Optimizing Short Duration Bicycle and Pedestrian Counting in Washington State

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Optimizing Short Duration Bicycle and Pedestrian Counting in Washington State

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This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT:

Across the United States, jurisdictions are investing more in bicycle and pedestrian infrastructure, which requires non-motorized traffic volume data. While some agencies use automated counters to collect continuous and short duration counts, the most common type of bicycle and pedestrian counting is still manual counting. The objective of this research is to identify the optimal times of day to conduct manual counts for the purposes of estimating annual average daily non-motorized traffic (AADNT) accurately.

This study used continuous bicycle and pedestrian counts from six U.S. cities, including three in the Pacific Northwest, to analyze AADNT estimation errors for multiple short duration count scenarios. Using two permanent counters per factor group reduces error substantially (>50%) compared to using just one; afternoon counts seem to be best for reducing error (2PM-6PM). While Monday is associated with high error, Friday is comparable to other weekdays. Error on Sunday is often as good, if not better than Saturday, contrary to what others have found. Arlington had the lowest AADNT estimation error (mean absolute percent error) likely due to better data quality and higher non-motorized traffic volumes and Mt. Vernon, Washington had the highest. Average AADNT estimation errors for the studied short duration count scenarios ranged from 30% to 50%. Error is lower for the commute factor group, bicycle-only counts, scenarios in which more peak hours are counted, and when more than one permanent counter was available to estimate adjustment factors.

To minimize error, this study recommends increasing the number of permanent bicycle and pedestrian count sites, validating and calibrating the equipment, and increasing the length of time counted at each count site to at least 8 hours (7-9AM, 11AM-1PM, 4-6PM TWorTh and 12-2PM Saturday), but preferably counting a whole week using calibrated automated equipment.

This project produced a guidebook for communities (see Appendix J for link), incorporating results from this research as well as those of a companion project by Dr. Michael Lowry at University of Idaho.

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EXECUTIVE SUMMARY

Lack of walking and cycling traffic data is an impediment to creating safe and prosperous communities. WSDOT is collecting bicycling and walking data statewide in collaboration with local agencies and other organizations through the Washington State Bicycle and Pedestrian Documentation Project (WSBPDP), but limited funding is available to do so. For this reason, it is critical to count cycling and walking in the most cost effective way. The goal is to develop reliable metrics for walking and cycling similar to those already available for motor vehicles. This research represents a step in establishing such a metric: annual average daily non-motorized traffic (AADNT) for walking and cycling. AADNT is a foundational measure needed for any study of non-motorized travel as well as existing reporting requirements such as ResultsWA and Target Zero.

For over a decade, the National Bicycle and Pedestrian Documentation Project (NBPDP) website has been the authoritative source on when and how to conduct manual counts (Alta Planning and Design and ITE, 2009). The Traffic Monitoring Guide (TMG) and other recent resources focus more on automated counting strategies, but acknowledge that human observers are needed to collect some data types, such as gender and helmet use (Federal Highway Administration, 2013; Griffin, Nordback, Gotschi, Stolz, & Kothuri, 2014). The recently released NCHRP 797 provides valuable guidance on pedestrian and bicycle manual count programs, but limits itself to reporting existing practice and does not investigate the optimal design of manual count programs (Ryus et al., 2015). Previous research by Nordback and others has found that one week of short duration counts is optimal for minimizing annual average daily bicycle traffic (AADBT) estimation error, which would require automated counters (Hankey, Lindsey, & Marshall, 2014; K.

Nordback, Marshall, Janson, & Stolz, 2013; Nosal, Miranda-Moreno, & Krstulic, 2014). However, manual counting programs, which are often collected at intersections, are by far the most common. NCHRP 797 reports that of those agencies surveyed who count pedestrians, 93% do so manually and of those who count bicycles, 87% do so manually (Ryus et al., 2015). For this reason, optimizing and providing specific guidance for such programs is needed.

The objective of this research is to improve bicycle and pedestrian manual count data quality. This research demonstrates that using manual counts to estimate annual average daily non-motorized traffic (AADNT) is likely to result in errors higher than 20%. However, since this is common practice, the report presents estimates of this error using common estimation methods applied to count data from six cities using frequently used manual count scenarios. For example, Mean Absolute Percent Error (MAPE) averages 45% for the often used 5:00-7:00PM 2-hour count period on Tuesday, Wednesday, or Thursday.

