COMPARATIVE ANALYSIS OF TRUCK VOLUMES FROM TRAFFIC COUNTS AND PROBE-BASED DATA: A CASE STUDY IN THE WINNIPEG METROPOLITAN REGION, CANADA

C. ZROBEK
M.Sc. student in the Department of Civil Engineering at the University of Manitoba.

G. GRANDE
Obtained his B.Sc. and Ph.D. from the Department of Civil Engineering at the University of Manitoba.

J.D. REGEHR
Associate Professor in the Department of Civil Engineering at the University of Manitoba.

B. MEHRAN
Associate Professor in the Department of Civil Engineering at the University of Manitoba.

Abstract

The widespread nature of cell phones and connected vehicle navigation systems has led to the development of commercially available probe-based traffic data products. Past research on the traffic volume estimates from a North American company called StreetLight Data (StL) was conducted in the U.S. and focused primarily on total traffic. This study assesses the accuracy of annual average daily total traffic, medium-duty truck traffic, and heavy-duty truck traffic volumes obtained using StL's traffic activity indices. The probe-based volumes were compared to 2019, 2020, and 2021 continuous count data at 11 sites in the Winnipeg Metropolitan Region. The results showed reasonable agreement between the ground truth and probe-based total traffic estimates with mean absolute percent errors (MAPEs) ranging from 8.8% to 22.1% across the study years. The medium-duty truck volume estimates had larger errors with a MAPE of up to 37.5%. Despite having higher volumes than medium-duty trucks, heavy-duty truck estimates had the largest errors, likely due to StL's lower sample size for this weight class.

Keywords: Probe Data, StreetLight Data, Truck Volumes, Truck Traffic Monitoring Programs, AADT, AADTT

1. Introduction

The procurement of accurate network-wide traffic volume estimates is a common goal of traffic monitoring programs. Truck volumes are of particular interest as they are a fundamental input for a variety of transportation engineering planning, design, operation, and maintenance applications. Compared to traditional traffic counts, probe-based data has the potential to significantly increase the spatial and temporal coverage of truck traffic volume estimates. Since probe-based data is produced by smartphones and vehicle devices, the data may be available anywhere vehicles travel. Probe and contextual data are now being used by third-party data firms to create traffic volume estimates that users can purchase. These firms have the potential to provide jurisdictions with traffic volume estimates on any roadway with limited effort by users. However, before jurisdictions commit to purchasing and incorporating these third-party data products into their traffic monitoring programs, it is important to evaluate their quality. This study assesses the accuracy of total and truck traffic volume estimates derived from probe data in Manitoba, Canada.

2. Background

The annual average daily traffic (AADT) and the annual average daily truck traffic (AADTT) are fundamental measures of traffic volume at a site. Permanently installed classification count equipment, such as weigh-in-motion (WIM) devices and automatic vehicle classifiers (AVCs), are routinely used to determine the AADTT on roadways. However, it is not feasible to install continuous count equipment on all roads within a network. Traditionally, short-duration counts (SDCs) are conducted to supplement the spatial coverage of continuous count data, but SDCs do not capture the temporal variability of traffic and the number of SDCs that can be conducted within a year is still limited. If the SDCs are conducted using intrusive equipment, the count locations are also limited by safety risks, traffic volumes, and vehicle speeds (FHWA, 2022). In Manitoba, truck traffic on unmonitored road segments has been estimated by transferring volume data and classification distributions from nearby count sites or a group of sites with similar truck traffic characteristics (Regehr and Reimer, 2013); however, these estimates are prone to error and their accuracy is unquantified. Boile et al. (2004) developed a linear model to estimate truck volumes on unmonitored roads in New Jersey, but creating such a model is resource intensive and requires several datasets. Due to these shortcomings, researchers and government agencies have investigated whether non-traditional data sources with greater spatial and temporal coverage, such as probe data, can be used to enhance system-wide truck volume estimation.

While jurisdictions could use probe data directly to develop models that estimate truck volumes, there are third-party data firms that buy, process, and integrate mobility and contextual data to produce proprietary traffic data products that they offer through a subscription procurement model. AADT and AADTT estimates from these firms are now accepted by the Federal Highway Administration (FHWA) for Highway Performance Monitoring System AADT reporting (FHWA, 2022). The North American third-party data provider StreetLight Data (StL) uses machine learning algorithms to produce traffic volume estimates from commercial vehicle global position system (GPS) data, location-based services (LBS) data, census data, and weather data. Using StL's online data platform InSight, users can select from nine different analysis types with different output types and metrics. Their outputs include total traffic volume estimates and truck activity indices. StL truck indices represent the relative volume of truck activity on a road and are normalized with continuous count data to account for seasonal changes in the underlying sample. While the truck indices are not a direct estimate of truck volume, known truck volumes from local continuous count data can be used to scale the indices into volume estimates. Prior to the summer of 2022, StL only provided a single index for trucks in Canada. Since then, the single truck index was removed for all time periods and replaced with separate medium-duty and heavy-duty truck indices. StL's data source for trucks is GPS data from connected commercial trucks. The truck weight classes within their dataset are defined using the following gross vehicle weight ratings (GVWRs):

- Medium-duty: 14,001-26,000 lbs (6,351-11,793 kg); GVWR class 4-6 (buses and trucks with 3 or less axles)
- Heavy-duty: 26,001+ lbs (11,794+ kg); GVWR class 7-8 (trucks with 4 or more axles)

While axle information is provided with the GVWR classes, it is known that weight classes do not directly align with the FHWA axle-based classes used by continuous counters (Lindsey et al., 2021; Schewel et al., 2021).

