal (RFP) to vendors.

If the data are being purchased only to meet the needs for a specific project, the accuracy requirements for that project should be used to drive the accuracy acceptance testing of different vendor's data.

If the data will be used only to provide volume estimates in places your agency currently is not able to develop AADT values of known quality, or if the AADT values will be supplied for local roads that have very low volumes, then the agency may be willing to accept accuracy levels

[1] Assessing Roadway Traffic Count Duration and Frequency Impacts on Annual Average Daily Traffic Estimation Assessing AADT Accuracy Issues Related to Short-Term Count Durations, by R. Krile, F. Todt, and J. Schroeder. FHWA Publication No. FHWA-PL-16-008, October 2015

[2] At this time, insufficient data exists to set target accuracy values for roads with AADTs less than 500. It is known that traffic variability on these roads is higher, in percentage terms, than higher volume roads. Probe-based AADT values are expected to have median bias and expected error ranges larger than those shown in Table 1 for the 500 – 4,999 volume range, however additional research is needed before these values can be determined.

slightly lower than those shown in Table 1 (<u>although Table 1 is the preferred outcome for all AADT estimates</u>.) Agencies will need to develop their own acceptance criteria for these data. A good way the agency could generate acceptable tolerances for data to replace the estimates currently used for these "uncounted" locations would be to perform an analysis of the error currently present in these estimates by counting a sample of these locations, expanding those data to AADT following their standard procedures, and comparing the "true" value with the estimates currently being used. The acceptance criteria would then be data equal to or more accurate than the current estimates shown in Table 1.

Determining the uses for the data gives the agency the opportunity to have an open discussion amongst its staff about traffic data needs across the agency. The accuracy requirements for the data being purchased (most likely the values in Table 1) is the most important outcome of those discussions.

**A.2) Who will use these data?**

Because AADT statistics are a key input to a large number of important analytical tasks, they are the foundation of the highway data program. AADT are heavily used by the HPMS, your agency's safety management system, pavement management system, roadway design process, performance reporting system, overall planning process for the agency, and a wide variety of analytical tasks and tools. Understanding the analyses for which the purchased data will be used also defines who will be using those data, and the technical procedures that need to access those data.

The questions below along with the checklist will help determine the data users.

- Do all agency staff need to access these data, or will only a small subset of agency personnel working on a specific project need access?
- Do these data need to be shared outside of the agency, for example with metropolitan planning organization (MPO), city, or county staff?
- Does the agency need to be able to share the data with the public?

The answers to these questions will define how the data will need to be accessed and stored, as well as defining the needed data rights. Examining the following four bullet points will help your agency formulate your request for proposals as well as and evaluate vendor responses.

- Data rights – who has ownership, usage, publication, and distribution rights to the data?

- Access to the data– is your agency provided with a copy of the data or is access to the data on a case-by-case basis via a web-platform? If a copy is provided, via what file format (e.g., csv, shapefile, database file, etc.) and what location referencing system will be used?
- Archiving the data – in the event a copy of the data is not provided, how will the data purchased be accessed in the event the web-platform usage right is terminated at some point in the future?[3]
- Data integration – how will your agency integrate the provided traffic data into its current software systems? This includes the need to conflate purchased data to the location referencing system used by your agency's software systems.
- Versioning control – Each data set needs to have a model version and date of extract so that the agency can properly reference changes in the future.

A final issue that must be identified in the RFP is whether there are contractual limitations on who can see and use the volumes being purchased. Many data providers contractually limit who can use their data in order to create a market for additional sales of that data to other agencies or companies. **Thus, if the data must be released to the public, the RFP used to purchase those data needs to be explicit that this sharing is required.** This could raise the cost of the purchase. In addition, if either outside agency staff or the public will be accessing the data, the agency needs to understand how that access will be supplied.

## A.3) How do the data need to be delivered from the vendor?

Understanding the answers to question A.1 and A.2 helps define the parameters that determine the most cost-effective mechanism for obtaining the purchased data from the vendor.

If agency staff will be accessing vendor data from the vendor's platform, then including a live demonstration of that portal in the bid process may be important to allow your staff to determine how easily they can find and download the data they need. If your agency intends to purchase large (e.g., statewide) quantities of data for use within the existing analytical processes the agency already performs, it is important to work with your agency IT staff to define how they wish the data to be delivered.

Short term counts are location specific. Probe-based volume estimates are typically road-segment specific. Thus, a key aspect of the data processing task associated with integrating purchased data with agency systems is the linking the purchased data to the correct roadway segments being used by your agency. This process may or may not be complex depending on the

[3] It is recommended that the agency ensure that they get to maintain, in perpetuity, access to any data used for federal reporting purposes, to meet various Freedom of Information Act or open government regulations.

location referencing systems currently used by both your agency and the vendor. At a minimum, your agency will need to understand the "conflation" process and be able to provide prospective vendors with information on the roadway segmentation of your highway system. Vendors may or may not be able to directly match your roadway segmentation precisely. Understanding the resources required from your agency to assign the purchased volume data into your required location referencing system is an important factor when selecting between vendors.

There are typically three ways in which large network data are transferred between data systems.

1) The agency delivers a basemap to the vendor to populate with volume data.
2) The vendor provides the agency with a standard basemap (e.g., Traffic Message Channel - TMC, Open StreetMap - OSM, or FHWA's ARNOLD) and the agency must translate/conflate the data from that mapping system into the format desired by the agency, or
3) The agency can provide geodetic locations and direction (heading) for which volume data are needed and the agency assigns those geolocated datapoints to the appropriate roadway location (e.g., road segment or route and milepost.)

**A.4) How often will the data be delivered?**

In addition to ensuring that your agency receives data it needs in a timely fashion, this question helps an agency understand the level of automation required to accept the data. The more frequently data will be transferred to the agency, the more automated the data acceptance and upload process needs to be. For example, in a once-a-year process, agency staff can download a compressed file from a secure server, after having the file name and server password noted in a phone call. Such an approach would not be feasible if data were being downloaded on a daily basis.

**A.5) How will the data be uploaded to the agency's corporate data system?**

The answer to question A.1 describes which data (in addition to AADT) are required from the vendor, whether the purchased data need to reside inside the agency's corporate data structure, and whether data items other than AADT will be part of the data purchase. The answer to question A.3 describes how the data will be obtained from the vendor and matched with your agency's location referencing system.

This question (A.5) starts with those answers and recommends that your agency's IT staff (or technology and data team) identify the tasks and software required to upload the data being obtained into the corporate data system. This includes their need to understand what data will be uploaded (e.g., extract version, directional volumes, definitions of direction of travel, whether hourly volumes provided, ADT values for specific days and locations, monthly average daily traffic) and how those variables map to the data currently stored in your agency's corporate data system., as the data you purchase need to be accessible by your existing analytical tools without having to make changes to those systems.

This information allows your IT staff to build conversion, quality assurance, and data upload scripts that check the received data and import valid data from the vendor into the corporate data system.

Finally, a key part of this task is to develop and implement data quality checks for the outside data headed into the corporate data system. This will likely to be a joint task of the central traffic office, which will be in charge of developing the acceptance testing rules), and the IT staff who need to code those rules into the data acceptance and upload process.

## A.6) How will the accuracy of the data be determined?

A key aspect of purchasing private sector data is acceptance testing those data to ensure that they meet the specifications identified in response to question A.1. Agencies can perform data quality analysis through a wide range of approaches including but are not limited to

- utilize independent third-party certification if such entities exist,
- perform validation of the vendor's data accuracy using either agency staff or outside assistance (e.g., consulting firm/university) by comparing data submitted by the vendor against a validation dataset (see Appendix B for a complete example),
- trust the vendor's data quality report.

Appendix B describes a rigorous method for performing validation tests. A cross validation[4] analysis which combines the ideas in the bullets provides an additional approach that is common to the review of "big data" machine learning analyses.

The first approach is the least expensive to the agency, while not relying entirely on the vendor. It assumes that tests performed by an independent agency or institution such as a university (not the vendor) for some other state or agency, under a well-defined protocol, can indicate the accuracy that the vendor will deliver for this purchase. The disadvantage of this approach is that the accuracy achieved elsewhere may or may not be similar to that achieved for your agency, as accuracy achieved by any given vendor will depend not just on its technical approach, but a variety

[4] https://en.wikipedia.org/wiki/Cross-validation_(statistics)

of factors such as the size of the dataset available to calibrate the vendor's algorithms, and the characteristics of the state (e.g., population demographics, penetration rates of specific cellular providers, density of cellphone towers, etc.)

The second option is most specific or tailored to the agency's needs. However, it requires that your agency have ground truth volume estimates and have the resources to perform analyses with those data. This can be difficult, in that many state's post their permanent count data online and those data are thus, readily available to potential vendors for their use in calibration activities. If used by the vendor, those data are no longer independent data sources that can be used for conventional testing.

The only real difference between using your agency staff and hiring outside assistance is whether your agency staff have the time and expertise to perform the validation work. If not, then hiring outside assistance is necessary. Appendix B includes the preferred method for computing independent accuracy statistics.

If the second option is selected, your agency must provide ground truth data against which to measure the accuracy of the vendor's data. In some cases, vendors will also wish to calibrate its algorithms by using AADT values from ground truth datasets that are similar to those needed for validation testing. The data provided to vendors for model calibration purposes should not be used in the accuracy validation tests. Thus, it is important for the agency to have access to a relatively large pool of ground truth AADT statistics that can be used for the accuracy testing process when those tests will be performed on the state specific data being provided by the successful vendor.

