Estimating Annual Average Daily Bicyclists

Error and Accuracy

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Cities around the United States are investing in bicycle infrastructure, and to secure additional transportation funding, cities are reporting bicycle use and safety improvements. Data on bicyclist traffic volume is necessary for performing safety studies and reporting facility use. Meeting the need for data, available manual bicycle counting programs count cyclists for a few hours per year at designated locations. A key issue in the design of counting programs is determining the timing and frequency of counts needed to obtain a reliable estimate of annual average daily bicyclists (AADB). In particular, in which days of the week, hours of the day, and months of the year should counts be collected? And, most important to program cost, how many hours should be counted? This study used continuous bicycle counts from Boulder, Colorado, to estimate AADB and analyze the estimation errors that would be expected from various bicycle-counting scenarios. AADB average estimation errors were found to range from 15% with 4 weeks of continuous count data to 54% when only 1 h of data was collected per year. The study found that the most cost-effective length for short-term bicycle counts is one full week when automated counting devices specifically calibrated for bicycle counting are used. Seasons with higher bicycle volumes have less variation in bicycle counts and thus more accurate estimates.

Cities around the United States are investing in bicycle infrastructure and seek to report resulting increases in bicycle use and safety improvements to gain additional access to transportation funds. National transportation funding, through state transportation departments, is allocated according to estimates of annual average daily motorized traffic, but no equivalent metric is available for bicycle use. National surveys provide city-level estimates of bicycle use, but for evaluation of the use and safety of specific facilities or before and after improvements, estimates of average use are required.

Responding to the need for estimates of bicycle use on roads and paths, transportation professionals have established manual bicycle counting programs with guidance from the National Bicycle and Pedestrian Documentation Project (NBPDP) (*1*). Such programs typically send staff or volunteers to count bicycles on roads or paths for 2 to 12 h per day once or twice per year. These manual count programs facilitate the estimation of bicycle use on each facility, but is this enough? How many hours of bicycle counts are needed before accurate estimates of annual bicycle use can be made? This study analyzes the errors in estimation of annual average daily bicyclists (AADB) that are the result of count duration and frequency and offers some recommendations.

For a count to be representative of bicycle use on a facility, it should be equal to the use on an average day, but rarely is any particular day truly average. For this reason, methods for annualizing short-term counts are needed. Counting programs for motorized traffic are a combination of continuous and short-term automated counters. Well-established methods are applied to these data for estimating annual average daily traffic (AADT) on all roadways of interest. Can motorized data collection and statistical traffic volume estimation methods be applied to nonmotorized modes? Because no industrywide accepted data collection and traffic volume estimation method exists for bicycle use, efforts are under way to establish a standardized methodology (*2*). This study informs these efforts by providing estimates of error for various short-term counting scenarios and makes specific recommendations about when and for how long to count bicyclists for the most cost-effective accuracy in estimating AADB.

Data from Boulder, Colorado, were used for studying the accuracy of estimating AADB from short-term counts. Boulder has been collecting continuous bicycle counts with automated inductive loop counters at 12 locations around the city since 1998. These continuous counters provide the basis from which factors were computed to estimate AADB with methods outlined in the *Traffic Monitoring Guide* (TMG) (*3*). Four sets of test data, each including one complete year of counts, were extracted from the continuous count data for calculating the error of AADB estimates for various count scenarios. The error for each scenario was examined, and the most cost-effective short-term count scenarios are recommended.

This paper describes the current practice for estimating bicycle volumes, details the data used, explains the methods used to estimate AADB and to compute the error associated with each count scenario, presents the AADB estimation errors for each scenario, and concludes with recommendations for the most cost-effective counting programs.

STATE OF THE PRACTICE

Much work has been done to create methods to annualize motorized traffic counts. For motorized counts, the state of the practice is summarized in the TMG, which is being updated to include guidance on monitoring bicycle and pedestrian volumes (*3*). The TMG gives multiple methods for establishing factor groups and estimating daily and seasonal factors for estimation of AADT for motor vehicles. Factor groups are groups of continuous count sites with

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similar traffic patterns that are used for computing temporal factors that can be applied to short-term counts for estimating AADT.

