DEPARTMENT OF TRANSPORTATION

# Evaluation of StreetLight Data's Traffic Count Estimates from Mobile Device Data

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Texas A&M Transportation Institute

**NOVEMBER 2020**

Research Project
Final Report 2020-30

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**Technical Report Documentation Page**

| 1. Report No. | 2. | 3. Recipients Accession No. |
|---|---|---|
| MN 2020-30 | | |
| 4. Title and Subtitle<br>Evaluation of StreetLight Data's Traffic Count Estimates from Mobile Device Data | | 5. Report Date<br>November 2020<br>6. |
| 7. Author(s)<br>Shawn Turner, Ioannis Tsapakis, and Pete Koeneman | | 8. Performing Organization Report No. |
| 9. Performing Organization Name and Address<br>Texas A&M Transportation Institute<br>3135 TAMU<br>College Station, Texas 77843 | | 10. Project/Task/Work Unit No.<br>11. Contract (C) or Grant (G) No.<br>(c) 1003324 (wo) 8 |
| 12. Sponsoring Organization Name and Address<br>Minnesota Department of Transportation<br>Office of Research & Innovation<br>395 John Ireland Boulevard, MS 330<br>St. Paul, Minnesota 55155-1899 | | 13. Type of Report and Period Covered<br>Final Report<br>14. Sponsoring Agency Code |

15. Supplementary Notes

http://mndot.gov/research/reports/2020/202030.pdf

16. Abstract (Limit: 250 words)

In this study, the Texas A&M Transportation Institute (TTI) conducted an independent, follow-up evaluation of StreetLight Data's 2019 traffic count estimates using MnDOT sources of traffic count data. At 442 permanent benchmark locations, TTI found that average annual daily traffic ( AADT) estimation accuracy by StreetLight Data has improved significantly since the 2017 evaluation, especially in moderate- to high-volume categories (i.e., more than 10,000 AADT). The mean absolute error ranged from 8% to 10% for locations greater than 10,000 AADT and gradually increased to 42% for sites with less than 1,000 AADT. TTI also found significant overestimation bias for low-volume roadways (i.e., less than 2,500 to 5,000 AADT). This result was present in the permanent benchmark sites and more pronounced in the 265 short-duration count sites.

Based on these findings, TTI recommends that MnDOT consider a phased approach to using probe-based traffic count estimates: 1) Continue to maintain MnDOT permanent counter sites; 2) start using probe-based counts for about 90% of the moderate- to high-volume roadways (20,000 or more AADT); 3) continue to use traditional short-duration counts at the remaining 10% of the moderate- to high-volume roadways as a spot check to ensure that probe-based AADT estimates remain within acceptable tolerances in the next five to ten years; 4) periodically monitor the error of AADT estimates on low- to moderate-volume roadways (less than 20,000 AADT); and 5) once acceptable error tolerances for these lower-volume categories are reached, repeat Step 2 for these lower-volume categories.

| 17. Document Analysis/Descriptors | | 18. Availability Statement | |
|---|---|---|---|
| Traffic volume, Traffic forecasting, Traffic counts, Global Positioning System, Annual average daily traffic, Accuracy | | No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312 | |
| 19. Security Class (this report) | 20. Security Class (this page) | 21. No. of Pages | 22. Price |
| Unclassified | Unclassified | 24 | |

# EVALUATION OF STREETLIGHT DATA'S TRAFFIC COUNT ESTIMATES FROM MOBILE DEVICE DATA

## FINAL REPORT

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## November 2020

*Published by:*

Minnesota Department of Transportation
Office of Research & Innovation
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

# ACKNOWLEDGMENTS

The Minnesota Department of Transportation (MnDOT) funded the research described in this report. The authors acknowledge members of the project's Technical Advisory Panel, who provided valuable oversight, direction, and feedback:

- Ian Vaagenes, MnDOT, technical liaison
- Katie Fleming, MnDOT, project coordinator
- Paul Czech, MnDOT, panel member
- Gene Hicks, MnDOT, panel member
- Darin Mertig, MnDOT, panel member
- Christina Prentice, MnDOT, panel member
- Garrett Schreiner, MnDOT, panel member

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| | |
|---|---|
| AADT | average annual daily traffic |
| ATR | automatic traffic recorder |
| MAPE | mean absolute percent error |
| MnDOT | Minnesota Department of Transportation |
| RTMC | regional traffic management center |
| TTI | Texas A&M Transportation Institute |
| VMT | vehicles-miles of travel |
| WIM | weigh-in-motion |

# EXECUTIVE SUMMARY

## INTRODUCTION

In a 2017 Minnesota DOT (MnDOT) study, the Texas A&M Transportation Institute (TTI) evaluated StreetLight Data's traffic count estimates derived from location-aware mobile devices and found that "…analytic enhancements are needed to improve accuracy and granularity of estimated traffic volumes." About three years have passed since this 2017 evaluation, and internal MnDOT staff assessments indicate that the accuracy of StreetLight Data's traffic count estimates has improved. Therefore, MnDOT contracted with TTI to conduct an independent, follow-up evaluation of StreetLight Data's 2019 traffic count estimates using trusted MnDOT sources of traffic count data.

## EVALUATION METHODS

In this study, TTI compared StreetLight Data's average annual daily traffic (AADT) estimates to trusted MnDOT sources of traffic count data (i.e., 442 permanent continuous counter locations). TTI also included several hundred low-volume sites at which MnDOT conducted short-duration counts in 2019. With these low-volume sites, MnDOT had seasonally adjusted the short-duration counts to represent an AADT count. Since these AADT estimates from low-volume short-duration count sites are expected to have more error than permanent benchmark locations, TTI's analysis attempted to account for this higher error and more uncertainty in MnDOT's AADT estimates.

## EVALUATION FINDINGS

At the 442 permanent benchmark locations, TTI found that AADT estimation accuracy by StreetLight Data has improved significantly since the previous 2017 evaluation, especially in moderate- to high-volume categories (i.e., more than 10,000 AADT). The mean absolute error ranges from 8% to 10% for locations greater than 10,000 AADT and gradually increases to 42% for sites with less than 1,000 AADT. The 2017 evaluation results had errors ranging from 34% at high volumes to 68% at low volumes.