The current best source of ground truth data are well calibrated, continuously operating traffic count locations that have gone through some data cleaning or quality assurance review. Your agency may need to allocate its available count locations between these two functions (calibrating vendor algorithms and validating the results of that calibration effort). It is important to note that continuous count stations (CCS) from other agencies (such as neighboring states or other MPOs in your state) may be able to be used for these purposes. Additional work being performed under the evaluation contracts of the Pooled Fund project TPF-5(384), Non-Traditional Methods to Obtain Annual Average Daily Traffic (AADT) Evaluation and Analysis, can provide more information on the data that can be used to perform accuracy validation.

The third option is easy and inexpensive, but is not recommended, as it provides no confirmation that the validation report provided by the vendor actually applies to the purchased data, as some probe-based models have worked well in some states, but poorly in others.

If the approach discussed in Appendix B is not possible due to lack of data, this guide recommends using a combination of the bullets above. The alternative to Appendix B is to require the vendor to share the results of their **Cross Validation** process to verify the accuracy of the vendor's estimates. Cross validation is typically performed by the vendor as part of developing their model and provides estimates of each model's accuracy. The technique involves splitting the available data into "training" and "validation" datasets. The model is developed/calibrated on the training dataset and the resulting model is used to predict the data in the validation dataset, with the difference between the model outcomes and the validation dataset being a good measure of the error in the model. This process (split the dataset / build model / check errors) is performed multiple times, with different datapoints being included in the training and validation datasets for each pass through this process. A summary of all of error estimates from these tests provides the estimate of the performance of the model.

Tests if cross validation should be specifically oriented to the calibration of the vendor's model to the state purchasing access to the data.

Having an independent group audit the vendor's cross validation process, confirm the validity of the model outputs, and report on the error rates achieved by the offered model is a good approach for limiting both the cost of the independent verification process and the need for independent data sources for performing that verification. Use of an independent group for performing the audit both allows the agency to access individuals with skillsets the agency might not otherwise have (e.g., machine learning calibration and testing experience), and ensures that the audit is viewed as being independent by both the vendor and the purchasing agency. This approach does require the vendor to provide access to their model calibration process and results to the independent auditor. This can be performed under NDA, so long as the results of that audit can be provided to the agency requesting that audit. The independent auditor must follow approved validation methods, and must report in detail to the hiring agency, any issues identified in the vendor's technical process, so that the resultant accuracy test results are clearly understood.

## B. DATA REQUIRED TO COMPARE BIDS (START HERE)

### B.1) What is the purchase price?

Every vendor's response to the agency's RFP will include a price. Understanding both the total cost of the vendor's bid and any ongoing expenses is key to understanding the vendor's full cost. For example, will new software licenses be required? What will be the cost of additional licenses if they are needed?

The agency also needs to consider the costs it will impose on itself in terms of the work required by agency staff or consultants to assist in calibrating the vendor's algorithms, validating the obtained data, and (potentially) refining existing agency software systems in order to import the purchased data into the current corporate data structure.

### B.2) Who owns the data you have purchased or licensed?

The answer to this question is needed to determine whether the agency "owns" a copy of the data or "rents" the data, which will help determine the agency's ability to share those data with other agencies or the public. The answer – and the structure of the "rental" license – also helps determine what will happen if the agency changes data vendors at some point in the future. Do they retain a copy of the data indefinitely, as well as the right to use it? (This is highly recommended!) Or do they lose access and rights to use to the data they have been using? This is particularly important if the data are stored on a vendor's server and accessed only remotely. In such a case, the concern is an audit issue, in which access to data from "last year's vendor" may be needed to confirm the data used in an analysis, but that vendor may no longer be under contract.

Also important is the ability of your agency to share those data. Can your agency further distribute the data to public partners? Can they be released to the public? Are there restrictions to the degree they can be released? Many companies restrict access to their data in order to maintain a market for further sales. Such restrictions can be problematic when they conflict with state public records laws which require publicly used data to be available to all members of the public.

### B.3) What is included in that price?

The answers to this question are used to compare the value obtained from competing vendors.

Value is determined by both the price and what is obtained for that price. The secondary questions in the checklist (Appendix A) are designed to help your agency identify the attributes offered in a bid. Some of these items will be "required" in the bid. Others may be offered by vendors as part of their data package. Your agency will need to determine the value of "extra" data provided by different bidders, as well as the significance of data "missing" from the list of required or desired traffic variables.

As part of this consideration, your agency will need estimates of the accuracy of each traffic variable being provided. These may be provided by the vendor as part of the bid. These estimates are used for the initial valuation of the bids. Your agency can then decide to validate those statistics as it sees fit.

Traffic statistics other than AADT (i.e. SU AADT, CU AADT, D factor, K factors, or other statistics) may or may not be of sufficient accuracy to meet the needs of the agency, but determining the value of these secondary statistics is important when determining the relative value of a vendor's proposal. (How accurate are they? Do they meet specific needs of the agency? Do they reduce either other data collection costs or safety concerns to the agency?) The value of additional traffic variables included in a bid, but not part of the minimum requirement in the RFP, will need to be determined as part of each bid review.

Other considerations your agency should include in its valuation of each vendor's bid include the following:

- How many years of data are included in the bid?
- Who can use the data being licensed?
- How many people may access the software and/or data?
- What is the geographic and roadway system extent included in the bid?
- What type of vendor support is provided as part of the bid? How does the vendor propose to handle outcomes in which quality assurance checks identify counts that are illogical or potentially in error?
- Does your agency have a choice in terms of the location referencing system the vendor uses to supply the data?

Your agency will have to determine the value of these additional bid attributes. For example, choosing one referencing system option over another may greatly reduce the cost of uploading the data into your corporate data system, and thus provide considerable value.

**B.4) How accurate are the provided data?**

This is a vital statistic for comparison between vendors. The checklist assumes that AADT is the primary statistic being supplied by the vendor. The accuracy of this statistic from each vendor is therefore of paramount importance, but the inclusion and accuracy of other traffic statistics should also be taken into account. A good set of error statistics to request from the vendors are the cross-validation results from each vendor that best approximate the data that will be provided for your state. (So, if the vendor has already produced estimates for your state, those accuracies. If they have not, chose a nearby state with similar traffic patterns.) Independent measurements of AADT accuracy provided by independent sources (e.g., other state agencies, independent testing organizations) can be used during the initial vendor selection process. However, these values should be validated for your state (see Checklist C.)

Purchased data need to meet the accuracy criteria being set by the agency and described in the answer to A.1. However, the agency should consider the relative importance of data accuracy levels better than the requirement, as well as the accuracy and importance of the other traffic statistics provided as part of the bid.

A key aspect of the RFP and purchase agreement is to include how accuracy will be tested, the expense to the vendor, and what will happen if the results of those tests demonstrate that the results for the selected vendor fall wholly or partially outside of the bid specifications. For example, how will your agency treat the bid of a vendor that produces acceptable accuracy validation test results for roads with AADTs of above 5,000 AADT but not below 5,000? These consequences must be spelled out in the RFP evaluation process.

**B.5) What data are required to calibrate the data for delivery to your agency?**

Most vendors will need access to accurately functioning, continuously operating traffic count data to calibrate their models/algorithms. Access to these data will likely be needed not just for the initial calibration but also for future updates to that calibration process, as expected changes to the input data the vendor uses (e.g., penetration rates for various cellphone providers, use of the apps that provide location-based service (LBS) data, and which apps are included in the vendor's data feed) mean that vendors will need to periodically update their models/algorithms.

If data are purchased for more than one delivery (e.g., the bid will supply data not just for the past three years but also for the next three years, or monthly AADT updates will be supplied for the next 24 months), then the vendor will likely want to re-calibrate its algorithms multiple times during the data delivery period. This means that the vendor will need updated calibration data. Each vendor may require that a different set of data be provided to calibrate its algorithm to the state purchasing data. The cost (and ability) of providing those data should be compared between vendor bids. If the agency is unable to supply the data some vendors require to calibrate their estimates it then becomes necessary to learn 1) how the lack of those data will change the expected level of AADT accuracy, and 2) whether that will change the cost of the vendor's bid.

Vendors may need data for a specific number of calibrated, permanent, continuously operating count sites for each geographic area and/or roadway classification requested by the state or included in the vendor specifications. The vendor may need multiple years of data for each of these locations. In addition to permanent count data, vendors may also ask for other datasets to be provided in support of its calibration or algorithm development process. For example, does the vendor need just the AADT value for each site? Daily ADT values? Hourly records? The cost of producing these data must also be included in the cost of each bid.

**B.6) How will the data be delivered?**

See Question A.4 for each potential vendor.

If agency staff will be accessing vendor data from the vendor's platform, then inclusion of a live demonstration of that platform in the bid process is important to help your agency determine whether a vendor's system is markedly better or worse than that of competing vendors. That is, how intuitive is the interface, so that agency staff can quickly and efficiently obtain the data they need?

The mechanism used by different vendors to deliver data may increase or decrease agency costs for obtaining data. These costs should be considered in selecting the best value to be obtained from the competing vendors.

**B.7) What is required to enter the data into your agency's corporate data system?**

See Question A.5 for each potential vendor.

Questions B.3 and B.6 will provide the information required by agency IT staff to determine the cost of incorporating the purchased data from each vendor into the agency's corporate data system. These costs should be considered in addition to the base price of each vendor's asking price to determine the true cost of each bid. It is imperative that IT staff familiar with the current corporate data system be included in the review and comparison of competing bids to determine the agency costs of obtaining and ingesting any traffic data purchased.

**B.8) What is the earliest date for when AADT values can be delivered?**

The answer to this question determines whether the vendor can deliver the purchased data within the timeframe required to meet user needs. Vendors that cannot deliver data before the required deadline should not be considered.