For nonmotorized modes, the NBPDP developed a set of factors for estimating pedestrian and bicycle volumes under various conditions (*1*). The set includes factors for combined pedestrian and bicycle counts on paths. Factors are provided for various climate regions, but the behavior of cyclists and pedestrians varies substantially across the country, so that calculating annual bicycle and pedestrian volumes with one set of nationally calibrated factors may result in substantial error.

The NBPDP recommends that weekday short-term bicycle counts be taken on a Tuesday, Wednesday, or Thursday during the evening peak period, assumed to be 5:00 to 7:00 p.m. by default, and that weekend counts be taken on Saturday from noon to 2:00 p.m. The NBPDP suggests that both weekday and weekend counts be collected during a designated week in mid-September. Around the country, teams of volunteers or staff members are rallied to complete these counts at locations throughout the area of interest. To be successful such efforts require substantial organization and training of volunteers and staff. This paper discusses the accuracy of this widespread approach.

FHWA sponsored a thorough review of the literature and methods used for counting bicycles and pedestrians (*4,* p. 81). The study found that cyclists are counted mainly for project evaluation and safety analysis and that no standard factoring method for bicycle counts has been established. The study also reported that the common practice of using several hours of count data to extrapolate annual counts can lead to skewed results and that more than 24 h of counts should be collected when short-term counts are used to estimate annual traffic.

A recent report from Sweden studied bicycle and pedestrian data for cities. It recommended that a harmonized approach of both surveys and count data be used for understanding bicycle and pedestrian use and specifically recommended that short-term counts include at least 2 weeks of count data (*5*).

Additional work is under way through NCHRP Project 8-78, which will produce a guide, *Estimating Bicycling and Walking for Planning and Project Development,* for measuring bicycle and pedestrian (*6*).

The errors in AADB estimation have not been systematically analyzed in a published work. This paper provides such an analysis.

DATA

The continuous bicycle count data set used in this analysis was provided by the city of Boulder. Since 1998, automated inductive-loop bicycle counters have been used to record continuous bicycle counts in Boulder. This study uses continuous counts from 26 stations at 12 locations from 1999 through 2012, totaling 930,290 hourly observations. Although some of the count stations record bicycles by direction of travel, this study focuses on total counts in both directions on paths and roads.

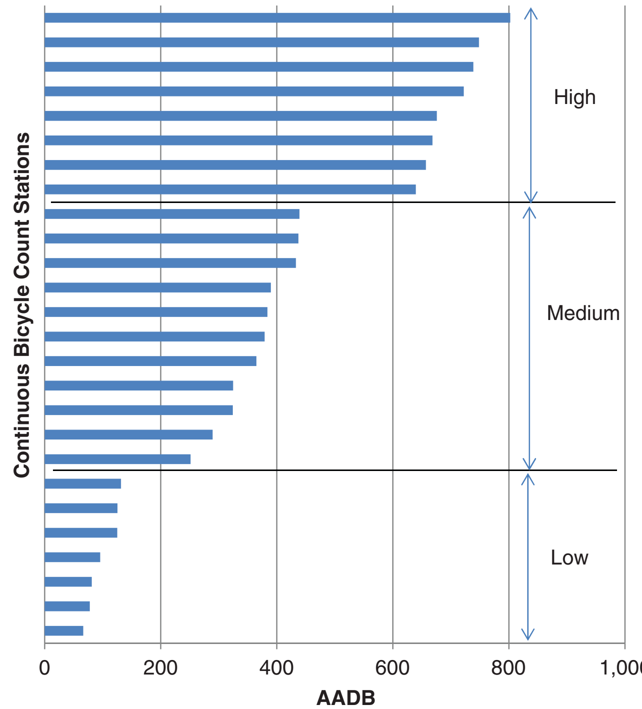


FIGURE 1 AADB averaged for all years at each continuous count station.

The accuracy of this data set was previously assessed (*7, 8*). Some data were removed because of inconsistency (technical issues caused counts in some years to be significantly lower than in other years), but most counts were used even if under- or overcounting was observed. As long as the inaccuracies are consistent over time, the data can be used for this study because the relative change in the counts is of interest, rather than the absolute volumes.

AADB averaged for all years at each continuous count station is shown in Figure 1, which illustrates that the stations can be roughly divided into three categories based on AADB: low (<200), medium (200 to 600), and high (>600).