At lower volumes (less than 1,000 AADT), it is difficult to make definitive conclusions about accuracy because of the limited number of comparison sites (i.e., 10 sites). The percent error values in this lowest volume category are much higher than other volume categories, but this is partly expected because even small absolute errors can translate into moderate or high percentage errors at low volumes. Based on the limited number of benchmark sites in low-volume categories, TTI decided to conduct an additional analysis at low-volume short-duration count sites.

TTI also found an overestimation bias when AADT values were less than 5,000. That is, StreetLight Data AADT estimates were consistently higher than the benchmark AADT values. For example, for less than 1,000 AADT, the mean percent error was 31%, whereas the absolute error was 42% (i.e., most of the error is positive, or overestimates). The bias was even greater for 1,000 to 4,999 AADT, wherein the mean percent error was 18% and the mean absolute percent error was 22%.

In a second phase of the evaluation, TTI compared StreetLight Data's AADT estimates at 265 low-volume sites at which MnDOT conducted short-duration counts in 2019. At these short-duration count sites, TTI used a confidence interval around MnDOT's AADT estimate to account for higher error and more uncertainty in a factored short-duration count.

Even when accounting for lower accuracy of annualized short-duration counts, the error for these low-volume counts was much higher than the results from the permanent benchmark sites. For example, the mean absolute percent error (based on MnDOT Confidence Interval) for AADTs less than 1,000 was 86% to 90% for short duration sites, as compared to 42% for permanent benchmark sites. This mean value was affected by numerous sites with high error values, which can be seen by comparing 68th and 95th percentile percent error values.

## RECOMMENDATIONS

Based on the evaluation findings, TTI recommends that MnDOT consider a phased approach to using probe-based traffic count estimates. The phased approach includes the following elements:

1. Continue to maintain permanent benchmark sites, both for spot checks and estimation algorithm calibration.
2. Start using probe-based counts for about 90% of the moderate- to high-volume roadways (20,000 or more AADT, to be conservative) since these roadways are where probe-based estimates are most accurate and within tolerance.
3. Continue to use traditional short-duration counts at the remaining 10% of the moderate- to high-volume roadways as a spot check to ensure that probe-based AADT estimates remain within acceptable tolerances in the next five to ten years.
4. Periodically monitor the error of AADT estimates on low- to moderate-volume roadways (less than 20,000 AADT) using the evaluation methods described in this report.
5. Once acceptable error tolerances for these lower-volume categories are reached, repeat Step 2 for these lower-volume categories. That is, start using probe-based counts for about 90% of the roadways and continue to use traditional short-duration counts for the remaining 10% as a spot check.

# CHAPTER 1: INTRODUCTION

## 1.1 BACKGROUND

In 2017, the Texas A&M Transportation Institute (TTI) worked with Minnesota DOT (MnDOT) and StreetLight Data to evaluate a beta version of traffic count estimates in Minnesota derived from location-aware mobile devices (http://mndot.gov/research/reports/2017/201749.pdf). This study found that "…traffic volume estimation from mobile devices has potential, but analytic enhancements are needed to improve accuracy and granularity of estimated traffic volumes. Some of the AADT volume estimates from StreetLight Data were within acceptable error ranges (10% to 20% absolute percent error), but other estimates were significantly outside this acceptable error range (greater than 100% absolute percent error)."

About three years have passed since this 2017 evaluation, and internal MnDOT staff assessments indicate that the accuracy of StreetLight Data's traffic count estimates has improved. If traffic count estimates derived from mobile devices have acceptable accuracy, MnDOT will start using these traffic count estimates for numerous applications.

## 1.2 PROJECT OBJECTIVE

MnDOT contracted with TTI to conduct an independent, follow-up evaluation of StreetLight Data's 2019 traffic count estimates using trusted MnDOT sources of traffic count data. The results of this follow-up evaluation will guide MnDOT decisions about using StreetLight Data traffic count estimates in its official traffic data program.

# CHAPTER 2: EVALUATION METHODS

## 2.1 COMPARISON SITES

The structure of the Task 2 evaluation was very similar to the 2017 evaluation and compared StreetLight Data's traffic count estimates to trusted MnDOT sources of traffic count data (i.e., benchmark data sources). These trusted MnDOT benchmark sources include:

- Permanent automatic traffic recorders (ATR): 65 sites.
- Permanent weigh-in-motion (WIM): 23 sites.
- Permanent regional traffic management center (RTMC): 340 sites.
- Permanent Wavetronix: 14 sites.

In addition to these permanent benchmark locations, TTI included several hundred low-volume sites at which MnDOT conducted short-duration counts in 2019. With these low-volume sites, MnDOT had seasonally adjusted the short-duration counts to represent an average annual daily traffic (AADT) count. These AADT estimates from low-volume short-duration count sites are expected to have more error than permanent benchmark locations, and TTI's comparisons with StreetLight Data's count estimates attempted to account for this higher error and more uncertainty in MnDOT's AADT estimates.

## 2.2 CALCULATION OF AADT VALUES AND ESTIMATES

In this evaluation, AADT counts were the only traffic statistic compared. MnDOT provided TTI with their calculated AADT values for all comparison locations. TTI used StreetLight Data's InSight® interface to generate their AADT count estimates at defined comparison locations. MnDOT had already created InSight® zones for use in the AADT analysis. TTI reviewed these MnDOT-created zones and, in a few cases, modified zones to more accurately reflect benchmark locations. For the low-volume short-duration count sites, a link-based shapefile was uploaded to InSight® to create a zone set and generate AADT estimates.