## C. TESTING THE QUALITY OF THE DATA

Because different vendors may have both different data sources and different mathematical approaches, the accuracy and precision of different vendor's AADT values will be different. Before your agency pays for data, it is vital that the vendor shows that its data and algorithm generate accurate, unbiased AADT values for your road system. Therefore, agencies need to be confident that a vendor's data are as accurate as it claims. This checklist will help an agency make that determination.

### C.1) Is your agency willing to accept independent 3rd party testing or audits of a vendor's cross validation work?

See the answer to question A.6.

Assuming that tests previously performed by an independent agency (not the vendor) for some other state or agency, under a well-defined protocol, indicate the accuracy that the vendor will deliver for this purchase, third-party testing can be a good way to save money on the data purchase. The advantage of making this assumption is that it will save time and money for the agency. One mechanism for doing this is to have an independent audit of the vendor's cross-validation results obtained during their model development. This involves having an independent third-party review the cross-validation steps performed, and the outcome of those steps, to ensure that the model has been calibrated appropriately, and is accurately reporting the expected error bounds using best practices for machine learning techniques.

The disadvantage of this approach is that the accuracy achieved elsewhere may or may not be similar to the accuracy that will be achieved for your agency, as accuracy achieved by any given vendor will depend not just on the technical approach it uses, but also on the size of the base data sample that is available from your jurisdiction. Sample sizes can differ from one state to another, as well as within different regions of a state.

Using existing testing results will likely be an acceptable choice if the previous tests were performed recently and in a similar environment (e.g., two contiguous states with a similar urban/rural profile, or two MPOs in the same state), as the underlying relationships between the available data and traffic volumes will likely be consistent across those similar locations.

A previous test may not be a good estimate of accuracy for your agency when the underlying relationships between probe data points and traffic volume have likely changed between that test and your roadway system. For example, if the existing tests were performed in a heavily populated area, and your agency needs data for rural, mountainous environments, then new validation tests will likely be required. This is because there may have been changes in the relationship between cellphone reports and traffic volumes because of the changes in cell service providers, cellphone usage rates, the cellphone applications being used, and the level of cell tower coverage.

**C.2) What is needed from the vendor to calibrate their AADT estimates for your state's conditions?**

See the response to question B.5.

Some vendors will wish to locally calibrate their algorithms to your agency's specific conditions. To do that, they will need local ground truth data which with to train their models. As part of each vendor's proposal, it is important to learn what each vendor requires to locally calibrate its algorithm.

Calibration typically requires a specific number of calibrated, permanent, continuously operating count sites for each geographic area and/or roadway classification requested by the state or included in the vendor specifications. The vendor may need multiple years of data for each of these locations. Does the vendor need just the AADT value for each site? Does it need directional volumes or total volumes in both directions? Hourly records or just daily volumes?

An important question for the vendor is whether ADT measurements—as opposed to AADT measurements from continuous counters would be used in the calibration process. ADT is readily available from a large number of short term counts taken around the state. These measurements are more accurate than the AADT values computed from a short count, because of the error inherent in the temporal adjustment process. Unfortunately, this has typically not been the case as the vehicle probe to traffic volume estimation process typically works more accurately at the annual level. Therefore, vendors may prefer a smaller number of accurate AADT values over a larger number of ADT values.

**C.3) Does your agency have a sufficient number of continuous count locations on the roads where they are needed?**

Given the requirements of the vendor(s) selected for testing, your agency needs to determine whether it has a sufficient number of count locations to give to the vendor for calibration. In making this calculation, also remember that your agency likely needs to reserve enough of these same counters for validation testing.

If the agency does not have enough count locations, it will be necessary to identify other count locations that can be used for these tests. Other sources of these counters may include other agencies (e.g., cities), other transportation agencies (e.g., toll authorities), or even other divisions within your agency (e.g., truck weigh station operations, where counts at those stations extend across the entire roadway).

### C.4) Collect and store the independent ground truth data needed to compare with the vendor data.

After providing the calibration data to the vendor, your agency should also tell the vendor the locations for which volume estimates will be provided. Your agency is then responsible for developing accurate ground truth traffic volume estimates from those locations in order to compare against the vendor's data. This includes making sure the equipment collecting the ground truth data is well calibrated and functioning correctly.

### C.5) Obtain and store data from the vendor.

Once the vendor has completed its calibration, it will provide your agency with its estimates at the agreed upon locations.

### C.6) Combine datasets, matching AADT locations from both datasets to ensure the correct one-to-one comparison between vendor data and ground truth AADT value.

Your agency (or its selected consultants) will then perform a series of one-to-one comparisons. This process is described in detail in Appendix B.

### C.7) Follow the accuracy testing procedures that are shown in Appendix B, or perform an audit of the cross-validation process and outputs used for model development and testing for your state.

Appendix B shows the recommended process for independent computation of the accuracy of a vendor's data. It requires a large number of permanent count locations that were not used by the vendor for model calibration. If an insufficient number of independent sites are available for testing, the recommended approach is to audit the vendor's cross validation results from that vendor's model development for your state.

## D. UNDERSTANDING THE DATA TO BE LICENSED

To have confidence in the quality of the AADT and other traffic volume estimates that your agency is licensing, it is important that the agency understand the basis for those estimates and have confidence that those estimates will be valid across the relevant set of roads. Obtaining this confidence starts with understanding three aspects about the way those estimates are produced:

- What are the input variables used to produce those AADT estimates and any other volume statistics being purchased?
- What are the basics of the analytical process used to convert those input variables into traffic volume estimates?
- What is the demonstrated accuracy of those volume estimates, and specifically the accuracy of the model they are using to provide the estimates being purchased?

### D.1) What are the input variables used to produce the AADT estimates and other volume statistics being licensed?

Understanding the basic inputs will give your agency an overview of the factors that can directly affect the estimation of the provided volumes—and conversely, the factors that can NOT directly affect those estimates (although they may indirectly affect them). Start with, “What is the basic data source used to produce the estimate? Is it mobile phone location data, GPS based navigation apps, LBS data, and/or Fleet-management system data?” This information will allow your agency to ask questions about how the analytical process accounts for potential biases that these data sources might introduce and to test for those outcomes.

For example, if the primary data source is smartphones observed, then there is a potential for underestimating vehicles driven by older drivers, as this population is less likely to carry smartphones or use many apps that provide LBS data. This suggests that when examining the accuracy of the data is examined, attention should be paid to determining whether geographic areas with high levels of older drivers or tourists have biased AADT estimates relative to other areas in the state. Similarly, data from connected cars come from newer model cars which are more likely to be driven by high income individuals. AADTs on roads with heavy transit use – where many users are using their smartphones in each bus – may be overestimated relative to roads with no transit service.

A key aspect of learning about the inputs a vendor uses to estimate AADT is the sample size associated with that input source. For AADT, the unit of sample size is the number trips. At a high level, the relevant sample size should be the number of distinct, observable vehicle movements during the time being studied at the specific count location in question. Different vendors may capture this in different ways, such as by making "trips" (e.g., "on average we capture 8 percent of trips at any given count location") or by linking two "activities" and inferring a trip uses the relevant segment. Obviously, the larger and more consistent the fraction of traffic being observed, the better the opportunity that the resulting AADT values will be accurate.

Another useful, but not definitive, input is the approximate fraction of unique smartphones or connected vehicles in operation that are being captured by the data supplier's data source (e.g., "Our suppliers have around ~25 percent of the smartphone market in your state.") The higher the penetration of phones or connected vehicles, the more opportunity to correct for demographic bias. However, some vendors may not have this number due to privacy protections. In all cases, the share of smartphones/vehicles will be much larger than the share of trips (the actual unit of sample for AADT) because the smartphones in a vendor system will not collect every (or even most) movement taken by each phone throughout the year.

An additional consideration in the sample size discussion is how frequently a given device reports its location – which is commonly referred to as the "ping rate" for that device. The more frequently a device reports its location, especially in urban areas, the better the ability to identify the road on which that device is located, and the better the accuracy of determining whether the device is in a car, truck, bus, or other motor vehicle, or whether the device is being carried by someone walking or biking. Frequent location reports also allow for better estimation of other traffic statistics, such as turning movement percentages and speeds. Ping rate is less important in rural areas. A review of the impact on increased ping rate on accuracy of volume indicates that ping rates that range from every 5-15 minutes enables equally as accurate volume estimations as ping rates of every 1-3 minutes. In other words, for volume estimation, ping rate at the resolution of minutes is sufficient for map matching. (See the Final Report for the project, "Non-Traditional Methods to Obtain Annual Average Daily Traffic (AADT)" for the detailed findings associated with this topic.)

However, a final area for consideration is the need to understand the spatial accuracy of those pings. The more accurately the device is located, the more accurately the device is assigned to a specific road segment, and the better the resulting AADT estimates (and all other derived metrics) will be. Thus, agencies should request not only the ping rate of the devices reporting their positions, but the accuracy of those devices, with more accurate devices (+/- 20 meters) being roughly twice as accurate as devices with spatial errors over 500 meters, and more than 25 percent more accurate than devices with spatial errors of between 50 and 500 meters.

Having access to sample size information associated with specific AADT statistics provides considerable insight into the accuracy of those estimates. However, some vendors consider sample size to be key, proprietary business information and often do not share it. While this is understandable, having access to these data is extremely helpful to an agency trying to understand the reliability of their purchased data and guide them in day-to-day implementation. The ideal scenario is for the vendor to share trip sample size on each analysis run (e.g., the trip sample size used for the AADT 2019 estimate on this road segment was X).