StL has been the subject of several recent studies, including a pooled-fund study by the FHWA in the United States (Roll 2019; Tsapakis et al., 2020; Yang et al., 2020; Codjoe et al., 2020; Turner et al. 2020; Fish et al. 2021; Schewel et al., 2021; Tsapakis et al., 2021). In general, the studies showed that at low volumes (AADT less than approximately 5000), StL tended to over-estimate and have higher percent errors. Table 1 summarizes the general objectives and other key findings of these studies.

Table 1 - Findings of Past Studies of StL Traffic Volumes

Study (Jurisdiction)	Objective and Findings
Roll, 2019 (Oregon, U.S.)	• Compared 2017 StL AADT estimates to AADTs from 173 continuous count sites and factored SDCs. • Considered accuracy, completeness, timeliness, validity, and accessibility of the third-party data. • Determined that 32% of the study sites exhibited 20% error or less.
Tsapakis et al., 2020 (Border Region of Texas, U.S.)	• Assessed the penetration rate (PR) of StL data and accuracy of 2017 StL AADT estimates at ports of entry, continuous sites, and SDC sites. • Found an average PR at ports of entry of 8.7% for GPS commercial vehicle trips and 0.85% for LBS trips.
Yang et al., 2020 (Virginia, U.S.)	• Developed a set of use guidelines for StL based on an evaluation of 2017/2018 AADT, origin-destination trips, traffic flow on roads, turning movements at intersections, and hourly truck traffic at intersections. • Compared to AADT estimates, using the StL index to estimate hourly truck volumes at intersections showed higher and less stable errors. • Found StL truck index to be less reliable at low truck volumes.
Codjoe et al., 2020 (Louisiana, U.S.)	• Compared 2018 AADT, 2019 monthly volumes, and 2018/2019 24-hour volumes against StL and Streetlytics estimates. • Considered accuracy, completeness, timeliness, validity, and accessibility of third-party data. • Data from StL and Streetlytics were determined to be valid for use in traffic assessments.
Turner et al., 2020 (Minnesota, U.S.)	• Compared 2019 StL AADT estimates to AADTs from 442 continuous count sites and factored SDCs. • Found significant over-estimation bias for AADTs below 5,000 and slight under-estimation bias for AADTs greater than 10,000.

	• Recommended that the Minnesota Department of Transportation consider a phased approach to using probe-based traffic count estimates.
Fish et al., 2021 (U.S.)	• Compared 2019 StL and continuous counter AADT at 566 sites with results reported by volume range and setting (urban/rural). • Observed strong correlation between StL and ground truth AADTs but found that StL tends to over-estimate. • Noted that there were statistical differences between StL and counter AADTs and errors may be unacceptable for some applications.
Schewel et al., 2021 (U.S.)	• StL evaluated their 2019 AADT estimates, the impacts of changes in probe data quantity and quality, and the applicability of probe data for a variety of traffic parameters including AADT by three vehicle classes. • Found a stronger relationship between the ground truth AADTs and estimated personal vehicle AADT and multi-unit truck AADT than single-unit truck AADT. • Observed a strong predictive relationship between multi-unit truck AADT and the GPS commercial heavy-duty truck sample trips.
Tsapakis et al., 2021 (U.S.)	• Assessed accuracy and precision of 2019 StL AADT estimates at 215 sites with results reported by volume range and setting (urban/rural). • Evaluation measures and tests produced mixed results. • Used professional judgment to consider each evaluation result and concluded that StL's AADT estimates are valid for roads with bi-directional AADT of 5000 or greater vehicles per day.

A survey of operations and planning personnel from 14 transportation agencies in the United States indicated that the most desired output from probe data besides total traffic volume was the percentage or volume of heavy truck traffic (Young et al., 2018). Despite the interest in truck volumes, most of the published assessments of StL's traffic volume estimates focused on total traffic. The research by Yang et al. (2020) only assessed hourly truck volume estimates at 17 intersections within a small area of less than 10 square kilometers (4 square miles). In addition, the study was conducted when only a combined total truck activity index was provided by StL. The study conducted by StL tested the applicability of StL's probe data for estimating AADT by vehicle type by creating models with multiple predictors (Schewel et. al 2021). However, these models are not available to users, and they did not assess the truck traffic products currently provided by StL. Moreover, no publicly available assessments of StL's total or truck traffic metrics have been conducted in Canada where it is expected that the probe-data sample size and biases may vary from the United States.

With third-party data providers now offering paid access to probe-based traffic data products, it is important to investigate whether they can deliver truck traffic estimates of reasonable quality. The findings of this study will help traffic monitoring practitioners understand how such products might enhance more traditional methods of obtaining truck volume data.

Research Objectives and Scope

This study evaluates the accuracy of StL truck traffic metrics by comparing them to traffic volumes obtained from permanently installed continuous classification count devices in Manitoba, Canada. Specifically, this study sought to answer the following research questions:

1. How do AADT estimates produced by scaling StL total traffic activity indices compare to ground truth AADT volumes from continuous count data?