The full set of continuous bicycle count data was used to estimate factors for computing AADB. A subset of this data, the four full years given in Table 1, was used to compute the error for the various short-term count scenarios. The test data were not removed from the data set before the factors were created, which likely will result in somewhat lower errors in estimating AADB. A full year of hourly count data was needed so that actual AADB would be known for each set of test data. Few such years existed in the data set since

TABLE 1 Hourly Continuous Counts Used to Compute AADB Error

Station Location	Station Name	Dates	Commute Pattern	AADB	Volume
Boulder Creek Path at 13th Street	Arap 13th	Jan. 2007–Dec. 2007	No	778	High
Arapahoe Path at 38th Street	Arap 38th	June 2004–May 2005	No	86	Low
Foothills Path at Arapahoe Avenue	Foothills	June 2004–May 2005	Yes	431	Medium
Arapahoe Path at Foothills Parkway	Arapahoe	June 2004–May 2005	Yes	311	Medium

many months and some years of hourly counts are missing because of various problems, such as power outages and lack of staff time for collecting data (*9*).

METHODS

The analysis had four steps. First, the continuous count data were used to create hourly, daily, and monthly factors. Second, these factors were multiplied by the hourly counts in the test data under the various scenarios to compute estimates of AADB. Third, count scenarios to be tested were chosen, and computed percent differences and absolute percent differences were used to compare the AADB estimates with the actual AADB. Finally, the AADB estimation errors were examined by month for one count scenario, and the AADB error was compared with the error of estimating AADT for motor vehicles.

Creating Factors

Before factors were created, the continuous count data were divided into two factor groups: those stations with clear commute patterns and those without. Figure 2 shows examples of stations with and without clear commute patterns. Stations with commute patterns were identified as those whose average peak morning and evening peak hours were higher than the noon peak hour. Half the stations showed clear commute patterns, and the stations could be evenly divided into two groups for factoring.

The TMG computes AADT by multiplying the 24 h of count data by a daily or monthly (or seasonal) growth and axle factors that are computed from the continuous counts in the factor group. Daily and monthly factors are generally computed by dividing the AADT by the daily average count for a particular day or month. State departments of transportation use variations on computing these factors, but their methods must be approved by FHWA because AADT volumes are used as part of the formula for allocating transportation funds to states.

For this study, growth factors and axle factors were not used. Because the study investigated only counts within the year of interest, growth factors were not used. Axle factors were not needed because manual counts and counts from bicycle-specific temporary automated counting equipment are typically already in terms of total bicycles.

Like motor vehicle factors, daily and monthly factors for bicycle use can be computed in multiple ways. Because many nonmotorized count programs collect less than 24 h of counts, an hourly factor is also needed for adjusting the hourly count up to a day. Two methods for computing these factors were used in this analysis. Both use the average AADB for the factor group for a given year as the numerator for most of the factors.

First, a straightforward method for computing factors was used. Monthly factors were computed by dividing the AADB for that year by the average daily count for that month. Daily factors were computed by dividing the AADB by the average daily count for that day of the week. Hourly factors were computed by dividing the AADB by the average hourly count for that hour of the day. The details of this factoring method are given in Equation 1.

Second, a set of peak hour–specific factors were computed with a subset of the continuous count data for the peak hours of 8:00 to 9:00 a.m., noon to 1:00 p.m., and 5:00 to 6:00 p.m. on Tuesdays, Wednesdays, and Thursdays for computing the denominator of the factors. Those days are associated with the highest bicycle use at locations with commute patterns and are the typical days on which motor vehicle counts are collected. The daily and hourly factors were combined, and instead of separate factors for each peak hour, the average of the three peak hours was used. The details of this factoring method are shown in Equation 2.

Estimation of AADB

AADB was estimated by multiplying the known short-term count by appropriate hourly, daily, and monthly factors. For short-term counts of 24 h or more, only daily and monthly factors were needed. For short-term counts of a week or more, only the monthly factor was applied to the average of the daily counts during that week.