In addition, vendors using modern machine learning or other techniques for analysis can calculate expected error ranges for any given road segment estimate. For example, they may be able to estimate an AADT for a certain segment of 8,200 with a 95$^{th}$ percentile accuracy range of 8,000-8,400. Another road segment with a best estimate of 8,200 might have a much broader 95$^{th}$ percentile range, say of 7,200 to 9,200. These individualized accuracy statistics can help staff understand and implement specific AADT road segment estimates.

In addition to the details associated with the primary data that serve as the basis for traffic count estimates, vendors may well use other supporting data sources to adjust their initial estimates.

Other variables that might explain variations in travel behavior (e.g., the presence of major snowstorms or other events) may also be used by a vendor's algorithms to adjust its AADT estimates in order to account for activities that affect the basic relationships between the number of observed devices and the number of vehicles using the roadway.

## D.2) What is the basic mathematical (theoretical) approach used?

It is important that your agency have a basic understanding of the algorithmic process being used to convert the input variables into the AADT statistics. Such an understanding will improve your agency's ability to quality assurance check the purchased data, as well as describe to decision makers and the public how the traffic volume estimates are being generated to maintain their confidence in the values being used.

Unfortunately, many of the current techniques being used involve complex machine learning approaches that identify, classify, and apply relationships between variables. Common approaches include various types of regression, neural networks, gradient boosting, and random forest techniques. These terms and techniques may not be well understood by the transportation engineering staff tasked with checking and using the resulting traffic estimates so an external panel may be needed to validate the subject data.

Consequently, each vendor should be required to include a description of its overall analytical process that can be understood by DOT staff. This does not mean that the vendor must supply specific equations to the agency or specific software code that perform the AADT estimation, as these are rightly the vendor's proprietary information. However, the vendor should be able to provide a clear description of the analytical process and the nature of the relationships being used to compute their volume estimates. Included in this description should be the vendor's plan for identifying when and how the algorithmic relationships are updated over time, and information about how that update process affects the year-to-year trends the vendor provides. For example, if the vendor uses LBS data to compute AADT values, then how does it adapt that algorithm over time when the smartphone apps that generate the base data change over time? In the realm of location-based services, the use of some apps that supply data grow over time, while others decline. This changes the relationship between the number of the location points obtained and traffic volumes on the road. Similarly, the business environment for apps causes data from new apps to be added to the data feed while others are removed. This changes the relationship between the data points being received and the traffic volumes that need to be reported. Thus, most vendors of traffic volume data frequently update their algorithms to account for these changing relationships. Understanding this update process and its implications for the traffic volume data being purchased is important.

While it is not possible when licensing data to understand how a specific vendor's algorithms will change over the course of the agreement, it is important for the agency to understand when the algorithms are changing, how they are changing, and the effect those algorithmic changes have on expected data accuracy.

**D.3) Can this explanation be released to the public?**

It is important that this "simplified description" of how traffic volumes being used by your agency, including the imbedded privacy protection measures, can be made publicly available. It is also important, because it supports a transparent government, and because this is a significant change in technology, that the public needs to be able to understand if they are to have confidence in the traffic volume data being used to design and operate their road system.

**D.4) Are the input data sources consistent from year to year, or do they change over time? And if the input source change over time, what activities are undertaken to maintain consistent trends over time?**

As noted in D.2, many of the data sources used by vendors change over time. This can be because of changes in the apps used to deliver location data points, or the usage of those apps, or even the companies that operate the cellphone network. For example, what happens when two cellphone companies merge, and data on phone locations from one of those companies is the basis for the AADT values? Does the coverage grow due to access to a larger set of cellphones, or does the traffic volume vendor have to sign a new data access agreement with a different cellphone data vendor?

Because these changes occur over time, the actual algorithms (or algorithmic coefficients) used to compute traffic volume also change over time. These changes have the potential to cause discontinuities in traffic volume estimates on some roads. (Note that these same discontinuities can occur with traditional short duration counting techniques. In this latter case, they typically occur either because of undetected equipment error or when the short term count observes traffic associated with an unusual event, for example, a traffic diversion due to a construction event, that was not accounted for when the count was scheduled.)

Your agency should be aware of the potential for these discontinuities and should work with the selected vendor to understand 1) the degree to which the vendor will proactively identify and mitigate the effects of these inconsistencies, 2) the frequency with which your agency should perform those inconsistency checks, and 3) the appropriate response to identified inconsistencies.

**D.5) Are there known limitations in the AADT estimations? And if there are known limitations in the system, how does the vendor address those limitations?**

Your agency should work with the successful vendor and other state and highway agencies that use the vendor's data to gain an understanding of any limitations in the purchased data. Historically, the accuracy of AADT estimates (in terms of expected percentage error) declines as traffic volume increases. This is likely true for some vendors' data simply because modest changes in absolute volume on low volume roads result in large changes in percentage error. At the same time, even when a modest fraction of vehicles using a low volume road are vehicle probes, there may still be a very low volume of probes observed on specific low volume roads. This will produce lower accuracy in the conversion of probe volumes to AADT or other traffic statistics because minor biases in which vehicles are or are not using those low volume roads will result in errors in the AADT estimation process.

In addition to this known limitation, machine learning techniques are subject to bias, in large part because these models are only as good as the data with which they are trained (calibrated). Many times, biases occur because some types of roads are under-represented in the training dataset. Biases can be geographic or associated with specific types of roads. For example, vehicle probe datasets often struggle to differentiate travel on contiguous roadways, such as general purpose (GP) and HOV lanes, or on roadways that are vertically stacked (e.g., an express lane roadway that is in a tunnel underneath a GP facility). In these cases, the probe data cannot provide reliable independent HOV/HOT and GP volumes, although they may well provide an excellent AADT for the combined roadway. The same limitation is typically true if lane-specific volumes are needed for operational analysis on a multi-lane facility.

Where limitations exist, your agency may need to perform traditional traffic counting to supplement the vehicle probe data.

**D.6) What data are used to calibrate the system? How much data (number of locations) are required to perform that calibration? (i.e., X% of calibration locations are on roads of <5,000 AADT)?**

Answers to previous questions (see B.5 and C.2) will affect your agency's understanding of the calibration requirements associated with the successful vendor. It is important to understand that your agency will need to maintain the appropriate calibration and validation dataset into the future. As noted in D.2 and elsewhere, most traffic volume data vendors continually update their estimation algorithms. This is a common outcome of the use of machine learning techniques when the input data stream changes over time, which also changes the relationship of that data stream with the desired forecast result also changes over time. In addition, as described in D.5, analyses performed over time may determine specific limitations in the current process due to limitations in the calibration dataset.

To resolve these issues, your agency must work with the vendor to supply and improve the ground truth datasets used to calibrate the vendor's process. Calibration data may also come from nearby, similar jurisdictions. The better those calibration datasets, the better the resulting AADT values. Thus, the agency should expect to work in concert with its selected vendor to both maintain and improve the calibration (training) datasets over time and to partner with similar jurisdictions to share calibration and validation data. The agency should also work with their traffic count database vendor to ensure that, when using the validation method shown in Appendix B, that subsets of the permanent count database are reserved for the validation task and not shared with vehicle-probe based AADT vendors.

## OTHER IMPORTANT CONSIDERATIONS

This section of the guidelines raises other issues that your agency should consider as it approaches the purchase of volume data based on vehicle probe technologies.

### Consider a phased approach to the integration of private sector data.

The shift toward vehicle probe-based traffic volume estimates, and away from traditional short duration counts is still a very new concept. The result is that some unexpected outcomes may occur. These can be both positive and negative.

For this reason, agencies may find value in a phased approach to the purchase and adoption of these new data sources with consistent verification of the data source over time. For example, an agency might wish to purchase a one-year license to a subset of the data while also funding a research project to compare those data to the current traffic volume estimates, while also allowing IT staff to explore the true IT costs associated with adopting that dataset within the corporate data system.

The research project should follow steps outlined in Checklist steps C.4 through C.7 and described in Appendix B.

# APPENDIX A:
# CHECKLISTS

## A. PREPARING TO PURCHASE AADT ESTIMATES

**A.1) How do you intend to use the data?**

☐ Meet specific project needs? Accuracy requirements for those project analyses

☐ Replace existing short term counts (Use accuracy Table 2 to test data)
If this is the intention, what additional traffic variables need to be included in the purchase, to replace data no longer being collected by short duration counts?