## 2.3 ACCURACY REPORTING CATEGORIES

TTI analyzed the count comparisons using functional classification and several different traffic volume categories and found that AADT estimation error was more closely associated with the traffic volume categories than with functional classification. TTI ultimately selected volume categories that are comparable to a larger national FHWA pooled fund study (https://www.pooledfund.org/Details/Study/636) that is also evaluating StreetLight Data count estimates. TTI used these volume categories for permanent benchmark locations:

- Less than 1,000 vehicles per day
- 1,000 to 4,999 vehicles per day
- 5,000 to 9,999 vehicles per day
- 10,000 to 19,999 vehicles per day

- 20,000 to 34,499 vehicles per day
- 35,000 to 49,999 vehicles per day
- 50,000 to 99,999 vehicles per day
- 100,000 or more vehicles per day

The evaluation of low-volume short-duration count sites focused on locations at which AADT estimates were less than 2,500 vehicles per day. At these locations, TTI used these more granular volume categories:

- Less than 500 vehicles per day
- 500 to 999 vehicles per day
- 1,000 to 1,499 vehicles per day
- 1,500 to 1,999 vehicles per day
- 2,000 to 2,499 vehicles per day

## 2.4 ACCURACY MEASURES

The accuracy measures in this follow-up evaluation include the same three measures as in the 2017 evaluation to allow for easy comparison. These three accuracy measures are based on prevailing traffic monitoring practice, as well as what can be easily understood and interpreted by practitioners:

1. Mean absolute percent error (MAPE) (Equation 1).
2. Mean percent error (Equation 2) to measure bias.
3. Mean error (Equation 3) to measure bias.

**Equation 1** $Mean\ absolute\ percent\ error, MAPE\ (\%) = \frac{1}{n}\sum_{i=1}^{n}\frac{abs(x_i - \bar{x}_i)}{\bar{x}_i}$

where $\bar{x}_i$ = MnDOT benchmark traffic count for the *i*th comparison

$x_i$ = the *i*th commercial data provider traffic count estimate

$n$ = number of estimate-to-benchmark comparisons

**Equation 2** $Mean\ percent\ error\ (\%) = \frac{1}{n}\sum_{i=1}^{n}\frac{(x_i - \bar{x}_i)}{\bar{x}_i}$

where $\bar{x}_i$ = MnDOT benchmark traffic count for the *i*th comparison

$x_i$ = the *i*th commercial data provider traffic count estimate

$n$ = number of estimate-to-benchmark comparisons

**Equation 3** $Mean\ error\ (vehicles\ per\ day) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x}_i)$

where $\bar{x}_i$ = MnDOT benchmark traffic count for the *i*th comparison

$x_i$ = the *i*th commercial data provider traffic count estimate

$n$ = number of estimate-to-benchmark comparisons

Several other accuracy statistics (like error percentiles) and visualizations have been added to better understand the full extent and distribution of error across all comparison sites.

# CHAPTER 3: EVALUATION RESULTS

The evaluation results are presented in two separate sections:

1. Permanent Benchmark Comparisons.
2. Low-Volume Short-Duration Comparisons

## 3.1 PERMANENT BENCHMARK COMPARISONS

Table 1 summarizes the mean absolute percent error (MAPE) and several other percentiles for absolute percent error. TTI concludes the following from the results in Table 1:

- **AADT estimation accuracy by StreetLight Data has improved significantly since the previous 2017 evaluation, especially in moderate- to high-volume categories (i.e., more than 10,000 AADT).** The mean absolute error ranges from 8% to 10% for locations greater than 10,000 AADT, and gradually increases to 42% for sites with less than 1,000 AADT. The 2017 evaluation results had errors ranging from 34% at high volumes to 68% at low volumes.

- **The error percentiles (i.e., 50$^{th}$, 68$^{th}$, 95$^{th}$) provide a fuller picture of error distribution across all comparisons than simply the mean error values.** The accuracy results for the mean absolute error apply through the 68$^{th}$ percentile, which means that about two-thirds of the comparison sites have error rates comparable to the average. However, the 95$^{th}$ percentile error increases to higher rates, in the 18% to 30% range for AADT values greater than 5,000.

- **It is difficult to make definitive conclusions about accuracy in the low-volume category (less than 1,000 AADT) because of the limited number of comparison sites (i.e., 10 sites).** The percent error values in this lowest volume category are much higher than other volume categories, but this is partly expected because even small absolute errors can translate to moderate or high percentage errors at low volumes. Based on the limited number of benchmark sites in low-volume categories, TTI decided to conduct an additional analysis at low-volume short-duration count sites (see next section).

Table 1 includes 65 MnDOT permanent ATRs as benchmark sites, and it is known that StreetLight Data has used at least some of these ATR sites for AADT model training. Therefore, TTI tested the effects of removing all ATRs from the benchmark site comparisons (see Table 2). The removal of all 65 ATRs did not substantially affect the accuracy results, except in the lowest volume category of less than 1,000 AADT. The number of sites in this lowest volume category was further reduced from 10 to 4 sites, so definitive conclusions cannot be made on this limited number of sites. For all volume categories greater than 1,000 AADT, the absolute error of StreetLight Data AADT estimates is the same or even better than when ATRs were included.

**Table 1: StreetLight Data AADT Estimates as Compared to Permanent Benchmark Sites**

| AADT Range (vehicles per day) | Number of Sites | Absolute Error (%) | | | |
|---|---|---|---|---|---|
| | | Mean | 50th percentile | 68th percentile | 95th percentile |
| Less than 1,000 | 10 | 42% | 27% | 56% | 116% |
| 1,000 to 4,999 | 24 | 22% | 17% | 23% | 69% |
| 5,000 to 9,999 | 12 | 13% | 11% | 15% | 29% |
| 10,000 to 19,999 | 17 | 10% | 5% | 11% | 30% |
| 20,000 to 34,999 | 35 | 8% | 6% | 8% | 25% |
| 35,000 to 49,999 | 39 | 8% | 7% | 10% | 18% |
| 50,000 to 99,999 | 200 | 10% | 8% | 12% | 27% |
| More than 100,000 | 105 | 8% | 5% | 10% | 26% |
| **Total Locations** | **442** | | | | |