Equation 1 shows how AADB was estimated for a 1-h short-term count. Such a program would estimate AADB for a location based only on 1-h of counts on 1 day of the year and the factors already computed for a representative factor group.

$$\mathrm{AADB}_e = c_{kh} * H_{yf} * D_{yf} * M_{yf} \tag{1}$$

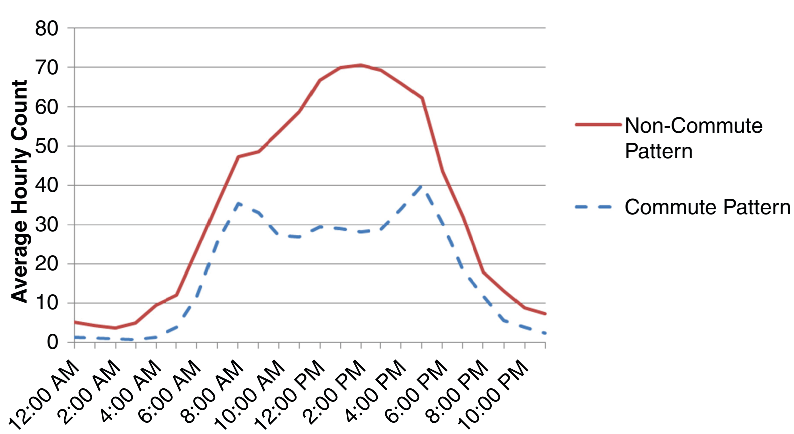


FIGURE 2 Commute and noncommute patterns.

where

$AADB_e$ = estimated annual average daily bicyclists;
c_{kh} = known count for 1 h;
H_{yf} = hourly factor for given hour of day in given year y for factor group f: (actual AADB for that year)/(average hourly bicyclists for that hour in that year);
D_{yf} = daily factor for given day of week in given year y for factor group f: (actual AADB for that year)/(average daily bicyclists for that day of the week in that year); and
M_{yf} = monthly factor for given month in given year y for factor group f: (actual AADB for that year)/(average daily bicyclists for that month of that year).

The second factoring approach calibrates factors specifically for a short-term count program that counts all three peak hours (8:00 a.m., noon, and 5:00 p.m.) on any single Tuesday, Wednesday, or Thursday in a given year. The method is as follows:

$$AADB_e = c_{kp} * D_{pyf} * M_{pyf} \quad (2)$$

where

c_{kp} = known sum of three peak hour counts on any single Tuesday, Wednesday, or Thursday;
D_{pyf} = daily factor for given month in given year y for factor group f for average of three peak hour counts for all Tuesdays, Wednesdays, and Thursdays: (average daily count per Tuesdays, Wednesdays, and Thursdays for given month in given year)/(average three peak hour count per Tuesdays, Wednesdays, and Thursdays for given month and year); and
M_{pyf} = monthly factor for given month in given year y for factor group f: (actual AADB for that year)/(average daily count per Tuesdays, Wednesdays, and Thursdays for given month in given year).

Comparison of Scenarios

Several short-term count scenarios were investigated, as listed in Table 2. These scenarios were chosen because they represent reasonable or typical count programs used in the United States. All the scenarios assumed that counts would be collected on days and at times throughout the year, regardless of weather and holidays. This assumption introduces some additional error, because the week between the Christmas and New Year holidays, for example, is likely not to be representative of the whole year.

Three 1-h count scenarios were investigated. First, a 1-h count was assumed to be collected at any hour between 7:00 a.m. and 7:00 p.m. on any day of the week, including weekends; this scenario would model the hypothetical situation in which staff members or volunteers were sent to count bicycles at a different intersection every other hour. The second 1-h count scenario also assumed that 1-h counts would be collected at any hour between 7:00 a.m. and 7:00 p.m., but it restricted the days of counting to all Tuesdays, Wednesdays, and Thursdays. The third 1-h count scenario further restricted the 1-h counts to peak hours only (8:00 a.m., noon, and 5:00 p.m.) on all Tuesdays, Wednesdays, and Thursdays, because these are the times when the highest bicycle counts typically occur for locations with commute patterns and are the times often used in motor vehicle count programs.

TABLE 2 Short-Term Count Scenarios

Duration of Count	Time Frame	Days of the Week
1 h	7:00 a.m.–7:00 p.m.	Any day
1 h	7:00 a.m.–7:00 p.m.	TWorR
1 h	8:00 a.m., noon, 5:00 p.m.	TWorR
2 h	5:00 p.m.–7:00 p.m.	TWorR
3 h	8:00 a.m., noon, 5:00 p.m.	TWorR
9 h	8:00 a.m., noon, 5:00 p.m.	TWR
12 h	7:00 a.m.–7:00 p.m.	Any day
12 h	7:00 a.m.–7:00 p.m.	TWorR
24 h	All hours	Any day
1 week	All hours	All days
2 weeks	All hours	All days
4 weeks	All hours	All days

NOTE: TWoR = Tuesday, Wednesday, or Thursday, TWR = Tuesdays, Wednesdays, and Thursdays.