☐ Provide AADT values where reliable counts are not affordable (Use Table 2 for an accuracy allowance)

☐ Others (explain)

**Table 2: Reference Accuracy and Precision for AADT Estimates To Replace Temporary Counts**

| AADT Volume Range | Minimally 95% Probability, TCE Median Error (Bias) (%) | Minimally 95% Probability, 95% TCE Population Error Range (%) |
|---|---|---|
| 500 – 4,999 (low) | ± 2.0 | ± 34.0 |
| 5,000 – 54,999 (medium) | ± 1.5 | ± 28.0 |
| 55,000 + (high) | ± 2.5 | ± 24.0 |

**A.2) Who will use these data?**

☐ A small set of staff working on a specific project – *Number of seat licenses required?*

☐ The entire agency - *Must be able to input AADT data to the existing agency data system*

☐ Outside agencies we work with (e.g., MPOs, cities, counties) - *Access to the data needs to be provided to those staff, either through the agency's corporate data system (see above) or through additional licenses*

☐ The general public – *Agency must be allowed to release the data. There must be a mechanism for releasing the data. Is that the existing agency's corporate data system?*

**A.3) How do the data need to be delivered from the vendor?**

☐ Via the vendor's web site (visual delivery of data at a location, downloading of selected data via link as Excel or CSV files) – *appropriate for MB of data.*

☐ Large CSV file transmitted via secure file transfer protocol – *appropriate for GB of data*

☐ API used to extract data based on software queries – *appropriate for real-time delivery of data, or automated downloading of frequent dataset updates.*

☐ Others

**A.4) How often will the data be delivered?**

☐ Annually – (*AADTs are provided as part of the "end of year" data processing*)

☐ Monthly – (*AADTs are routinely updated by the vendor to reflect changing travel conditions*)

☐ On demand – (*based on a selection/query to the vendor's web site*)

☐ In real time – (*the vendor provides volume data for operational use, in addition to AADTs, so data is delivered routinely through an API.*)

**A.5) How will the data be uploaded to the agency's corporate data system?** (*Required only if the answer to questions 1 and 2 indicate that the data need to be uploaded into the current corporate data system. This question requires discussion with the agency IT staff and an understanding of how the AADT values will be stored – either as location specific values or as segment values within the agency system, and requires an understanding of how data can be uploaded to, stored in, and accessed within the corporate data system currently used by agency staff.*)

____________________________________________________________

____________________________________________________________

**A.6) How will the accuracy of the data be determined?**

☐ Based on independent 3rd party testing – (*this assumes tests in other geographic areas will produce similar results in your state*)

☐ Performing your own validation testing – (*This is best done by using data from well calibrated, permanent, continuously counted locations as ground truth for comparison*)

## B. DATA REQUIRED TO COMPARE BIDS

### B.1) What is the purchase price?

What is the pricing model? (for example: by number of concurrent users allowed, by mile of roadway, by population, by internal vs. external access rights)

_______________________________________________________________

### B.2) Who owns the data you have purchased or licensed?

- ☐ Does your agency retain a copy of the data indefinitely, as well as the right to use it, after the conclusion of the contract period?
- ☐ Can your agency share those data (or a subset of the data), with other public agencies?
- ☐ Can the data be shared with the public?
- ☐ Are there conditions associated with sharing the data (*e.g., no live data can be shared, but data archived for over a week can be shared*)?
- ☐ Are there limitations on what programs and projects the data can be used for?

### B.3) What is included in that price?

- ☐ Extent of licenses included
- ☐ Number and frequency of data deliveries
- ☐ Number of years of data provided (historical and future years)
- ☐ Amount of roadway covered in the data (*e.g., State routes only, city & county roads? local roads?*)
- ☐ Access to data allowed to other agencies and the public
- ☐ If changes in vendor modeling approach or input data availability change during the contract, and better estimates result from those changes, are new estimates of previously supplied data included in the bid price?
- ☐ Does the vendor supply a sample size value with each estimate? What about a confidence interval?
- ☐ What other traffic statistics are included in the price (if any)?
  - ☐ AADT by truck class? (which classes?)
  - ☐ MADT
  - ☐ Average Hourly Volumes?
  - ☐ Average Weekday Volumes?
  - ☐ ADT volumes at specific sites?
  - ☐ Turning movements?
  - ☐ K?
  - ☐ D?
  - ☐ T?
  - ☐ Percent Peak Trucks?
  - ☐ Other ______________________________________________

### B.4) How accurate are the provided data?

- ☐ What accuracy does the vendor claim?
- ☐ Is it possible/desirable to use the results from accuracy tests performed by independent 3rd parties?

_☐_ Perform state specific tests (*see Testing Guidelines – Appendix B and Table 2 above*)

**B.5) What data are required to calibrate the data for delivery to your agency?**
(vendor response required, response can be "no state specific calibration is needed)
_☐_ Number of calibration sites required
- _☐_ permanently operating, continuous count locations (AADT values)
- _☐_ short duration count locations (ADT values)
- _☐_ other

_☐_ Distribution of those sites across roadway volume classes or geographic areas

__________________________________________________________

__________________________________________________________

**B.6) How will the data be delivered?** (*How the data are delivered may add costs to the agency, based on the work required by agency staff to make those data accessible to others in the agency.*)

__________________________________________________________

__________________________________________________________

**B.7) What is required to enter the data into your agency's corporate data system?** (*This question is not required if data are only obtained by staff via direct download of data or data files from a vendor's web site*).

__________________________________________________________

__________________________________________________________

**B.8) What is the earliest date for when AADT values can be delivered?**

__________________________________________________________

Are these values for the past 12 months or for a calendar year? (*Also see the answer to the question in (B.2), how often will the data be delivered? If data are delivered monthly, are new AADT values provided, and are they for a rolling 12-month period, or updates of the previous calendar year?)*

## C. TESTING THE QUALITY OF THE DATA

**C.1) Is your agency willing to accept independent 3rd party testing or audits of a vendor's cross validation work?**

☐ This allows initial vendor selection (subject to validation review)

**C.2) What is needed from the vendor to calibrate their AADT estimates for your state's conditions?** (*Repeated from B.9*)

☐ Number of calibration sites required
- permanently operating, continuous count locations (AADT values)
- short duration count locations (ADT values)
- other

☐ Distribution of those sites across roadway volume classes or geographic areas
☐ Can data be purchased and tested for accuracy without local calibration?
☐ Can ADT measurements be used instead of AADT values for ground truth testing?

**C.3) Does your agency have a sufficient number of continuous count locations on the roads where they are needed?** (*Note: If the vendor requires data for calibration, sites given to the vendor for calibration purposes should NOT be used as part of the dataset used for accuracy validation testing.*)

☐ Geographical coverage?
☐ By volume or factor group?
☐ Can they obtain those data from other sources in your agency or other agencies? (e.g., *high definition traffic signal system data, WIM enforcement count locations, toll road payment statistics, etc.*)

**C.4) Collect and store the independent ground truth data needed to compare with the vendor data.** (*This likely requires providing the vendor with calibration data from your agency.*)

**C.5) Obtain and store data from the vendor.**

☐ Tell the vendor the locations for which independent AADT estimates are available, so that the vendor can provide their AADT values for those locations
☐ Arrange to obtain, and store the vendor data

**C.6) Combine datasets, matching AADT locations from both datasets to ensure the correct one-to-one comparison between vendor data and ground truth AADT value.**

**C.7) Follow accuracy testing procedures that are shown in Appendix B, or audit the vendor's cross validation analyses used for model development and testing for your state.**

## D. UNDERSTANDING THE DATA BEING PURCHASED

**D.1) What are the input variables used to produce the AADT estimates and other volume statistics being purchased?**

☐ In addition to cellphone and other passive, mobile data, what other sources of data are required to obtain the required inputs? (*e.g., census data, weather data, employment statistics, economic indicators, etc.*)

☐ Do any of these data need to be contributed by the agency?

☐ If the primary input data come from cellphone location reporting or location-based services (LBS), what is the average sample trip rate (# of sample trips compared to actual trips at any given location) and "ping rate" (frequency with which each device reports its location) for those location reports? (*Note that there can be multiple sources of data in each vendor's input data stream, and each of those sources might have a different ping rate. The goal is to understand the approximate fraction of devices with each ping rate.)*

**Table 3: Input Data and Characteristics to AADT Model**

| Type of Data | Overall Sample Size of Trips | Ping Rate | Spatial Accuracy of Data Points |
|---|---|---|---|
| Cellphone derived trips | | | |
| Location based services data-derived trips | | | |
| WiFi/Bluetooth location-derived trips | | | |
| Fleet management-derived trips | | | |
| Other ________________ ______________________ | | | |

**Table 4: Supplemental Data For AADT Models**

| Type of Data | Provided By? | Data Description |
|---|---|---|
| Census Data | | |
| Weather Data | | |
| Employment Data | | |
| Construction Activity | | |
| Other | | |
| Other (2) | | |
| Other (3) | | |

**D.2) What is the basic mathematical (theoretical) approach used?** (*The vendor should provide a written description that can be understood by a transportation professional that may not have a degree in modern data science techniques.*)

☐ Is there an identifiable, and direct relationship between the input data variables and the output values (AADT), or is the relationship mostly a "black box"?

**D.3) Can this explanation be released to the public?** (*Or are there trade secret issues with the release of the proprietary approach to AADT estimation?*)

☐ Yes/No

**D.4) Are the input data sources consistent from year to year, or do they change over time? And if the input source data change over time, what activities are undertaken to maintain consistent trends over time?**

☐ Yes/No

*For example, if the data source is cellphone location records, does the data supplier of those records ever change? If the data source is primarily location-based services data, do the applications which provide those data points change over time?*

________________________________________________

________________________________________________

**D.5) Are there known limitations in the AADT estimations? And if there are known limitations in the system, how does the vendor address those limitations?**

☐ For example, do the estimates lose reliability on

- very low volume roads?
- roads that are open only on a seasonal basis?
- volumes are not available on adjacent roadways (for example, it is not possible to reliably differentiate volumes on adjacent general purpose and HOV/HOT lanes)
- volume estimates in areas without cell phone coverage, or where such coverage is very low quality

________________________________________________

________________________________________________

________________________________________________

**D.6) What data are used to calibrate the system? How much data (number of locations) are required to perform that calibration and are there distribution requirements (i.e., X% of calibration locations are on roads of <5,000 AADT)?** (*See question B.5 and C.2*)

________________________________________________

________________________________________________

# APPENDIX B
# COMPUTING EXPECTED AADT ACCURACY AND PRECISION

## BASIC CONCEPT

The section provides a discussion of accuracy, precision and confidence intervals, which are key concepts used to understand the quality and reliability of the traffic data your agency is purchasing. No data should be purchased without a thorough understanding of the accuracy, precision, and confidence intervals associated with those data.