**Table 2: StreetLight Data AADT Estimates as Compared to Permanent Benchmark Sites WITH ATRs EXCLUDED**

| AADT Range (vehicles per day) | Number of Sites | Absolute Error (%) | | | |
|---|---|---|---|---|---|
| | | Mean | 50th percentile | 68th percentile | 95th percentile |
| Less than 1,000 | 4 | 84% | 75% | 82% | 136% |
| 1,000 to 4,999 | 6 | 11% | 7% | 9% | 28% |
| 5,000 to 9,999 | 7 | 12% | 14% | 16% | 20% |
| 10,000 to 19,999 | 10 | 11% | 7% | 14% | 33% |
| 20,000 to 34,999 | 24 | 10% | 6% | 9% | 36% |
| 35,000 to 49,999 | 32 | 8% | 6% | 10% | 19% |
| 50,000 to 99,999 | 195 | 10% | 8% | 12% | 27% |
| More than 100,000 | 99 | 8% | 5% | 9% | 27% |
| **Total Locations** | **377** | | | | |

Tables 1 and 2 summarize absolute percentage error, which represents the overall magnitude of the error but does not indicate whether that error is consistently negative (e.g., StreetLight Data underestimates the true AADT value) or positive (e.g., StreetLight Data overestimates the true AADT value). Table 3 summarizes two error bias measures – mean percent error and mean error (vehicles per day) – that reflect the extent to which StreetLight Data consistently underestimates or overestimates the true AADT value. Bias matters for aggregate traffic statistics like statewide vehicle-miles of travel (VMT), where slight but consistent overestimation at many sites can result in large cumulative errors. If bias is low, however, then random underestimates and overestimates tend to cancel each other for aggregate VMT statistics.

**Table 3: Measures of Bias in StreetLight Data AADT Estimates as Compared to Permanent Benchmark Sites**

| AADT Range (vehicles per day) | Number of Sites | Mean Absolute Percent Error | Measures of Bias: Mean Percent Error | Measures of Bias: Mean Error (vehicles) |
|---|---|---|---|---|
| Less than 1,000 | 10 | 42% | 31% | 141 |
| 1,000 to 4,999 | 24 | 22% | 18% | 287 |
| 5,000 to 9,999 | 12 | 13% | 3% | 175 |
| 10,000 to 19,999 | 17 | 10% | -5% | -775 |
| 20,000 to 34,999 | 35 | 8% | 0% | 55 |
| 35,000 to 49,999 | 39 | 8% | -3% | -1,547 |
| 50,000 to 99,999 | 200 | 10% | -6% | -4,792 |
| More than 100,000 | 105 | 8% | -2% | -3,021 |
| **Total Locations** | **442** | | | |

Based on Table 3, TTI concludes the following about estimation bias:

- **There is an overestimation bias when AADT values are less than 5,000.** That is, StreetLight Data AADT estimates are consistently higher than the benchmark AADT values. This bias can be seen when comparing mean percent error to mean absolute percent error, and both error percentages are similar in magnitude. For example, for less than 1,000 AADT, the mean percent error is 31% whereas the absolute error is 42% (i.e., most of the error is positive, or overestimates). The bias is even greater for 1,000 to 4,999 AADT, wherein the mean percent error is 18% and the mean absolute percent error is 22%.

- **There is a slight underestimation bias for moderate to high volumes (i.e., AADT values greater than 10,000).** That is, StreetLight Data AADT estimates tend to be slightly lower than the benchmark AADT values at moderate to high volumes. For example, for AADT between 50,000 and 99,999, the mean percent error is -6% whereas the mean absolute percent error is 10%. Similarly, for AADT between 10,000 and 19,999, the mean percent error is -5% whereas the mean absolute percent error is 10%.

Figures 1 and 2 provide visual representations of the benchmark comparisons and the bias can be more readily seen in these charts. If estimation error is randomly distributed between overestimates and underestimates, then the data points in Figures 1 and 2 would be equally scattered on both sides of the 45-degree line of perfect agreement. However, Figure 1 shows that in moderate to high volumes, more data points are below than above the line of perfect agreement, which indicates underestimation. Figure 2 (a zoomed-in view of Figure 1) shows more clearly that, at less than 5,000 AADT, more data points are above than below the line of perfect agreement, which indicates overestimation of AADT values.