One 2-h count scenario was investigated. This scenario was similar to the NBPDP count program because it specified counts from the evening peak hours (5:00 to 7:00 p.m.) on all Tuesdays, Wednesdays, and Thursdays. Because it also samples these periods year-round instead of on days specifically chosen as representative, the error from this counting scenario is likely to be higher than that from NBPDP short-term counts.

One 3-h count scenario was included. This program was based on a program of turning movement count used by the city of Boulder for timing signals (primarily for motor vehicles). Because the second set of factors was developed specifically for this count scenario, the scenario may have a lower associated error. The specific hours for which turning movement counts are collected will vary from program to program, but this scenario is an example of one such program.

Like the 3-h count scenario, the 9-h count scenario specifies that counts are collected during the three peak hours (8:00 a.m., noon, and 5:00 p.m.) for Tuesdays, Wednesdays, and Thursdays of a given week. A count program of this type could be a rational approach. The set of factors specific to peak hour was used for this scenario.

Two 12-h count scenarios were investigated. Both required that counts be taken during the 12-h period between 7:00 a.m. and 7:00 p.m. The first scenario allows such counts to be collected on any day of the week, including weekends; the second scenario restricts count to just Tuesdays, Wednesdays, and Thursdays. Both scenarios were computed with the set of hourly, daily, and monthly factors.

The remaining count scenarios specify 24 h or more of short-term counts. Such counts usually would be collected with an automated bicycle counting device, such as a tube counter specifically calibrated to bicycles. The week-long and multiweek count scenarios are typical of the short-term count program currently used by the Colorado Department of Transportation for combined bicycle and pedestrian counts.

A comparison of the count scenarios computed the average absolute percent difference error and the standard deviation of the average percent difference error between the actual AADB and that predicted for each model for the four test data sets. These two means of computing error are detailed in Equations 3 and 4.

$$\text{error as percentage of difference} = \frac{(\text{AADB}_e - \text{AADB})}{\text{AADB}} \quad (3)$$

$$\text{error as absolute percentage of difference} = \frac{|\text{AADB}_e - \text{AADB}|}{\text{AADB}} \quad (4)$$

where AADB_e is the estimated AADB and AADB is the actual AADB.

Methods for Analyzing Error

After the error was computed for each count scenario, seasonal variation in AADB error was also investigated with the scenario constant held constant. The three-peak-hour count scenario was chosen for this analysis. The results are presented graphically. This paper ends with a brief comparison, based on a published source, to motorized volume estimation error for AADT.

RESULTS

Scenario Comparison

The average AADB estimation error for each short-term count scenario is given in Table 3 for each test data set. The same information is graphed by hours of counts collected in Figure 3.

AADB estimation error changes substantially with the duration of the short-term counts (Figure 3). The shape of the curves in the upper graph of Figure 3 indicate that 1 week of count data results in the most cost-effective accuracy, because the reduction in error with additional hours of data beyond 1 week is not as large as reductions in error between the 24-h and 1-week counts. The average error for scenarios requiring one or more weeks of counts is below 30%; scenarios with shorter periods average as much as 60% error.

Figure 3 also shows that the location with the highest bicyclist traffic (Arap 13th) is associated with lower error, and the location with lowest bicycle traffic (Arap 38th) is associated with highest error. This may be because of lower greater variability in counts as a percent of total traffic at low-volume locations.

There also appears to be a reduction in AADB error for counts collected on Tuesday, Wednesday, or Thursday, as opposed to any day of the week including weekends. This is shown by the first two 1-h count scenarios and the two 12-h count scenarios in Table 2.

AADB estimates computed with the second set of factors, which were specifically calibrated to assume peak hours (8:00 a.m., noon, and 5:00 p.m.) on Tuesdays, Wednesdays, and Thursdays, were sometimes but not always more accurate. This result is shown by a comparison of the error for the 3-h and 9-h count scenarios, which used the second set of factors, with that of the 2-h and 12-h scenarios. Figure 3 shows a reduction in error for the 3- and 12-h scenarios for the Arap 13th and Arap 38th locations but a slight increase or no increase in error for the other two test data sets. The TMG recommends the creation of such data-specific factors, and although the factors do reduce error in some cases, they also reduce the flexibility of adding other data sources with counts at times not included in the calibration.