Your data vendor should provide your agency with information about the accuracy, and precision of the data they are providing, as well as the confidence intervals associated their AADT estimates. Directions provided later in this Appendix describe how to independently verify a vendor's accuracy and precision values.

Accuracy describes how close the estimated AADT values provided by the vendor are expected to be to the ground truth AADT for a given location (e.g., the expected error). Ground truth AADT is the value computed from a well calibrated and fully functioning continuous permanent count.

Precision is a measure of statistical variability.[5] It describes the distribution of the errors when examined across a number of sites. That is, the distribution of the computed differences between the estimated and true AADT measurements taken across a number of sites.

A "confidence interval" is a statistical technique used for describing the upper and lower bounds within which the ground truth value for an estimate is expected to reside, given an estimate of that ground truth. The confidence interval is associated with a "confidence level" which is a percentage that represents the likelihood that the true value will fall within the confidence interval's upper and lower bounds. When used for vehicle-probe based AADT estimates, the confidence interval typically takes the form:

"estimated AADT (X) with a confidence interval (±Y) and confidence level (Z percent)" meaning:

"the ground truth AADT value estimated by the term "X" can be expected to fall between the values of X-Y (the lower bound) and X+Y (the upper bound), Z percentage of the time."

---

[5] https://en.wikipedia.org/wiki/Accuracy_and_precision, extracted December 12, 2020

For example, a 95 percent confidence level of plus or minus 10 percent indicates that 95 times out of 100, the true AADT will fall within the error bounds described by the estimated AADT plus or minus 10 percent.

For normally distributed error bounds, a 68 percent confidence interval has error boundaries of the mean +/- one standard deviation; the 95 percent confidence interval has error boundaries of the mean +/- two standard deviations. The higher a confidence levels is, the larger the confidence interval gets. Figure 1 provides an illustration of this concept. (The horizontal axes refers to the number of standard deviations from the mean value. The shaded area equals the confidence level, for which the numeric value is shown in red text.)

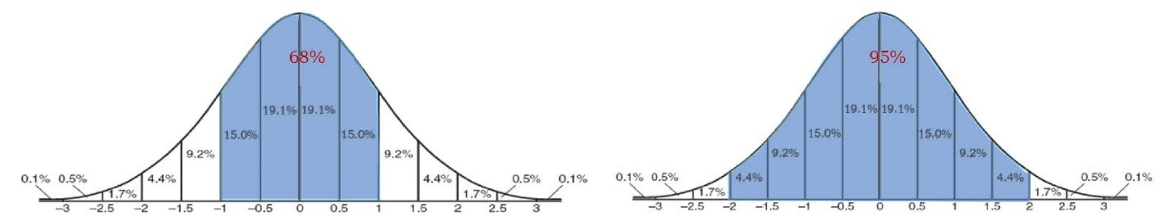


**Figure 1: Illustration of Confidence Intervals**

## HISTORICAL ACCURACY AND PRECISION EXPERIENCED WHEN USING SHORT TERM, 48-HOUR PORTABLE COUNTS FOR ESTIMATING AADT

In 2015, a pool-fund transportation research project titled "Assessing Roadway Traffic Count Duration and Frequency Impacts on AADT Estimations TPF-5(292)" led by the FHWA and supported by 7 state highway agencies researched and assessed AADT accuracy and precision related to using short-term counts and AADT estimations.[6, 7]

In the above study, full-year hourly data (365 days of complete 24-hour volumes) from 205 site and year combinations (i.e., complete sites) were obtained that collectively represented 9 functional classifications, 32 different states, and years from 2000 through 2012. These 205 complete sites had 48-hour counts extracted (done through 1,000's of iterative calculations)

[6] All AADT values were calculated using the AASHTO methodology (see page 1-6 of the 2016 Traffic Monitoring Guide at https://www.fhwa.dot.gov/policyinformation/tmguide/), though a subsequent improved FHWA method has been approved. The impact of the AADT calculation methodology is expected to be very small here.

[7] Jessberger S, Krile R, Schroeder J, Todt F, Feng J, "Improved Annual Average Daily Traffic (AADT) Estimation Processes", Transportation Research Record: Journal of the Transportation Research Board, No. 2593, TRB 16-2477, 2016.

systematically from the beginning of the year to the end of the year. Each of these 48-hour counts was expanded to an estimated AADT based on the use of adjustment factors for the days of week and month of year when the count was taken. These factors were based on the functional classification of the road being counted. The factors were computed based on using the 205 sites, as well as an additional 346 incomplete sites (i.e., where a full year of data was not available.) To most closely mirror short-term count practices, only those AADT estimates that began and ended on a Monday through Thursday and which did not span any Federal holiday were included in subsequent analysis.

The AADT estimates from the 48-hour-based short-term counts were compared to the known true AADT, since each of the 205 sites had data for all hours for every day of the year. This error is termed the Traffic Count Error (TCE), and is calculated as:

$$TCE = AADT_{error} = 100*(AADT_{48\text{-}hour} - AADT_{true})/AADT_{true}$$

The TCEs (dependent) were collectively fit to a quantile regression model with base10 logarithm of $AADT_{true}$ as the predictor (explanatory). From the quantile regression model, the $50^{th}$ percentile (median) of the TCEs response was estimated as a function of AADT. The model also produced $95^{th}$ percentile confidence bounds for the TCE median error, which are shown in Table 5a. Note that there were an insufficient number of sites in the study dataset that had AADT values under 500 for accuracy and error tolerances to be determined for that volume range, so the lowest AADT volume range in the results below is for AADT starting at 500. As TCE only applies to scenarios when at least 93 comparison samples to permanent counters are available, and that is not always feasible in each bin for agencies, Table 5b shows reference accuracy values that can be used in those circumstances: MAPE, Median Bias, and NRMSE.

**Table 5a: Reference accuracy for same year, 48-hour short term counts for AADT estimates to be used in validation exercises with <u>greater</u> than 93 permanent counter comparisons per bin**

| AADT Volume Range | Lower 95% Confidence Bound for TCE Median Error (%) | Upper 95% Confidence Bound for TCE Median Error (%) | Minimally 95% Probability, TCE Median Error (Bias) (%) (margin of error) |
|---|---|---|---|
| 0-500 | *Unknown* | | |
| 500 – 1,999 | -2.0 | -1.4 | ± 2.0 |
| 2,000 – 4,999 | -1.1 | -0.7 | ± 1.1 |
| 5,000 – 9,999 | -0.4 | 0.0 | ± 0.4 |
| 10,000 – 19,999 | 0.3 | 0.6 | ± 0.6 |
| 20,000 – 34,999 | 0.8 | 1.2 | ± 1.2 |
| 35,000 – 54,999 | 1.2 | 1.6 | ± 1.6 |
| 55,000 – 84,999 | 1.5 | 2.0 | ± 2.0 |
| 85,000 – 124,999 | 1.8 | 2.4 | ± 2.4 |
| 125,000+ | 2.0 | 2.6 | ± 2.6 |

**Table 5b: Reference accuracy statistics for same year, 48-hour short term counts for AADT estimates to be used in validation exercises with <u>fewer</u> than 93 permanent counter comparisons per bin**

| Road Size Bin | Median Error (Bias) % | 68th Percentile Absolute Error (%) | 95th Percentile Absolute Error (%) | NRMSE | MAPE |
|---|---|---|---|---|---|
| A: 0 – 499 | *Unknown* | | | | |
| B 500 - 1,999 | -0.1 | 11.8 | 26.9 | 13.0 | 10.1 |
| C: 2000 - 4,999 | 2.3 | 10.8 | 33.6 | 17.3 | 10.5 |
| D: 5,000 - 9,999 | 3.2 | 9.7 | 28.1 | 14.0 | 9.3 |
| E: 10,000 - 19,999 | 1.3 | 9.2 | 27.9 | 12.9 | 9.0 |
| F: 20,000 - 34,999 | 0.9 | 8.4 | 24.4 | 13.3 | 8.2 |
| G: 35,000 - 54,999 | 0.5 | 8.4 | 19.3 | 9.8 | 7.3 |
| H: 55,000 - 84,999 | -0.3 | 6.1 | 14.5 | 7.3 | 5.3 |
| I: 85,000 - 124,999 | 0 | 4.9 | 14.7 | 6.8 | 4.7 |
| J: > 125,000+ | 3.1 | 7.1 | 17.7 | 10.0 | 6.2 |

The last column in Table 5a, titled “Minimally 95% Probability, TCE Median Error (Bias) (%) (margin of error)” shows that the TCE median error is within +/- 2.0 percent of its true value at least 95 percent of the time when the AADT volume range is more than 500 but less than 1,999.

The results of the 2015 Pooled Fund study[3] showed that AADT estimation from 48-hour counts under the conditions outlined tended to produce median estimates (for any eligible day in a year) that were systematically below the true AADT for sites with lower AADT and systematically above the true AADT for sites with higher AADT. The statistical model was evaluated at several specific AADT values corresponding to the midpoints of similar volume ranges from HPMS as documented in the 2016 TRB paper[8], except for sites in the 125,000+ volume range, which were done at 125,000. The sites in the study ranged in true AADT from 500 to 269,418. From these results, FHWA selected the largest absolute percentile error for the median. An alternative methodology for AADT estimation can be labeled equivalently accurate to short-term counts if the median error it produces for any particular time period, with at least 95 percent probability, falls within the identified bounds shown in Table 5a.