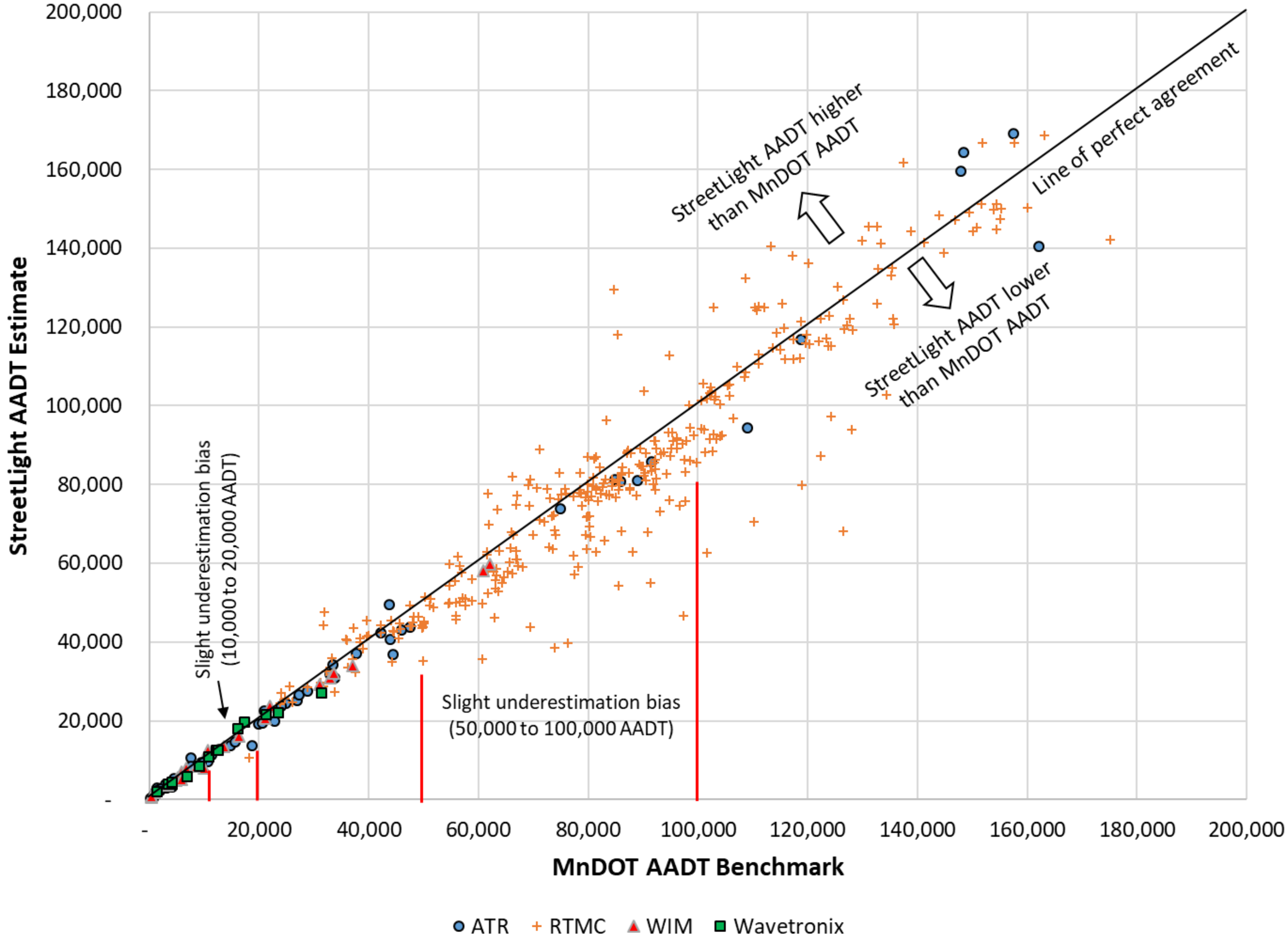


Figure 1: Visual Comparison of StreetLight Data AADT Estimates to MnDOT Benchmark AADT Values

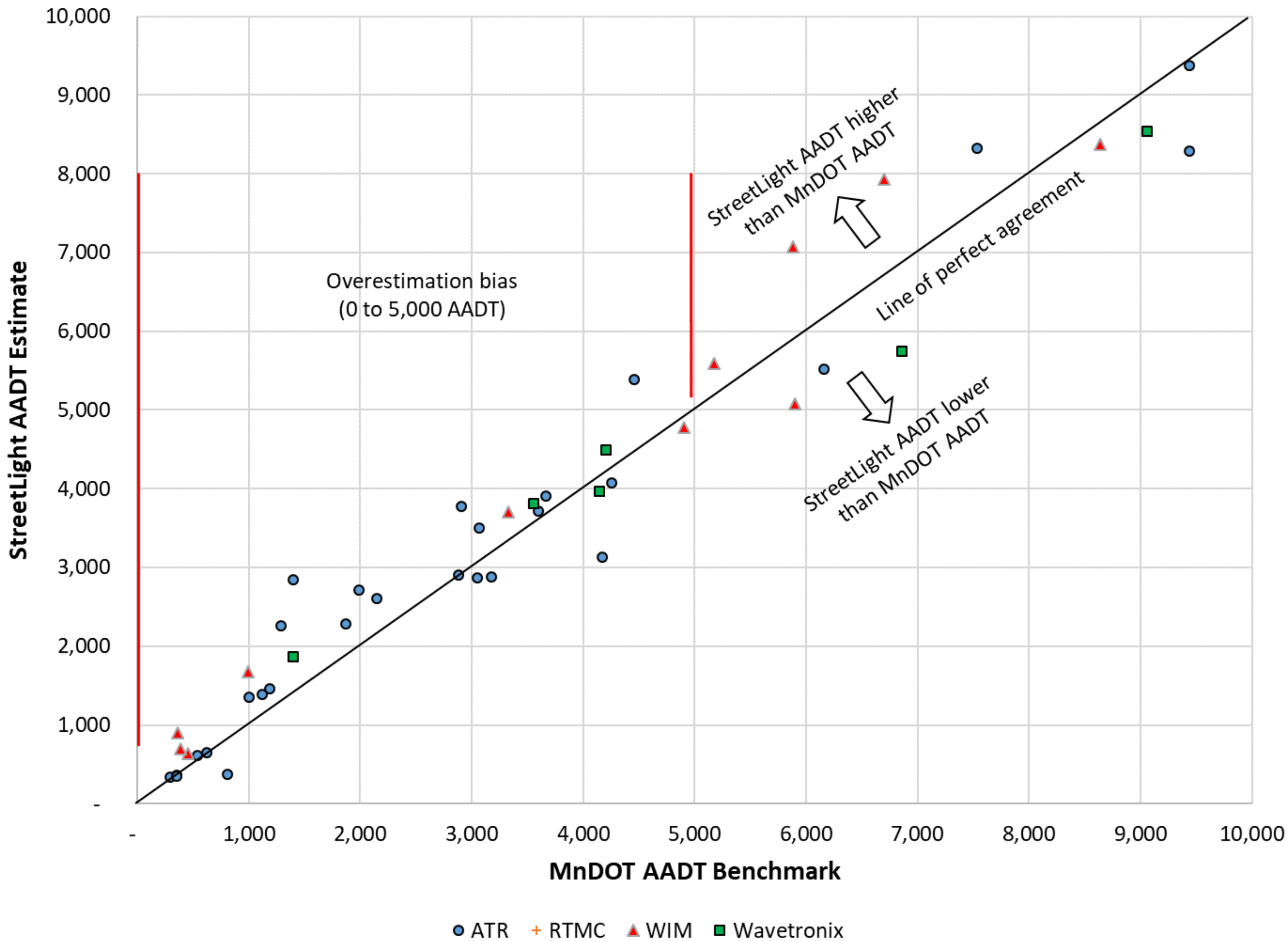


**Figure 2: Visual Comparison AT LOW VOLUME RANGES of StreetLight Data AADT Estimates to MnDOT Benchmark AADT Values**

## 3.2 LOW-VOLUME SHORT-DURATION COUNT COMPARISONS

TTI conducted additional comparisons at several hundred low-volume sites for two reasons:

1. There were a limited number of permanent benchmark sites on low-volume highways, making it challenging for TTI to draw definitive conclusions about StreetLight Data estimation accuracy on low-volume highways.
2. The preliminary results at the existing low-volume permanent benchmark sites showed a pronounced overestimation bias, but this result was based on a limited number of sites.