Error Analysis

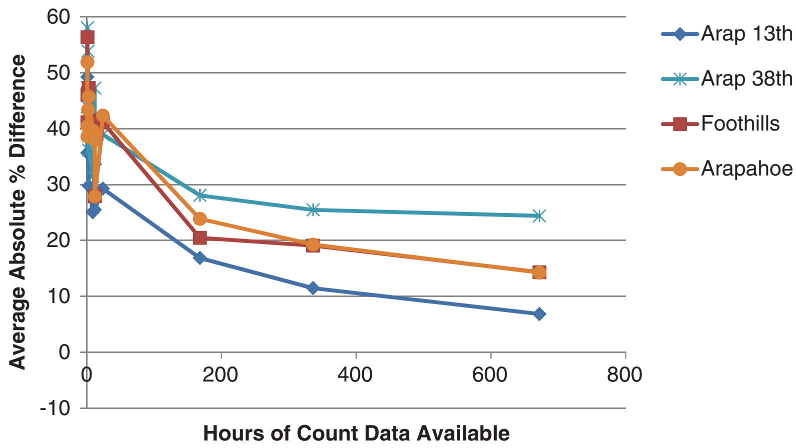
In addition to errors related to the duration of short-term counts, volume of traffic, day of the week on which counts were collected, and factoring method, elements such as seasonal variation, variation in hourly bicycle counts, and number of continuous count stations used to calibrate the factors also affect AADB estimations. Because the count scenario was held constant so the effects of the other variables on AADB accuracy could be observed, one count scenario was chosen: counting on all three assumed peak hours (8:00, noon, 5:00 p.m.) on any Tuesday, Wednesday, or Thursday.

The average AADB errors by month are shown in Figure 4 and listed in Table 4. When AADB estimates are based on counts in July through October, the error in these estimates is substantially lower than in other months. This is plausible because these months tend to have

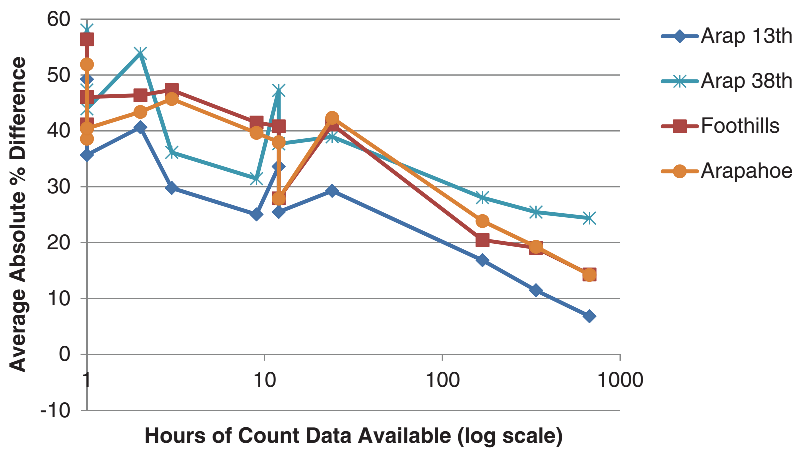
TABLE 3 Average AADB Estimation Error by Scenario

		Error as Average Absolute Percentage Difference				
Short-Term Count Scenario	Hours	Arap 13th	Arap 38th	Foothills	Arapahoe	Average
1 h: 7:00 a.m.–7:00 p.m. any day	1	49	58	56	52	54
1 h: 7:00 a.m.–7:00 p.m. TWorR[a]	1	41	47	41	39	42
1 peak hour: 8:00 a.m., noon, 5:00 p.m. TWorR[a]	1	36	44	46	40	42
2 peak hours: 5:00 p.m.–7:00 p.m. TWorR	2	41	54	46	43	46
3 peak hours: 8:00 a.m., noon, 5:00 p.m. TWorR average/day[b]	3	30	36	47	46	40
3 peak hours: 8:00 a.m., noon, 5:00 p.m. TWR[b]	9	25	31	41	40	34
12 h: 7:00 a.m.–7:00 p.m. any day	12	34	47	41	38	40
12 h: 7:00 a.m.–7:00 p.m. TWorR[a]	12	25	38	28	28	30
24 h any day	24	29	39	41	42	38
1 week	168	17	28	20	24	22
2 weeks	336	11	25	19	19	19
4 weeks	672	7	24	14	14	15

[a]Scenarios that use the monthly factors calibrated specifically to 8:00 a.m., noon, 5:00 p.m. TWR day.
[b]Scenarios that use the daily and monthly factors calibrated specifically to 8:00 a.m., noon, 5:00 p.m. TWR day.