In addition to the median TCE from the quantile regression model, population tolerance intervals were also estimated. The tolerance interval is a range of values expected to bracket a fraction “p” of a population, where p in this study was 0.95, or 95 percent. To capture 95 percent of the population, estimates were obtained from the regression model for the 2.5$^{th}$ and 97.5$^{th}$ percentiles. As was the case with the regression fit of the median, there is uncertainty in the model fits of the 2.5$^{th}$ and 97.5$^{th}$ percentiles. Consequently, the lower, one-sided 95 percent confidence bound on the lower 2.5$^{th}$ percentile and the upper, one-sided 95 percent confidence bound on the upper 97.5$^{th}$ percentiles were estimated (Table 6). These two bounds form an interval within which 95 percent of the TCE population is expected to be contained with at least 95 percent confidence.

---

[8] Jessberger S, Krile R, Schroeder J, Todt F, Feng J, “Improved Annual Average Daily Traffic (AADT) Estimation Processes”, Transportation Research Record: Journal of the Transportation Research Board, No. 2593, TRB 16-2477, 2016.

**Table 6: Reference Precision for AADT Estimates**

| AADT Volume Range | Lower 95% Confidence Bound for the TCE ( 2.5$^{th}$ Percentile Error (%)) | Upper 95% Confidence Bound for the TCE ( 97.5$^{th}$ Percentile Error (%)) | Minimally 95% Probability, 95% TCE Population Error Range (%) |
|---|---|---|---|
| 0-500 | *Unknown* | | |
| 500 – 1,999 | -31.6 | 34.2 | +/-34.2 |
| 2,000 – 4,999 | -26.8 | 30.8 | +/-30.8 |
| 5,000 – 9,999 | -23.3 | 28.5 | +/-28.5 |
| 10,000 – 19,999 | -20.2 | 26.7 | +/-26.7 |
| 20,000 – 34,999 | -17.7 | 25.7 | +/-25.7 |
| 35,000 – 54,999 | -15.7 | 24.8 | +/-24.8 |
| 55,000 – 84,999 | -13.9 | 24.1 | +/-24.1 |
| 85,000 – 124,999 | -12.3 | 23.5 | +/-23.5 |
| 125,000+ | -11.6 | 23.3 | +/-23.3 |

The statistical model that produced these outcomes was evaluated in the same manner as described above for Table 5a. From these results, FHWA selected the larger absolute percentile error between the 2.5$^{th}$ and the 97.5$^{th}$ percentile estimates for a more tolerant limit and included those values in the right-hand column of Table 6. By further aggregating the volume groups and selecting the largest of the error ranges from tables 5 and 6 for each of the new aggregated volume groups, Table 7 is produced to show the reference values for the expected accuracy and precision of the current AADT values used by state agencies, when those AADT values are based off of factored, short duration counts.

**Table 7: Reference Accuracy and Precision for AADT Estimates**

| AADT Volume Range | Minimally 95% Probability, TCE Median Error (Bias) (%) | Minimally 95% Probability, 95% TCE Population Error Range (%) | MAPE | NRMSE |
|---|---|---|---|---|
| 0 – 500 | *Unknown* | | | |
| 500 – 4,999 (low) | ± 2.0 | ± 34.0 | 10.3 | 18.0 |
| 5,000 – 54,999 (medium) | ± 1.5 | ± 28.0 | 8.7 | 14.3 |
| 55,000 + (high) | ± 2.5 | ± 24.0 | 5.3 | 9.5 |

An alternative methodology used for estimating AADT can be labeled as producing estimates as precise as those produced by using 48-hour, short-term counts if 95 percent of the values it produces across all conditions, with at least 95 percent probability, fall within the values shown in Table 7.

## TRAFFIC DATA ACCURACY AND PRECISION EXPECTATION

Based on the above historical data analysis and traffic data professionals' familiarity with permanent and portable counting, data professionals should consider data quality from any other source with the following reference values. Ideally, no data quality dimension should perform below the reference values shown in Tables 5a or 7, if there are 93+ comparisons to permanent loop counters in each bin, or Table 5b if there are fewer than 93 comparisons to permanent counts.

## HOW TO USE TABLE 5A/7

Suppose that an alternative technology is proposed and used for AADT estimation. To demonstrate that this technology produces AADT estimates that are equivalent to those produced by conventional short-term counts, the technology should be used to produce estimated AADT values for a range of roadways and conditions where there are corresponding calibrated permanent automatic traffic recording equipment capable of determining true AADT. The collective set of AADT estimates may then be converted to percentage errors relative to the true AADT values and these error values used to estimate the following:

1) 95 percent confidence interval for the median percentage error,
2) lower one-sided 95 percent confidence bound for the 2.5$^{th}$ percentile error, and
3) upper one-sided 95 percent confidence bound for the 97.5$^{th}$ percentile error

If both the upper and lower bounds from bullet #1 fall within the standard limits in the second column of Table 7, the technology can be considered equivalently accurate.

If the bounds for the terms defined in bullets 2 and 3 fall within the standard limits of the third column in Table 7, the technology can be considered at least equivalently precise. This process may need to be repeated for roadways in different volume ranges if the technology is ultimately used in different volume ranges. Alternatively, a model-based approach can be used as was done by FHWA to fit all the data across a range of true AADT values.

There are additional considerations to assure the test data are representative of the subsequent population for which the accuracy and precision must be demonstrated. These include the range of days of the year, how factoring is completed, what functional classifications are included, and possibly others that should be reviewed with subject matter experts in traffic counting.

## STEP-BY-STEP ILLUSTRATION OF HOW TO USE TABLE 7

Suppose a non-traditional method led to 100 individually estimated AADT values for 100 different roadway segments on roadways with AADT in the 5,000 – 54,999 range as shown in Table 8.

**Table 8: Sample of Measured AADT Estimates against True AADT**

| n | AADTtrue | AADTtest | PctError | n | AADTtrue | AADTtest | PctError | n | AADTtrue | AADTtest | PctError | n | AADTtrue | AADTtest | PctError |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 25,301 | 26,056 | 2.98 | **26** | 16,213 | 16,319 | 0.65 | **51** | 17,322 | 16,744 | -3.34 | **76** | 38,712 | 42,626 | 10.11 |
| **2** | 6,447 | 6,043 | -6.27 | **27** | 18,398 | 19,266 | 4.72 | **52** | 35,502 | 34,298 | -3.39 | **77** | 12,690 | 11,749 | -7.42 |
| **3** | 23,127 | 22,853 | -1.18 | **28** | 21,380 | 21,095 | -1.33 | **53** | 20,290 | 20,566 | 1.36 | **78** | 10,164 | 9,726 | -4.31 |
| **4** | 30,977 | 31,599 | 2.01 | **29** | 26,620 | 27,299 | 2.55 | **54** | 17,720 | 17,214 | -2.86 | **79** | 14,812 | 14,403 | -2.76 |
| **5** | 11,763 | 11,303 | -3.91 | **30** | 10,904 | 10,408 | -4.55 | **55** | 5,973 | 6,102 | 2.16 | **80** | 11,883 | 12,019 | 1.14 |
| **6** | 12,404 | 11,899 | -4.07 | **31** | 8,720 | 9,131 | 4.71 | **56** | 48,726 | 49,598 | 1.79 | **81** | 8,414 | 7,957 | -5.43 |
| **7** | 5,813 | 5,337 | -8.19 | **32** | 18,396 | 17,268 | -6.13 | **57** | 19,416 | 19,690 | 1.41 | **82** | 47,900 | 46,871 | -2.15 |
| **8** | 9,621 | 9,606 | -0.16 | **33** | 37,857 | 38,627 | 2.03 | **58** | 35,117 | 37,238 | 6.04 | **83** | 29,953 | 31,451 | 5.00 |
| **9** | 17,954 | 17,908 | -0.26 | **34** | 27,598 | 27,686 | 0.32 | **59** | 5,476 | 5,956 | 8.77 | **84** | 21,233 | 23,812 | 12.15 |
| **10** | 12,787 | 12,745 | -0.33 | **35** | 47,966 | 50,414 | 5.10 | **60** | 53,551 | 54,278 | 1.36 | **85** | 6,540 | 6,469 | -1.09 |
| **11** | 10,986 | 11,202 | 1.97 | **36** | 54,751 | 51,544 | -5.86 | **61** | 7,325 | 6,494 | -11.34 | **86** | 29,523 | 31,618 | 7.10 |
| **12** | 34,194 | 34,369 | 051 | **37** | 6,275 | 5,850 | -6.77 | **62** | 5,763 | 5,697 | -1.15 | **87** | 5,840 | 5,698 | -2.43 |
| **13** | 46,100 | 49,369 | 7.09 | **38** | 14,297 | 14,403 | 0.74 | **63** | 32,621 | 32,101 | -1.59 | **88** | 35,860 | 34,556 | -3.64 |
| **14** | 17,313 | 20,043 | 15.77 | **39** | 14,994 | 16,423 | 9.53 | **64** | 37,690 | 37,152 | -1.43 | **89** | 10,534 | 10,526 | -0.08 |
| **15** | 34,205 | 33,110 | -3.20 | **40** | 5,232 | 4,992 | -4.59 | **65** | 24,039 | 22,432 | -6.68 | **90** | 6,690 | 6,116 | -8.58 |
| **16** | 18,967 | 19,475 | 2.68 | **41** | 15,056 | 15,476 | 2.79 | **66** | 12,086 | 12,351 | 2.19 | **91** | 48,447 | 47,019 | -2.95 |
| **17** | 43,005 | 42,878 | -0.30 | **42** | 14,042 | 13,598 | -3.16 | **67** | 11,398 | 11,476 | 0.68 | **92** | 6,091 | 6,366 | 4.51 |
| **18** | 7,922 | 7,927 | 0.06 | **43** | 8,997 | 8,680 | -3.52 | **68** | 25,833 | 25,294 | -2.09 | **93** | 33,073 | 33,602 | 1.60 |
| **19** | 20,766 | 21,297 | 2.54 | **44** | 14,122 | 14,971 | 6.01 | **69** | 12,128 | 12,405 | 2.28 | **94** | 9,997 | 9,803 | -1.94 |
| **20** | 20,979 | 21,153 | 0.83 | **45** | 9,487 | 8,867 | -6.54 | **70** | 14,054 | 14,696 | 4.57 | **95** | 24,698 | 24,483 | -0.87 |
| **21** | 6,233 | 5,498 | -11.79 | **46** | 16,991 | 17,654 | 3.90 | **71** | 12,138 | 12,397 | 2.13 | **96** | 7,142 | 7,631 | 6.85 |
| **22** | 5,779 | 5,716 | -1.09 | **47** | 6,027 | 6,060 | 0.55 | **72** | 11,227 | 10,349 | -7.82 | **97** | 20,760 | 20,967 | 1.00 |
| **23** | 52,893 | 50,667 | -4.21 | **48** | 6,242 | 6,169 | -1.17 | **73** | 9,270 | 10,188 | 9.90 | **98** | 27,094 | 28,176 | 3.99 |
| **24** | 9,792 | 8,593 | -12.24 | **49** | 26,180 | 25,857 | -1.23 | **74** | 23,595 | 24,851 | 5.32 | **99** | 16,017 | 16,216 | 1.24 |
| **25** | 16,179 | 15,888 | -1.80 | **50** | 20,841 | 19,864 | -4.69 | **75** | 5,764 | 5,568 | -3.40 | **100** | 6,211 | 6,154 | -0.92 |