Therefore, MnDOT and TTI identified 265 low-volume sites at which MnDOT had conducted short-duration counts in 2019. These 265 short-duration count sites were optimal for evaluating StreetLight Data count estimates due to count stability over the past decade. That is, all previous field counts at these 265 sites were within the bounds of MnDOT's year-to-year variation tolerance, and no recounts or adjustments or historical averaging was necessary at these sites. With these low-volume sites, MnDOT had seasonally adjusted the 2019 short-duration counts to represent a 2019 average annual daily traffic (AADT) estimate. These AADT estimates from low-volume short-duration count sites are expected to have more error than permanent benchmark locations (due to possible errors in the seasonal adjustment process), and TTI's comparisons with StreetLight Data's count estimates attempted to account for this higher error and more uncertainty in MnDOT's AADT estimates using confidence intervals.

Figure 3 illustrates the differences in accuracy and uncertainty between 365-day counts collected from permanent sites and 48-hour counts collected from portable equipment and then annualized using seasonal adjustment factors. The left side of Figure 3 shows an AADT estimate from a permanent count site as a green dot. Because the site is permanent, collects counts all year long, and typically undergoes more scrutiny and maintenance, the AADT accuracy is relatively high. However, AADTs from permanent counters are not perfect and do contain some inaccuracy. Therefore, the green bracket around the AADT estimate (green dot) illustrates the interval within which we are confident that the true and 100% accurate AADT value is (called a confidence interval).

For example, assume that a permanent counter site produced an AADT value of 20,000 vehicles per day. With proper calibration and maintenance, assume that this permanent counter is typically accurate to within about ±2%. Therefore, we are confident that the true AADT value for this permanent counter is within 400 vehicles of 20,000 vehicles per day, or 19,600 to 20,400 vehicles per day.

Now consider the right side of Figure 3: a 48-hour count collected from portable equipment and then annualized to an AADT estimate (yellow dot) using seasonal adjustment factors. These AADT estimates from short duration counts that have been annualized are known to be less accurate than AADT estimates from permanent equipment. Therefore, the yellow bracket (confidence interval) is wider for this AADT estimate, because we are less certain that the true, 100% accurate AADT value is very close to our AADT estimate (yellow dot).

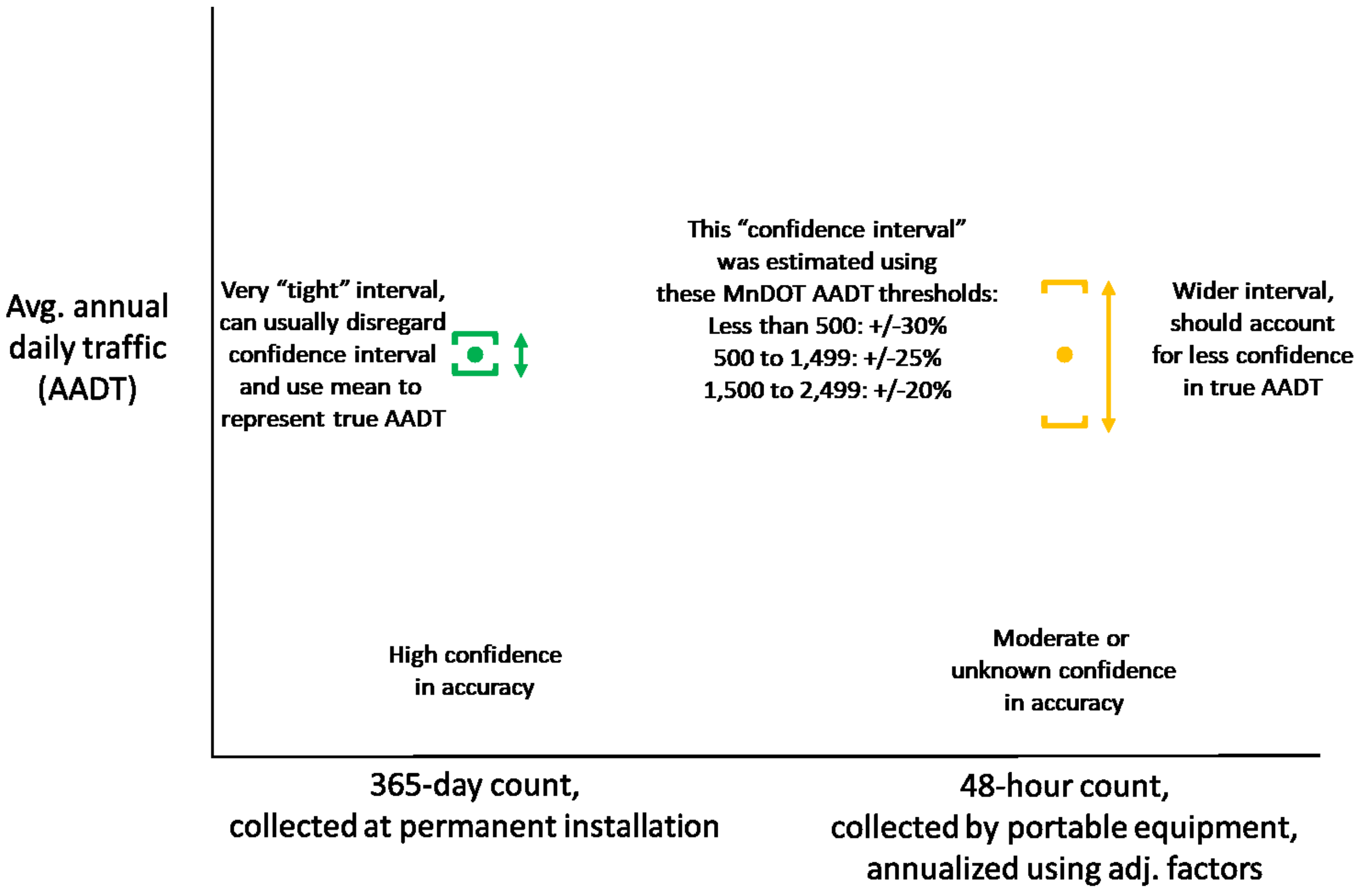


**Figure 3: Illustration of Confidence Intervals for AADT Estimates from Permanent Sites and Annualized Short-Duration Sites**

For example, assume we have an AADT estimate of 20,000 vehicles per day from an annualized short-duration count. Next, assume that the typical error for an annualized short-duration count is about ±20% (10 times higher than permanent counts). Therefore, we are confident that the true AADT value from this annualized short-duration count lies within 4,000 vehicles of 20,000 vehicles per day, or 16,000 to 24,000 vehicles per day.