(a)



(b)

FIGURE 3 AADB error for each test data set by short-term count duration: (*a*) without log scale and (*b*) with log scale.

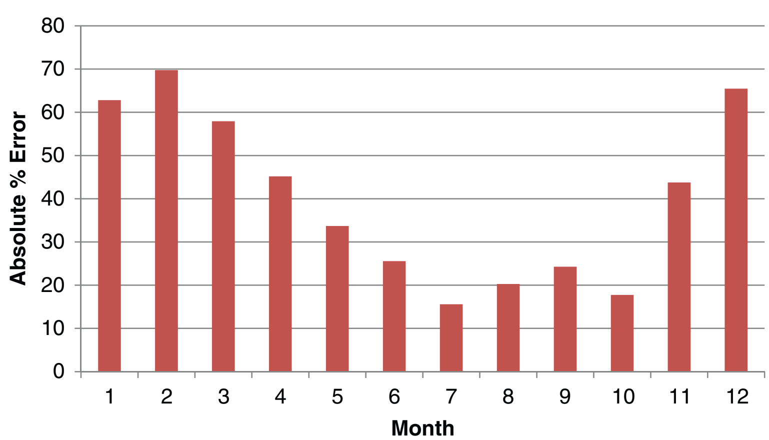


FIGURE 4 AADB error as function of month when short-term counts were collected.

TABLE 4 AADB Estimation Error by Month

Month	Number of Hourly Counts Available	AADB Error as Average Percentage Difference		AADB Error as Average Absolute Percentage Difference	
		Average	SD	Average	SD
1	96,000	29	75	63	49
2	77,000	42	70	70	43
3	74,000	36	63	58	43
4	63,000	26	46	45	28[a]
5	63,000	17	38[a]	34	24[a]
6	62,000	2	37[a]	26	26[a]
7	80,000	–5	18[b]	16	10[b]
8	90,000	–2	26[a]	20	16[b]
9	81,000	–6	30[a]	24	19[b]
10	81,000	–9	22[a]	18	16[b]
11	73,000	14	51	44	30[a]
12	88,000	34	70	65	42
Average	77,000	15	46	40	29

NOTE: SD = standard deviation.
[a]Standard deviation below 40%.
[b]Standard deviation below 20%.

higher bicycle volumes and thus less variability. Figure 5 shows that variation in bicycle counts is lowest overall for May through October.

If this is the case, why are AADB estimates for May through June relatively poor for the Boulder data? The total hours of counts available from the permanent count stations (second column of Table 4) show that July through October has more hours of counts than May and June. Thus, a combination of more continuous counts available for calibrating AADB estimation factors (Table 4) and lower variability in summer counts (Figure 5) result in lower error for July through October AADB estimates (Figure 4).

This finding underscores the importance of permanent continuous count stations. Although Boulder has 13 continuous count stations for each of the two factor groups, less than half that data was available for any given month because of times when data were not collected or counters were not accurate. In effect, the available data made the 13 stations equivalent to five or six permanent count stations per factor group, the minimum recommended by the TMG for motorized traffic. Had more continuous count data been available, AADB error likely would have been lower. However, had the city installed only one or two permanent count stations, the error might have been higher.

Comparison with AADT

How does AADB error compare with error in motorized traffic volume estimates? According to an analysis of AADT estimates in Florida and Minnesota, average absolute percent differences in AADT estimates range from 5% to 83% per location and averaged 12% in Minnesota and 14% in Florida (*10*). Although this AADT analysis was based on hundreds of locations, it provides perspective for understanding the errors observed in AADB for the four locations discussed in this study. When a week of counts is available, the average AADB absolute percent difference error ranges from 15% to 30%, which is near the range observed for AADT. When 4 weeks of bicycle counts are available for each location, the average error is 15%, which is very close to the average error reported for AADT from 24-h counts.