2. How do AADTT estimates produced by scaling StL medium-duty and heavy-duty truck activity indices compare to ground truth AADTT volumes from continuous count data?
3. How do the errors of the scaled StL AADTT estimates vary by truck volume?

Geographically, the comparative analysis is limited to primary highways located in the Winnipeg Metropolitan Region in Manitoba, Canada, which covers an area of approximately 770 square kilometers (3,000 square miles). The 2019, 2020, and 2021 data from 11 bi-directional continuous count sites were used as the ground truth data for comparison with the scaled estimates from StL.

3. Methodology

The approach used to conduct this study included two phases: Manitoba data preparation and StreetLight Data analysis.

3.1 Manitoba Data Preparation

Manitoba Transportation and Infrastructure provided raw hourly classification count data with notes about data quality for the 11 bi-directional continuous count sites (22 site-directions) used in the study. Nine sites had AVCs, one site had WIM devices, and one site had WIM devices in the drive lanes and AVCs in the passing lanes. Following the Manitoba Highway Traffic Information System (MHTIS) data cleaning process, erroneous hourly data was omitted and any days with two or more hours of missing data were removed. The cleaned hourly data was then summed by class for each site-direction to provide daily volumes. Next, FHWA classes 4-6 (buses and trucks with 3 or less axles) and classes 7-13 (trucks with 4 or more axles) were summed to give medium-duty and heavy-duty daily truck volumes, respectively. Using the daily volumes, ground truth estimates of AADT, annual average daily medium-duty truck traffic (AADMT) and annual average daily heavy-duty truck traffic (AADHT) were calculated using the American Association of State Highway and Transportation Officials (AASTHO) method outlined in the FHWA Traffic Monitoring Guide (FHWA, 2022). The AASHTO AADT method averages daily volumes by day-of-week and month-of-year according to Equation (1).

$$AADT_c = \frac{1}{12}\sum_{i=1}^{12}\left[\frac{1}{7}\sum_{j=1}^{7}\left(\frac{1}{n_{ij}}\sum_{k=1}^{n_{ij}} V_{ijk,c}\right)\right] \quad (1)$$

Where i = month-of-year (1 to 12); j = day-of-week (1 to 7); k = occurrence of day-of-week j in month i for which traffic data are available; n_{ij} = number of occurrences of day-of-week j in month i for which traffic data are available; c = class group (total traffic, medium-duty trucks, heavy-duty trucks); V_{ijk} = traffic volume on the occurrence k of day-of-week j within month i.

The AASHTO AADT formulation requires daily volumes for at least one of each day of the week within each month. Of the 22 site-directions, 15 had sufficient data for AADT and AADTT calculation in 2019, whereas 17 had sufficient data for AADT and AADTT calculation in 2020 and 2021. The continuous count site details, including the type of counter, direction of travel, data availability, and average percentage of trucks to total traffic by weight class are summarized in Table 2. Figure 1 shows the annual average daily volumes for each direction of travel at the sites and Figure 2 shows the locations of the study sites.

Table 2 – Continuous count site details

Site	1	2	3	4	5	6	7	8	9	10	11
Type	AVC									AVC/WIM	WIM
Direction	Westbound/Eastbound						Northbound/Southbound				
2019 Data	Y/Y	Y/Y	N/Y	N/Y	N/Y	Y/Y	Y/Y	Y/Y	N/N	Y/Y	N/N
2020 Data	Y/Y	Y/Y	Y/Y	Y/N	Y/Y	Y/Y	Y/N	Y/Y	N/Y	N/N	Y/Y
2021 Data	N/N	Y/Y	Y/Y	Y/Y	Y/Y	Y/Y	Y/N	Y/Y	Y/Y	N/N	Y/Y
%AADMT	2.3	1.6	2.4	3.7	3.7	1.5	1.6	1.1	2.0	2.4	10.9
%AADHT	15.8	11.0	10.0	9.4	12.6	7.9	2.4	2.1	11.9	16.9	21.2