The confidence interval for an annualized short-duration AADT estimate can be much wider than the AADT estimate from a permanent site. **This is a very important difference when comparing MnDOT AADT estimates to StreetLight Data estimates (for which we are trying to determine error).** If we compare an AADT estimate from StreetLight Data to a MnDOT AADT estimate from an annualized short-duration count and there is a 20% difference, we cannot be certain that the error is contained within the StreetLight Data estimate, since the MnDOT AADT estimate may also have up to 20% error.

In the comparison with permanent benchmark sites, TTI disregarded the confidence interval (green brackets on Figure 3) because it was considered to be very small and therefore negligible. As a result, TTI compared the AADT estimate from StreetLight Data to the MnDOT benchmark estimate and assumed that the entire difference was due to error in StreetLight Data estimates.

Because the error in MnDOT's annualized short-duration counts could be up to 10 times higher than the permanent benchmark sites, TTI included this confidence interval in the comparison with annualized short-duration counts. The width of the confidence interval (yellow brackets on Figure 3) was derived from MnDOT count tolerances (Table 4) that are used to judge whether short-duration counts are accurate enough or need to be redone.

**Table 4: AADT Acceptable Percent Change Developed by MnDOT Traffic Forecasting and Analysis Section**

## Percent Change Tolerances

These tolerances went into effect as of the 2019 data collection season.

| Past Official AADT Range | Acceptable % Change (Recount and Segment) |
|---|---|
| 0-99 | No Recounts |
| 100 - 499 | +/- 30% |
| 500 – 1,499 | +/- 25% |
| 1,500 – 4,999 | +/- 20% |
| 5,000 – 49,999 | +/- 15% |
| 50,000+ | +/- 10% |

*Source: MnDOT*

Assume a hypothetical example to illustrate the use of confidence intervals to compare StreetLight Data AADT estimates to the MnDOT AADT estimates from annualized short-duration counts:

- The MnDOT AADT estimate is 1,000 vehicles per day.
- Based on Table 4, a confidence interval for this estimate is ±25%, or 750 to 1,250 vehicles per day.
- The StreetLight AADT estimate is 1,500 vehicles per day.
- When the StreetLight Data estimate is outside the MnDOT confidence interval, the error is calculated from the difference between the StreetLight Data estimate and the closest confidence limit (the upper or lower bracket in Figure 3).
- In this case, the error is 1,500 – 1,250, or 250. The percent error is 250/1,250, or 20%.

Assume another hypothetical example in which the StreetLight Data AADT estimate falls within the MnDOT confidence interval:

- The MnDOT AADT estimate is 1,000 vehicles per day.
- Based on Table 4, a confidence interval for this estimate is ±25%, or 750 to 1,250 vehicles per day.
- The StreetLight AADT estimate is 800 vehicles per day.
- When the StreetLight Data estimate is inside the MnDOT confidence interval, the error is considered zero because we cannot definitively say whether the difference can be attributed to the MnDOT estimate or the StreetLight Data estimate.

The University of Maryland has used this same confidence interval approach to evaluate the accuracy of private sector travel times for over a decade as part of the I-95 Corridor Coalition (now the Eastern Transportation Coalition) Vehicle Probe Project (https://tetcoalition.org/projects/vpp-marketplace/, see “Data Validation” tab).

Table 5 compares the traditional way of calculating error (comparing an estimate to a single benchmark value, Column 3) to the use of confidence intervals (Columns 4 through 7). One can easily see that the confidence interval-based error is always less, because the confidence interval approach assumes that the MnDOT value also contains some of error/difference. TTI concludes the following from Table 5:

- **Even when accounting for lower accuracy of annualized short-duration counts, the error for these low-volume counts are much higher than the results from the permanent benchmark sites.** For example, the MAPE (based on MnDOT Confidence Interval) for AADTs less than 1,000 is 86% to 90% for short duration sites, as compared to 42% for permanent benchmark sites. This mean value is affected by numerous sites with high error values, which can be seen by comparing 68$^{th}$ and 95$^{th}$ percentile percent error values.

Table 6 and Figure 4 more clearly illustrate the overestimation bias that exists at these low-volume short duration count sites. For example, Table 6 shows the similarity of mean absolute error values and mean error values. For sites less than 500 AADT, the mean absolute error is 140% and the mean error is +131%, which means that almost all error comes from overestimates.

**Table 5: StreetLight Data AADT Estimates as Compared to Low-Volume Short Duration Count Sites**

| AADT Range (vehicles per day) | Number of Sites | Mean Absolute Error (%) | Absolute Error (%) when compared to MnDOT Confidence Interval | | | |
|---|---|---|---|---|---|---|
| | | | Mean | 50th percentile | 68th percentile | 95th percentile |
| Less than 500 | 110 | 140% | 90% | 9% | 33% | 621% |
| 500 to 999 | 71 | 129% | 86% | 30% | 77% | 310% |
| 1,000 to 1,499 | 41 | 56% | 30% | 3% | 23% | 151% |
| 1,500 to 1,999 | 26 | 40% | 20% | 6% | 23% | 79% |
| 2,000 to 2,499 | 17 | 29% | 12% | 1% | 9% | 50% |
| **Total Locations** | **265** | | | | | |

**Table 6: Measures of Bias in StreetLight Data AADT Estimates as Compared to Low-Volume Short Duration Count Sites**

| AADT Range (vehicles per day) | Number of Sites | Mean Absolute Error | Mean Error or Bias (%) | Mean Error (vehicles) |
|---|---|---|---|---|
| Less than 500 | 110 | 140% | 131% | 371 |
| 500 to 999 | 71 | 129% | 118% | 802 |
| 1,000 to 1,499 | 41 | 56% | 47% | 524 |
| 1,500 to 1,999 | 26 | 40% | 33% | 555 |
| 2,000 to 2,499 | 17 | 29% | 12% | 250 |
| **Total Locations** | **265** | | | |