Why might more bicycle counts be needed than motor vehicle counts for computing annualized daily volumes at the same level of accuracy? Bicyclist traffic volumes are lower and more variable than are motor vehicle volumes because of weather and events; the relatively smaller volume of bicycle counts means that the change in counts from day to day caused by random or other variation is a higher percentage of the total count, which increases the variability of the counts and makes estimating average annual volumes more difficult.

CONCLUSIONS AND RECOMMENDATIONS

AADB estimation error is least when based on one or more weeks of hourly bicycle count data. On average the AADB estimation error for the one or more weeks of counts is less than 30% if counts are taken year-round. When the estimation is based on only 1 h of bicyclist counts, the error in predicting AADB can be prohibitively high at average absolute percent differences of 54%.

Lower error is associated with locations that have greater bicycle traffic and seasonality and where calculated traffic volumes are based on short-term counts collected from July through October. For these months, even when only three assumed peak hours of

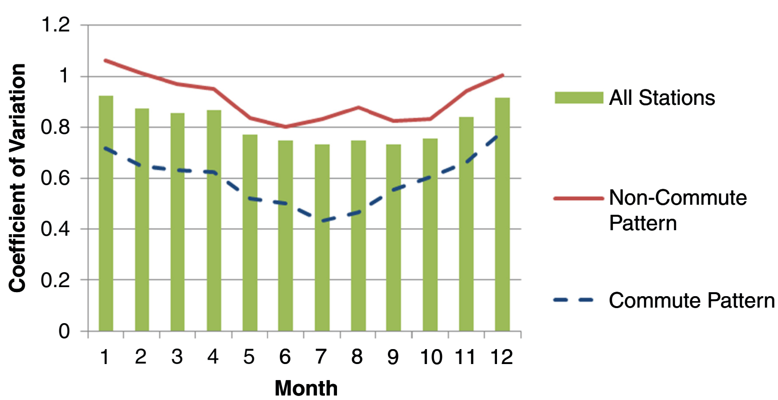


FIGURE 5 Variation in daily bicycle counts by month.

counts are known, error is less than 20% as measured by average absolute percent difference between actual and estimated AADB. Regardless of which scenario is used by a city to count bicyclists, this work reports what error could be associated with the scenario.

As data sources, counting technologies, and calculation methods improve, AADB accuracy should improve. An increase in bicycle use may also lead to less variability in counts and thus higher AADB accuracy.

The following recommendations are made:

- Continuous bicycle counters are essential. AADB cannot be calculated from short-term counts without bicycle counters. The TMG recommends at least five permanent automated motor vehicle count stations per factor group to reduce error. Because bicycle volumes are more variable than motorized traffic volumes, more counters may be needed per factor group. Cities interested in or required to report bicycle volumes should install multiple permanent automated bicycle counters per factor group. A city with fewer than five operating permanent automated counters per factor group is likely to have higher AADB estimation error than that reported here.
- One week of continuous hourly counts is most cost-effective for reducing AADB error. Such counts can be collected with portable tube counters specifically designed for bicycle counting or with similar equipment. If this is not possible, 12-h counts on Tuesdays, Wednesdays, or Thursdays are the minimal necessary information. Although not ideal, these counts reduced average errors from 46% for a 2-h count to 30% in this study and provide information on weekday traffic patterns, which indicates whether a commute pattern is present. Estimates based on 1-, 2-, or 3-h counts were found to have average error of as much as 58%. If less than 12 h of data is collected, actual peak hours cannot be identified and the appropriate factor group (commute or noncommute) cannot be determined. If manual counting is the only data collection method available, the next best scenario according to this study is to collect data for at least the three peak hours on Tuesday, Wednesday, and Thursday at each location.
- Short-term counts should be conducted when variability in counts is lowest. For this study, that period was between May and October. This period varies with location and climate, but it can be identified when a year of continuous count data is available.

Although much more work can and should be done on this topic, this paper is a first look at minimizing AADB estimation error and contributes to the discussions about data collection methods for quantifying bicycle facility use and performance. Without an accurately calculated traffic volume statistic on which to base project evaluations, safety studies, and funding decisions, transportation professions risk losing funding and reaching inaccurate safety conclusions. Establishing such a metric and a standardized method for collecting data and computing that metric are essential for planning, designing, and funding safe, efficient, and long-term bicycle transportation facilities.

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