Note. Y = AADT and AADTT available, N = AADT and/or AADTT not available

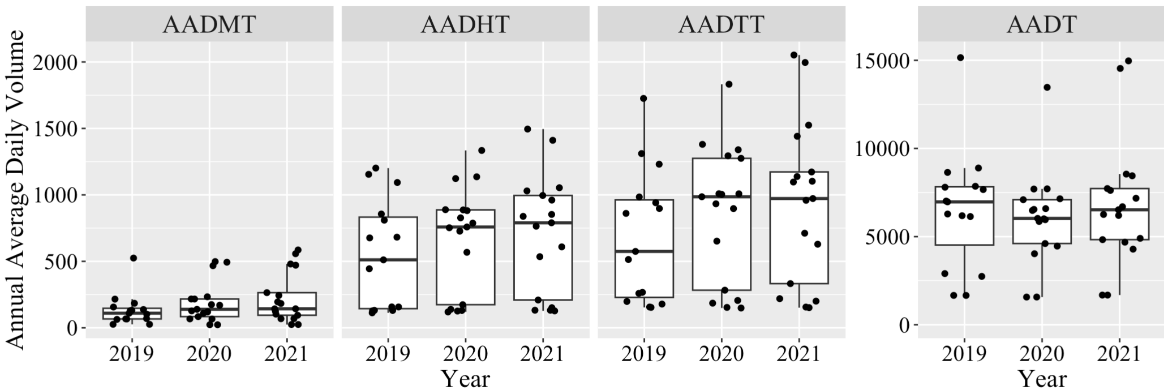

Figure 1 – Directional annual average daily volumes for continuous count sites

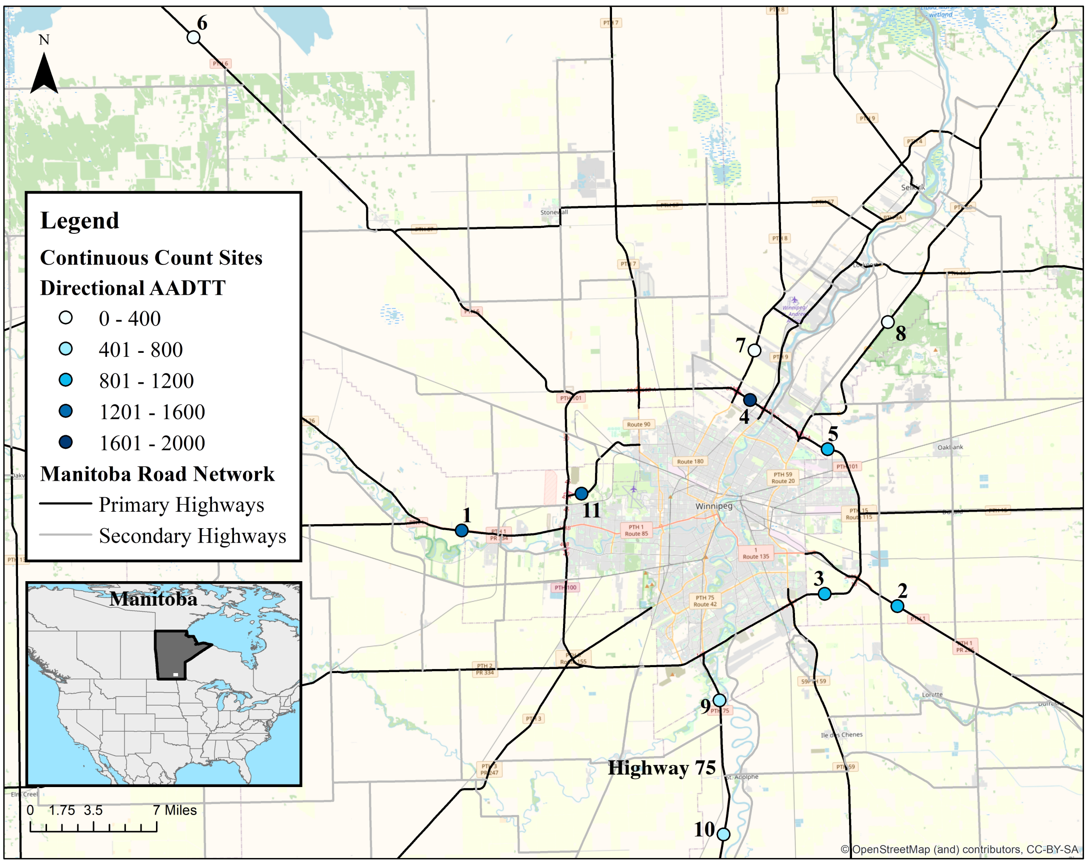

Figure 2 – Location of continuous count sites

3.2 StreetLight Data Analysis

StL allows users to create zones that represent the area or road they would like to analyse. Unlike a traditional traffic counter, StL zones can be many shapes and sizes. A shapefile of manually drawn polygon zones approximately rectangular in shape corresponding to each of the 11 Manitoba continuous count sites shown in Figure 2 were drawn in ArcGIS and uploaded to InSight. Each zone was drawn to capture both sides of the highway without including any adjacent service roads or ramps near the counting device. The zones were set as pass-through, which means that the traffic parameters are based on trips through the zones. The direction of the roadway was manually added to each zone, and the zones were set to uni-directional so that each direction of travel was analysed separately. The AADT and percentage of medium-duty and heavy-duty trucks obtained from the continuous classification count data were added to the zones in InSight for each analysis year to facilitate the scaling of StL indices into volumes. StL provides a built-in function called single factor calibration that uses the user-entered ground truth data to scale the StL indices. StL states that the use of 10-20 calibration zones is best, with a recommended minimum range of 6-10 zones. For this study, 8-9 zones were used for calibration in each year. Given the limited number of sites, leave-one-out cross-validation was used to scale the StL indices into volumes and evaluate the errors. Using this method, each site was left out of the calibration data set when its indices were scaled into a volume. Each year of medium-duty and heavy-duty data was scaled using StL single factor calibration separately as the indices from different data periods and weight classes cannot be directly compared. The StL single factor calibration process for a single year (l), class group (c), and excluded site (a) is outlined in steps 1 to 4:

1. The volume factor (VF) is computed as the ratio of the ground truth annual average daily volume to the StL index (SI) for each site-direction (m) as follows

$$VF_{m,l,c} = \frac{AADT_{m,l,c}}{SI_{m,l,c}} \tag{2}$$

2. Outlier site-directions are removed, leaving (n) site-directions in the calibration dataset (StL's method of identifying outliers is unknown)
3. The scaling factor (SF) for site a is computed as the average of the volume factors from the other sites as follows

$$SF_{a,l,c} = \frac{\sum_{m=1}^{n} VF_{m,l,c}}{n} \tag{3}$$

4. The estimated annual average daily volume ($StL\ AADT$) for each direction of travel (d) at site a is computed by multiplying the StL index by the scaling factor as follows

$$StL\ AADT_{a,d,l,c} = SI_{a,d,l,c} * SF_{a,l,c} \tag{4}$$

While StL only provides indices for trucks, they have developed models that directly estimate AADT volumes. However, to provide a fair comparison between the StL total traffic and truck traffic estimates, the AADTs were estimated by scaling StL total traffic indices in the same way as trucks. In addition, the use of StL total traffic indices allowed for a completely independent comparison of the Manitoba and StL estimates as 2019 Manitoba AADT values were included in the calibration of the Canada-wide 2019 and 2020 StL AADT models.

The error metrics used to compare the scaled StL AADTs to the ground truth values include percent error (PE), median percent error (bias), mean absolute percent error (MAPE), and median absolute percent error (MdAPE). The PE for each site-direction was calculated according to Equation (5). The sign of the median PE indicates the direction of any bias, but it is not a good measure of overall accuracy if the error distribution is symmetric (Fish et al. 2021). Both MAPE and MdAPE provide an indication of the typical error; however, MdAPE is less sensitive to outliers than MAPE.

$$PE = 100 * \frac{StL\ AADT - AADT}{AADT} \tag{5}$$

4. Results and Discussion

For StL single factor calibration to provide accurate traffic volume estimates, the volume factors need to be consistent across the sites used for calibration and the site of volume estimation. When the medium-duty or heavy-duty volume factor at a site is high, it indicates that the PR of StL's commercial GPS data sample for that weight class is low. Figure 3 shows the normalized volume factors by ground truth volume for each class group. The volume factors for each year and class group were divided by the corresponding mean volume factor to facilitate comparison.

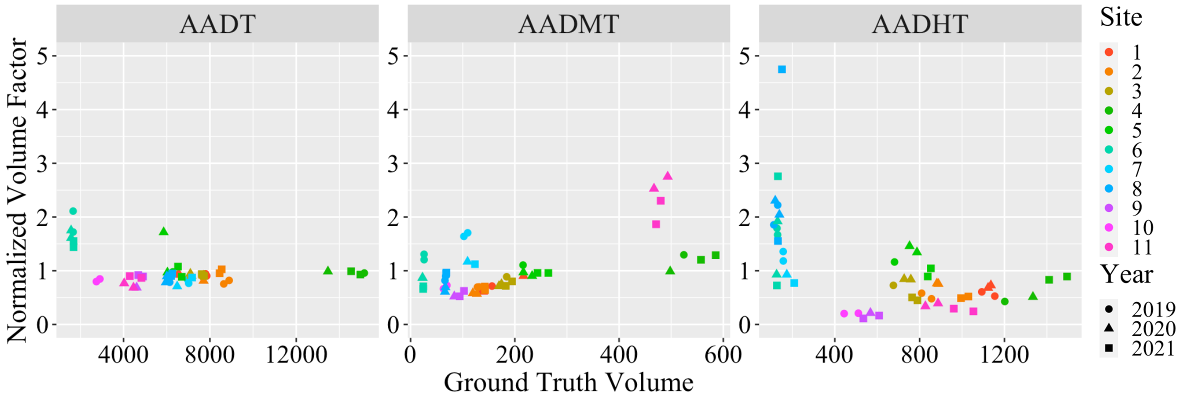

Figure 3 – Comparison of normalized volume factors by class group

Figure 3 indicates that the volume factors are more consistent for total traffic than for trucks. For Sites 6, 7, and 8, there is a wide range of heavy-duty volume factors at a similar AADHT, which indicates that the StL heavy-duty index has a weak relationship with AADHT at these low volumes. For 2021 in particular, the StL heavy-duty index for the southbound direction is significantly lower than in the northbound direction at Sites 6, 7, and 8, despite the ground truth volumes being approximately the same for both directions. The quality of StL's truck data sample is impacted by the commercial vehicle GPS sample size and any bias in the sample toward certain truck fleets. While StL does not disclose their data sources, they do state that their truck probe data source is more likely to include commercial trucks that rely on up-to-date fleet management tools than fleets that lag in the adoption of such tools. Trucks with up-to-date technology may not be equally present on roadways with the same volume or classification, which could contribute to the greater variability in StL's truck sample PR across sites. Sites 9 and 10, which are located on the main link between Winnipeg and the U.S. (Highway 75), have low heavy-duty volume factors and thus higher heavy-duty truck sample PRs than the other sites. This indicates that StL's heavy-duty truck sample may also be biased toward fleets that operate in both Canada and the U.S.

For the AADT estimation at each site, up to one site-direction from Site 5 and/or Site 6 were identified as an outlier by StL and excluded from the calibration data set. A comparison of ground truth and StL AADTs and corresponding PEs are provided in Figure 4 with the line of perfect agreement shown in black.