Error varies by number of count sites in the factor group, month, time of day, day of week, and city. It is also likely to vary by variability and volume at the count sites, and quality of the data. The commute factor group demonstrates the lowest error. Afternoon counts seem to be best for reducing error (2:00-6:00PM). While Monday is associated with high error, Friday is closer to the other weekdays in terms of reducing error. Sunday is often as good if not better than Saturday in terms of error contrary to what others have found. Likely due to data quality but also non-motorized traffic volume, Arlington had the lowest AADNT estimation error (mean absolute percent error (MAPE)) and Mt. Vernon, Washington had the highest. Average AADNT estimation errors for the studied short duration count scenarios ranged from 30% to 50%. Error is lower for scenarios in which more peak hours are counted and when more than one permanent counter was available to estimate adjustment factors.

Recommendations for the Washington State Bicycle and Pedestrian Documentation Program (WSBPDP):

- Communities are urged to use counting equipment to count longer than 24 hours (preferably one week) in order to reduce the error.
- If manual counting is continued, the 8-hour peak hour count scenario (7-9AM, 11AM-1PM, 4-6PM on a Tuesday, Wednesday or Thursday and 12-2PM Saturday) during a nonholiday week and good weather from May through September is recommended for potential future WSBPDP use.
- Conduct segment (screenline) counts for manual short duration counts.
- Install more than one continuous counter per factor group. Error (MAPE) decreases over 50% for factors groups with two continuous counters rather than one. A minimum of 24 groups in the state (4 regions X 3 pattern groups X 2 modes), though there are likely to be more groups if, for example, rural and urban areas have different noon activity patterns or different cities have different patterns. Adding counters in the Coast Range and Cascades is especially needed as these areas had not counters at the time of analysis.
- Maintain and calibrate continuous counters and short duration counting equipment at initialization and annually thereafter.
- Collect data from both continuous and short duration coverage count sites for a network-wide count program.

Detailed recommendations from this research are included in a guidebook for communities cited and linked to in Appendix J of this report.

INTRODUCTION

In order to support efforts to create safe and prosperous communities, Washington State Department of Transportation (WSDOT) is collecting bicycling and walking data statewide in collaboration with local agencies and other organizations through the Washington State Bicycle and Pedestrian Documentation Project (WSBPDP). With limited funds for the WSBPDP, it is critical to count cycling and walking in the most cost effective way.

The goal of this line of research is to develop reliable metrics for walking and cycling similar to those already available for motor vehicles. This research represents a step in establishing such a metric: annual average daily non-motorized traffic (AADNT) for walking and cycling. AADNT is a foundational measure needed for any study of non-motorized travel as well as existing reporting requirements such as ResultsWA and Target Zero. This metric may be mode specific using the terms annual average daily bicycle traffic (AADBT) and annual average daily pedestrian traffic (AADPT), but for simplicity, the authors use the term AADNT as a generic metric in this report when either or both modes are referred to.

This research seeks to optimize bicycle and pedestrian short duration manual counting in Washington State by identifying what times are best for counting bicyclists and pedestrians for the purposes of estimating AADNT. The metric has many purposes. For example, retail businesses interested in locating in areas with high foot and bicycle traffic may use such metrics. Metropolitan Planning Organizations (MPOs) may use such data to either create or validate travel models which include pedestrian and bicycle traffic. Traffic engineers working to create a more equitable signal timing plans may also use such data. Without such metrics, robust studies of pedestrian and bicyclist safety at the facility level cannot be conducted and applications for federal safety funds to protect those who walk and cycle may be denied.

For over a decade, the National Bicycle and Pedestrian Documentation Project (NBPDP) website has been the authoritative source on when and how to conduct manual counts, but has not been substantially updated since its creation (Alta Planning and Design and ITE 2009). The Federal Highway Administration (FHWA) Traffic Monitoring Guide (TMG) and other recent resources focus more on automated counting strategies, but acknowledge that human observers are needed to collect some data types, such as gender and helmet use (Federal Highway Administration 2013; Griffin, Nordback, Gotschi, Stolz, & Kothuri 2014). The TMG acts as a primary reference for traffic counting for motorized and non-motorized traffic for researchers and practitioners, and thus it will serve as an important reference in this study. The recently released NCHRP 797 provides valuable guidance on pedestrian and bicycle manual count programs, but limits itself to reporting existing practice and does not investigate the optimal design of manual count programs (Ryus et al. 2014).

Previous research by Nordback and others has found that one week of short duration counts is optimal for minimizing AADBT estimation error, which would require automated counters (Hankey, Lindsey, & Marshall 2014; K. Nordback, Marshall, Janson, & Stolz 2013; Nosal, Miranda-Moreno, & Krstulic 2014). However, manual counting programs, which are often collected at intersections, are by far the most common. NCHRP 797 reports that of those agencies surveyed who count pedestrians, 93% do so manually and of those who count bicycles, 87% do so manually (Ryus et al. 2014). For this reason, optimizing and providing specific guidance for such programs is needed and would lead to higher quality data.