These 100 measured values are from  sites and roadway segments with true AADT (based on complete yearly counts from a permanent traffic counter) that range from 5,000 to 54,999. For each value the AADT percent error is calculated as specified in the previous documentation. It is now desired to determine if the AADTs from this non-traditional method are demonstrated to be accurate and precise to the established standards, which were derived from the current standard method of short-term counts factored to AADT.

Note that there may be multiple ways to evaluate the data in Table 8, but the method provided here is based on **no parametric assumptions**. That is, the error statistics do not need to be normally distributed, or to follow any particular distribution. To perform this analysis, the error estimates from Table 8 are ranked and sorted from smallest (most negative) to largest (most positive) percent error and the subsequent analysis will be performed first to determine the appropriate ranks of the data and then the estimates will be the percent error value of those ranks. This ranking is shown in Table 9.

**Table9: Percent Error Data from Table 5 Ranked, with Highlights of Important Ranks**

| Rank | PctError | Rank | PctError | Rank | PctError | Rank | PctError | Rank | PctError |
|---|---|---|---|---|---|---|---|---|---|
| *1* | *-7.91* | 21 | -2.68 | 41 | -1.04 | 61 | 0.24 | 81 | 1.68 |
| 2 | -7.71 | 22 | -2.39 | 42 | -0.85 | 62 | 0.25 | 82 | 2.24 |
| 3 | -7.51 | 23 | -2.37 | 43 | -0.74 | 63 | 0.27 | 83 | 2.26 |
| 4 | -6.48 | 24 | -2.28 | 44 | -0.71 | 64 | 0.31 | 84 | 2.26 |
| 5 | -6.03 | 25 | -2.27 | 45 | -0.7 | 65 | 0.4 | 85 | 2.33 |
| 6 | -5.92 | 26 | -2.23 | 46 | -0.63 | 66 | 0.41 | 86 | 2.35 |
| 7 | -5.18 | 27 | -2.16 | 47 | -0.61 | 67 | 0.63 | 87 | 2.41 |
| 8 | -5.16 | 28 | -2.13 | 48 | -0.59 | 68 | 0.69 | 88 | 2.82 |
| 9 | -5.12 | 29 | -2.04 | 49 | -0.57 | 69 | 0.75 | 89 | 3.31 |
| 10 | -5.04 | 30 | -1.97 | **50** | **-0.38** | 70 | 0.77 | 90 | 3.5 |
| 11 | -4.06 | 31 | -1.81 | **51** | **-0.33** | 71 | 1.03 | 91 | 3.51 |
| 12 | -4.02 | 32 | -1.79 | 52 | -0.32 | 72 | 1.04 | 92 | 3.56 |
| 13 | -3.45 | 33 | -1.59 | 53 | -0.32 | 73 | 1.13 | 93 | 3.66 |
| 14 | -3.44 | 34 | -1.47 | 54 | -0.18 | 74 | 1.29 | 94 | 3.91 |
| 15 | -3.17 | 35 | -1.4 | 55 | -0.16 | 75 | 1.38 | 95 | 4.03 |
| 16 | -3.08 | 36 | -1.37 | 56 | -0.13 | 76 | 1.45 | 96 | 4.91 |
| 17 | -3.02 | 37 | -1.34 | 57 | -0.01 | 77 | 1.52 | 97 | 5.63 |
| 18 | -3.01 | 38 | -1.29 | 58 | 0.06 | 78 | 1.6 | 98 | 6.6 |
| 19 | -2.99 | 39 | -1.25 | 59 | 0.06 | 79 | 1.64 | 99 | 8.08 |
| 20 | -2.82 | ***40*** | ***-1.18*** | ***60*** | ***0.22*** | 80 | 1.66 | *100* | *9.32* |

The median of the estimated AADT percent errors for a data set with n=100 is the average of the $50^{th}$ and $51^{st}$ largest values. In this case, that value is the average of -0.38 and -0.33 percent (see green shaded cells), or about -0.36 percent. This median as a measure of accuracy is only an estimate and a minimally 95 percent confidence interval for its estimate can be found by solving for the data rank, R, that corresponds to either the lower (l) or upper (u) confidence bound. These quantities are identified as R(l)acc and R(u)acc, and can be found using the equations below with functions in Excel:

R(l)acc = BINOM.INV(n, m, α/2)
R(u)acc = BINOM.INV(n, m, 1-α/2),

n is the sample size equal to 100, m refers to the median as the percentile to be estimated and is a value of 0.5, and α (the probability of rejecting the Null Hypothesis when, in fact, it is true) is selected as a value of 0.05 to obtain a 95percent confidence interval. The BINOM.INV function in Excel produces the smallest value from a cumulative binomial distribution of n trials, probability of success m, with at least the corresponding alpha term.

For this example, the values of R(l)acc and R(u)acc are 40 and 60, respectively. Looking up the $40^{th}$ and $60^{th}$ ranked values from Table 9, which have been highlighted in blue, the 95 percent nonparametric confidence interval for the median percentage error is (-1.23, +0.83). Because this range is entirely inside the ±1.5 percent accuracy limits for sites with AADT in the 5,000 to 54,999 range found in Table 7, these data provide evidence that the alternative methodology meets the accuracy standards.

To evaluate precision, a minimally $95^{th}$ confidence tolerance interval for 95 percent of the population can also be estimated non-parametrically. The appropriate equations with functions in Excel are:

R(l)prec = INT[(n – BINOM.INV(n,p,1-α))/2]
R(u)prec = INT[(n+1) – (n – (BINOM.INV(n,p,1-α))/2]

where n is the sample size of 100, p is the proportion of the population that is desired to be bracketed (0.95), and α is a value of 0.05 to obtain a 95 percent tolerance interval. The INT function rounds to the next lower integer.

For this example, the values of R(l)prec and R(u)prec are 1 and 100, respectively. Looking at the $1^{st}$ and $100^{th}$ ranked values in Table 7, the 95 percent tolerance interval for 95 percent of the population percentage errors is (-7.91, +9.32). Since these limits are well within the ±28.0 percent precision limits for sites with AADT in the 5,000 to 54,999 range, these data provide evidence that the alternative methodology meets the precision standards.

If the sample size is too small (less than 93 in this example), the ranks developed above could result in a lower value of zero. If this occurs, then the sample size is not adequate to produce the $95^{th}$ percentile confidence tolerance interval for 95 percent of the population and either more data are required, or a different methodology must be employed.

## HOW TO USE TABLE 5B

MAPE, NRMSE, and percentile errors are widely used statistical methods. For reference, the equations used for each are:

$$MAPE = \left(\frac{1}{n}\right) * \sum_{i=1}^{n} 100 * \left|\frac{AADT_{Estimate(i)} - AADT_{Permanent\ counter(i)}}{AADT_{Permanent\ counter(i)}}\right|$$

$$NRMSE = 100 * \frac{\sqrt{\left(\frac{1}{n}\right) * (AADT_{Permanent\ counter(i)} - AADT_{Estimate(i)})^2}}{\left(\frac{1}{n} * \sum_{i=1}^{n} (AADT_{Permanent\ counter(i)}\right)}$$

$$Median\ Error\ (\%) = P_{50\%}\left(\left\{100 * \frac{AADT_{Estimate(i)} - AADT_{Permanent\ counter(i)}}{AADT_{Permanent\ counter(i)}}, i = 1, \dots, n\right\}\right)$$

$$68th\ Percentile\ Absolute\ Error\ (\%) = P_{68\%}\left(\left\{100 * \left|\frac{AADT_{Estimate(i)} - AADT_{Permanent\ counter(i)}}{AADT_{Permanent\ counter(i)}}\right|, i = 1, \dots, n\right\}\right)$$

$$95th\ Percentile\ Absolute\ Error\ (\%) = P_{95\%}\left(\left\{100 * \left|\frac{AADT_{Estimate(i)} - AADT_{Permanent\ counter(i)}}{AADT_{Permanent\ counter(i)}}\right|, i = 1, \dots, n\right\}\right)$$