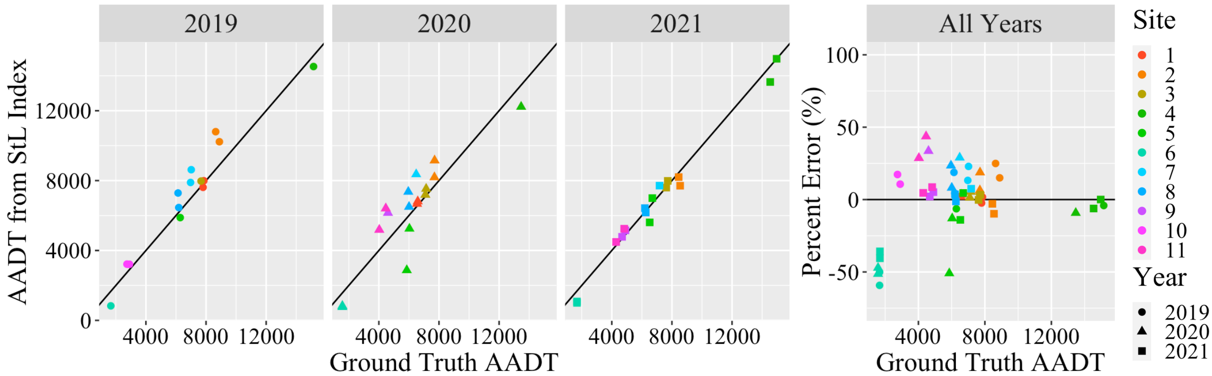

Figure 4 – Comparison of ground truth AADT and AADT from StL index

Overall, Figure 4 shows that there is reasonable agreement between the StL estimates and ground truth AADT in each year. When comparing years, the strongest and weakest agreement between StL and ground truth AADTs are observed in 2021 and 2020, respectively. The lowest volume site (Site 6) had considerably larger PEs in 2019 and 2021 than the other sites, which agrees with observations from previous research on StL AADTs. However, several of the previous studies found that StL over-estimated at low volumes, whereas StL under-estimated the volume at Site 6 (Turner et al., 2020). In addition to having the lowest AADT, Site 6 is the furthest from the other sites geographically, which could be contributing to the differences in StL's sample at the site. In 2020, one direction of travel at Site 5 also had a large PE. This large negative error appears to be caused by an issue with StL's sample data as the activity index for one direction of travel at Site 5 is approximately 1.8x larger than in the other direction, while the ground truth volumes are approximately the same.

Like total traffic, StL medium-truck indices were scaled into AADMT estimates using StL single factor calibration. One to two directions of travel from Site 7 or Site 11 were removed from the calibration data set for each site as StL identified their high volume factors to be outliers. Figure 5 provides a comparison of ground truth and StL estimated AADMTs along with the PEs.

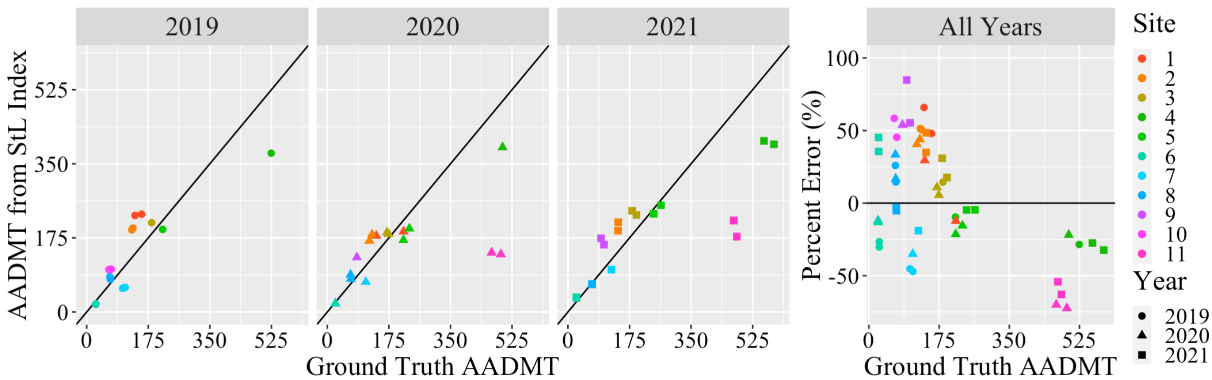

Figure 5 – Comparison of ground truth AADMT and AADMT from StL index

As expected, based on the wider range of volume factors in Figure 3, the magnitudes of the minimum and maximum percent errors are higher for medium-duty trucks than total traffic. In addition to biases in StL's commercial GPS data, it is possible that the discrepancy between the GVWR groupings and FHWA class groups is contributing to the error as some sites may have more FHWA class 4-6 vehicles classified as heavy-duty than other sites. The most prominent outlier in Figure 5 is Site 11. As presented in Table 1, there is a notably higher percentage of medium-duty trucks at Site 11 compared to the other sites. The additional medium-duty truck traffic at Site 11 could be from a truck fleet not included in StL's sample that operates more frequently on this highway than the others in the study. Conversely, trucks on Highway 75 appear to be overrepresented in StL's sample, resulting in over-estimation at Sites 9 and 10. Finally, there is no clear relationship between AADMT and either PE or absolute PE.