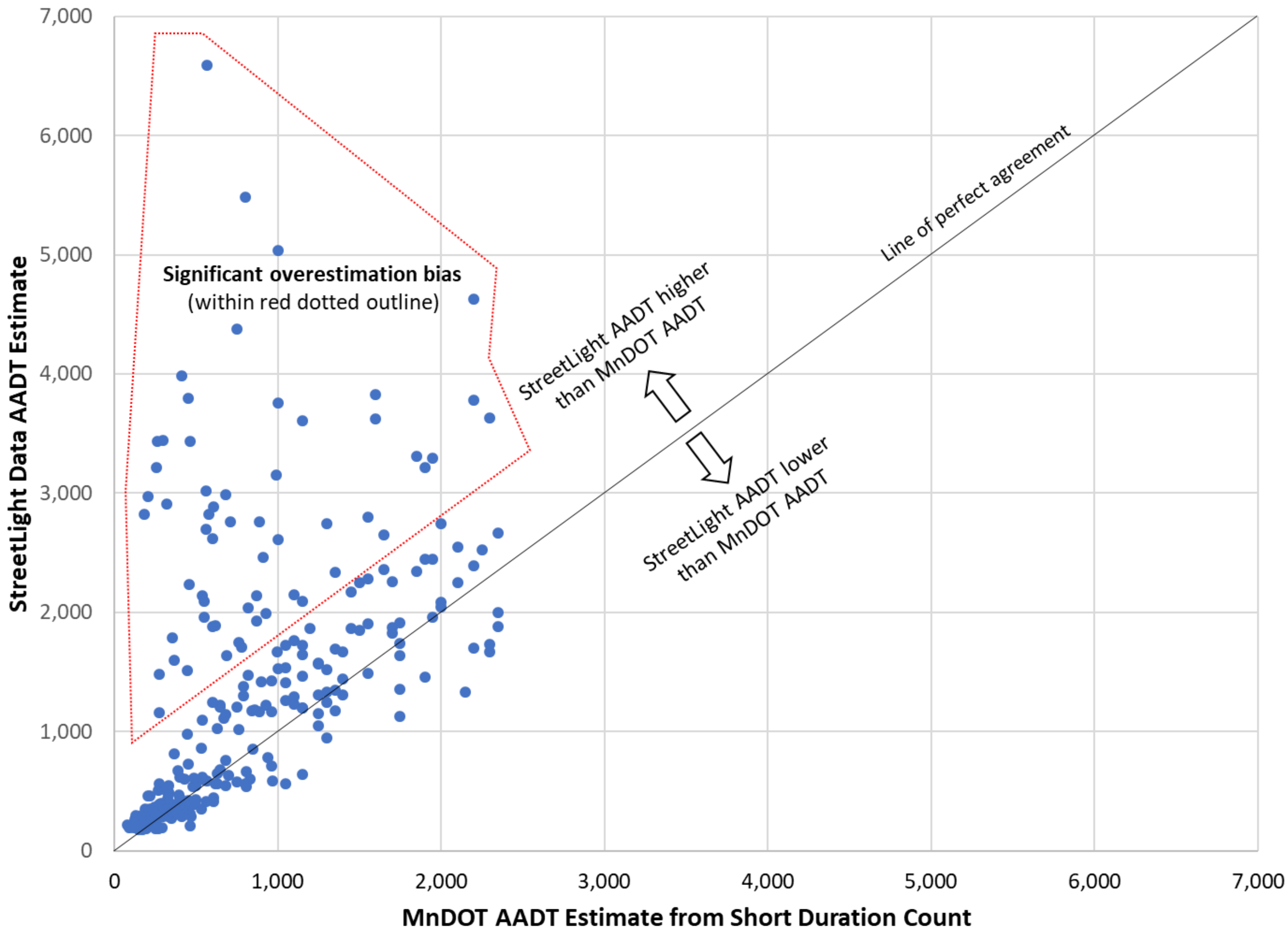


**Figure 4: Visual Comparison of StreetLight Data AADT Estimates to MnDOT AADT Estimates from Short-Duration Count Sites**

# CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

Based on the evaluation results, TTI summarizes the major conclusions:

- **AADT estimation accuracy by StreetLight Data has improved significantly since the previous 2017 evaluation, especially in moderate- to high-volume categories (i.e., more than 10,000 AADT).** The mean absolute error ranges from 8% to 10% for locations greater than 10,000 AADT and gradually increases to 42% for sites with less than 1,000 AADT. The 2017 evaluation results have errors ranging from 34% at high volumes to 68% at low volumes.

- **There is a significant overestimation bias for low-volume roadways (i.e., less than 2,500 to 5,000 AADT).** This result is present in the permanent benchmark sites but even more pronounced in the short-duration count sites. Higher percentage errors are tolerable in low-volume categories, but the overestimation bias can be problematic for estimating aggregate traffic statistics like VMT for lower-functional classes.

Based on these findings and conclusions, TTI recommends that MnDOT consider a phased approach to using probe-based traffic count estimates. The phased approach includes the following elements:

1. Continue to maintain permanent benchmark sites, both for spot checks and for estimation algorithm calibration.
2. Start using probe-based counts for about 90% of the moderate- to high-volume roadways (20,000 or more AADT, to be conservative) since these roadways are where probe-based estimates are most accurate and within tolerance.
3. Continue to use traditional short-duration counts at the remaining 10% of the moderate- to high-volume roadways as a spot check to ensure that probe-based AADT estimates remain within acceptable tolerances in the next five to ten years.
4. Periodically monitor the error of AADT estimates on low- to moderate-volume roadways (less than 20,000 AADT) using the evaluation methods described in this report.
5. Once acceptable error tolerances for these lower-volume categories are reached, repeat Step 2 for these lower-volume categories. That is, start using probe-based counts for about 90% of the roadways and continue to use traditional short-duration counts for the remaining 10% as a spot check.