For the estimation of AADHT at each site, up to four site-directions from Sites 5, 6, and 8, were identified as outliers by StL and excluded from the calibration data set. Figure 6 shows a comparison of the ground truth and StL AADHTs as well as the PEs.

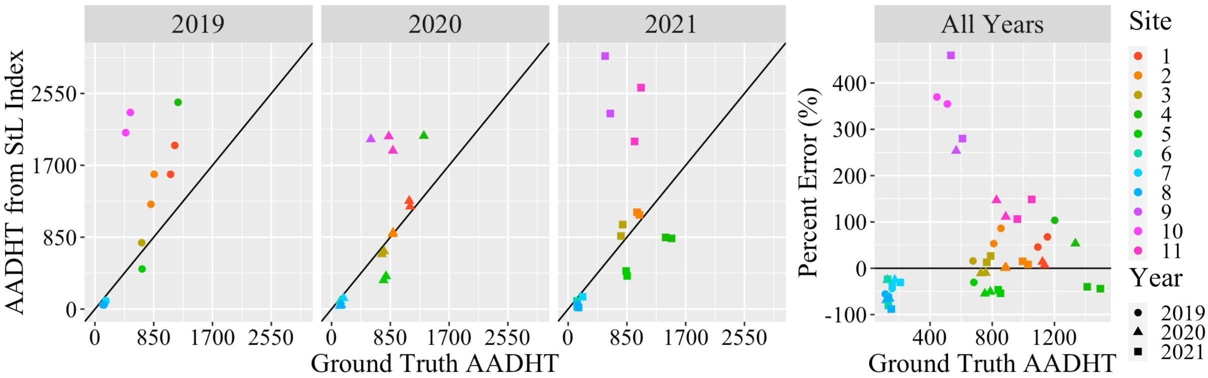

Figure 6 – Comparison of ground truth AADHT and AADHT from StL index

Compared to AADT and AADMT, the AADHT estimates have the largest percent errors. As previously discussed, the estimation of AADHT based on the StL heavy-duty index is unreliable at the lowest volume sites. Figure 6 illustrates that there is no discernable relationship between the percentage error and volume of heavy-duty trucks. Upon further investigation, there was also no relationship identified between PE and the percentage of heavy-duty trucks to total traffic, percent of heavy-duty trucks to truck traffic, or StL heavy-duty activity index. Again, the large over-estimation at Sites 9 and 10 appears related to bias in StL's truck data sample.

Table 3 provides a summary of the errors, StL sample trip counts, and average PRs by class group and year. The trip count is the total number of sample trips at all 11 sites for the entire year and the PR for a site is the ratio of the sample trip count to the AADT multiplied by 365. The approximate sample trip count and PRs were provided by StL.

Table 3 – Summary of error metrics and StL sample size by class group and year

Metric	Year	Total Traffic	Medium-Duty Trucks	Heavy-Duty Trucks
Median PE (%)	2019	4.4	14.5	15.9
	2020	5.4	-12.0	-9.9
	2021	0.0	-3.0	-23.7
MdAPE (%)	2019	13.2	45.2	59.4
	2020	18.8	21.9	50.7
	2021	4.6	32.4	46.3
MAPE (%)	2019	17.0	37.5	96.4
	2020	22.1	29.9	56.6
	2021	8.8	33.3	89.9
StL Approximate Sample Trip Count [PR (%)]	2019	392,000 [0.91]	329,000 [40]	10,000 [0.29]
	2020	223,000 [0.51]	224,000 [25]	6,000 [0.13]
	2021	438,000 [1.05]	29,000 [3]	4,000 [0.11]

Table 3 reveals the following:

- The PEs had a slight positive bias (approximately 5%) for total traffic in 2019 and 2020 and roughly no bias in 2021. In contrast, medium-duty and heavy-duty truck estimates had both positive and negative biases with larger magnitudes across the three years.
- The total traffic MAPE ranged from 8.8% to 22.1%. These MAPEs are comparable to those reported in the studies of StL's 2019 AADTs in the U.S., and prior work conducted for traditional SDCs in Manitoba by Milligan et al. (2016) and by Grande et al. (2021).
- The MAPE and MdAPE for total traffic were the highest in 2020. It is possible that the changes in travel patterns during the COVID-19 pandemic and reduced PRs of StL LBS data contributed to the larger errors in 2020. Overall, the continuous count data showed that passenger car volumes decreased in 2020 while truck traffic was the same or higher, which could explain why larger errors were not observed for trucks in 2020.
- StL's LBS data sample increased in 2021 and the commercial GPS sample decreased. Despite the substantial reduction in sample size and average PR for medium-duty trucks in 2021, the MdAPE and MAPE are comparable to those from 2019 and 2020. This indicates that above 3%, a higher PR does not necessarily result in lower errors.
- StL recommends a PR for total traffic of 2% or more for calibration zones; however, the results show sufficiently low bias, MdAPE, and MAPE for AADT with a PR of just over 1%. Despite the lower PR for total traffic compared to medium-duty trucks, the LBS data used for the StL total traffic indices appears to be more consistent (less biased) across sites, resulting in more consistent PRs and thus more accurate volume estimates.
- The high MdAPE and MAPE for heavy-duty trucks demonstrates that StL single factor calibration does not currently provide reliable AADHT estimates at the study sites. While medium-duty trucks have lower volumes than heavy-duty trucks at all sites, StL's data source provides a substantially larger sample size for medium-duty trucks, resulting in lower MAPEs and MdAPEs for these trucks.

The presented results were obtained using StL's built-in single factor calibration. However, there may be more flexibility if StL indices were scaled manually. For example, judgement could be used to remove outlier site-directions more logically. For some cases in this study, StL's algorithm only removed the direction of travel with the highest volume factor at a site, even though it appeared that both directions of travel were outliers. Further, using regression to identify a relationship between the StL indices and ground truth volumes instead of using a single mean volume factor may improve the estimated volumes. Future work could investigate whether manual scaling methods result in more accurate truck volume estimates than StL's single factor calibration function. Since the sample size for medium-duty trucks was larger than that of heavy-duty trucks, future work could also examine whether AADTT estimates obtained by scaling the medium-duty truck index are more accurate than those obtained by summing the scaled AADMT and AADHT estimates. Regardless of the estimation method, there are still limitations when comparing the continuous count and probe-based estimates. The continuous count data was extensively reviewed to remove erroneous data, but the resulting annual average daily volumes are expected to contain a small degree of error. In addition, it is known that the FHWA axle-based class groupings used for the ground truth data do not perfectly correspond to the GVWR classes used in StL's commercial GPS data.

5. Conclusion

For this study, StL single factor calibration was used to scale StL indices into AADT, AADMT, and AADHT estimates. While there were outliers in each class group, the percent errors were the lowest for total traffic with MAPEs ranging from 8.8% to 22.1%, and highest for heavy-duty trucks with MAPEs ranging from 56.6% to 96.4%. The errors of the truck estimates are likely too high for design applications, but they may be useful for planning applications on unmonitored road segments where truck volume estimates are unavailable or of unknown quality. To limit the impact of bias in StL's data sample, calibration sites of the same road classification and setting with similar expected truck fleet characteristics should be used when possible. Overall, more work is needed to obtain site-specific truck volume estimates from StL data with similar quality to that of StL's total traffic estimates or traditional traffic counts.

References

- Boile, M.P., Spasovic, L.N., Ozbay, K., Mittal, N. and Golias, M. (2004), Estimation of Truck Volumes and Flows, New Jersey Department of Transportation.
- Codjoe, J., Thapa, R. and Yeboah, A.S. (2020), Exploring Non-Traditional Methods of Obtaining Vehicle Volumes, U.S. Department of Transportation.
- Federal Highway Administration. (2022), Traffic Monitoring Guide, U.S. Department of Transportation.
- Fish, J., Young, S., Wilson, A. and Borlaug, B. (2021), Validation of Non-Traditional Approaches to Annual Average Daily Traffic (AADT) Volume Estimation, U.S. Department of Transportation.
- Lindsey, C., Beagan, D., Viswanathan, K., Motamed, M. and Yadav, V. (2021), Linking FHWA and NHTSA Vehicle Types and Deciphering Various Truck Weight Data, U.S. Department of Transportation.
- Regehr, J. D. and Reimer, M. J. (2013), "Methodology to Estimate the Distance Traveled by Trucks on Rural Highway Systems", Journal of Transportation Engineering, 139, 390-398.
- Roll, J. (2019), Evaluating Streetlight Estimates of Annual Average Daily Traffic in Oregon, Oregon Department of Transportation.
- Schewel, L., Co, S., Willoughby, C., Yan, L., Clarke, N. and Wergin, J. (2021), Non-Traditional Methods to Obtain Annual Average Daily Traffic (AADT), U.S. Department of Transportation.
- Tsapakis, I., Cornejo, L. and Sánchez, A. (2020), Accuracy of Probe-Based Annual Average Daily Traffic (AADT) Estimates in Border Regions, Center for International Intelligent Transportation Research, Texas A&M Transportation Institute.
- Tsapakis, I., Turner, S., Koeneman, P. and Anderson, P. (2021), Independent Evaluation of a Probe-Based Method to Estimate Annual Average Daily Traffic Volume, U.S. Department of Transportation.
- Turner, S., Tsapakis, I. and Koeneman, P. (2020), Evaluation of StreetLight Data's Traffic Count Estimates from Mobile Device Data, Minnesota Department of Transportation.
- Yang, H., Cetin, M. and Ma, Q. (2020), Guidelines for Using StreetLight Data for Planning Tasks, Virginia Department of Transportation.
- Young, S. E., Sadabadi, K., Sekuła, P., Hou, Y. and Markow, D. (2018), Estimating Highway Volumes Using Vehicle Probe Data – Proof of Concept: Preprint, National Renewable Energy Laboratory.
- Milligan, C., Montufar, J., Regehr, J. and Ghanney, B. (2016), "Road Safety Performance Measures and AADT Uncertainty from Short-term Counts", Accident Analysis and Prevention, 97, 186–196.
- Grande, G., Paramita, P. and Regehr, J. D. (2021), "Data-Driven Approach to Quantify and Reduce Error Associated with Assigning Short Duration Counts to Traffic Pattern Groups", Transportation Research Record, 2675, 271–283.