The objective of this research is to improve bicycle and pedestrian manual count data quality for the purposes of estimating AADNT. Manual counts are by far the most commonly collected type of non-motorized traffic counts and can provide data on gender and helmet use which cannot be collected otherwise (Ryus et al. 2014). If manual counts are collected, when, how often, and how long should they be collected? These questions will be addressed in this study.

This report provides a review of the literature on bicycle and pedestrian short duration counting and techniques for estimating AADNT. Next, a description of the data used and its quality is detailed. This is followed by a description of the analysis conducted to identify optimal manual count strategies for reducing AADNT estimation error. The report concludes with discussion of the findings and recommendations for WSDOT's count program. The recommendations are detailed in a guidebook included in Appendix J.

REVIEW OF PREVIOUS WORK

COUNTING METHODS

There are two primary methods for collecting non-motorized traffic count data: manual and automated. The TMG lists three methods of counting non-motorized traffic:

"1 = Human observation (manual)

2 = Portable traffic recording device

3 = Permanent, continuous count station (CCS)"

We discuss the TMG's category 1 as "manual" counts below, and the TMG's category 2 and 3 as "automated" counts below.

Manual

Manual counts are collected by human beings either in the field or through reviewing video recordings at screenline, intersection, or midblock locations. In the field, these counts may be collected by hand by drawing lines on a paper schematic of a count location, by using a smartphone with a counting application, using a handheld electronic count board, or by various other methods. Additionally, manual counts may be used to validate counts from automated technologies.

Automated

Automated counts continuously record traffic flow using counting devices (i.e., Automated Traffic Recorder (ATR) or Portable Traffic Recorder (PTR)) or computer automated video image processing for the purposes of counting (Figure 1). Counts are either collected by timestamp or in discrete time bins (e.g., 15 minutes, hour of the day)(Lindsey et al. 2014; FHWA 2013)[1]. Automated counts may be taken by permanent or portable/temporary counters.

Technology Type	Common Manufacturers	User Type	Duration	Typical Uses
Infrared (Active and Passive)	• TRAFx • EcoCounter • TrailMaster	*Does not automatically distinguish between peds/bikes.*	Short or long	Sidewalk or shared-use path
Pneumatic Tubes	• EcoCounter • MetroCount • TRAFx • Road Sys		Short	On-road
Inductive Loop	• EcoCounter • Road Sys		Long	On-road or paved shared-use path
Magnetometer	• TRAFx		Long	Shared-use path
Piezoelectric	• MetroCount		Long	On-road
Radar Sensors	• Sensys Networks		Long	On-road
Thermal Imaging	• FLIR		Long	On-road
Video Imaging	• Miovision		Short or long	On-road

Figure 1 Automated counter technologies commonly used to count pedestrians and bicyclists.

Source: Alta Planning + Design, "Innovation in Bicycle and Pedestrian Counts: A Review of Emerging Technology," 2016.

[1] TMG, Section 1.2.2

Temporary

A temporary counter is an automated counting device that is installed at a site to collect short duration counts. For example, pneumatic tubes or temporary inductive loops (e.g., Eco-Counter's Easy Zelt) may be used as temporary counters.

Permanent

A permanent counter is an automated counting device that is installed with the intent to keep at that count location indefinitely. It is important to note that while all permanent counters collect data continuously, not all continuous counters are permanent. For instance, researchers may collect continuous data from a site for a number of years before uninstalling the counting device when the project ends or funding runs out.

COUNT TYPES

Even with efforts on the local, state, and federal levels to establish guidelines for non-motorized traffic monitoring, the terms commonly used in these programs have yet to be standardized (Lindsey et al. 2014). For the purposes of this report, the authors adopt the following definitions for bicycle and pedestrian count types using guidance from the Traffic Monitoring Guide (TMG).

Short Duration (< 1 year)

Lindsey et al. (2014) found that short duration counts are conducted in a specific geographic study area for less than one year either using manual or automated technologies in order to cost-effectively increase the number of count locations. Short duration counts usually range from 1 day to 1 month, but may also be 2 hour counts during peak periods (e.g., NBPDP counts)(Lindsey et al. 2014).

Manual counts are conducted by individuals, often an agency staff member, volunteer, or intern (Nordback et al. 2015). Due to limited data collection resources, these counts are generally taken once or twice a year over a very short duration (e.g., 2 hour) during peak hours at designated locations. The TMG recognizes that using short duration manual counts may also be due to the perceived difficulty of using automated technologies and the desire to collect data on gender and helmet use (FHWA 2013)[2].

Temporary automated counts are another type of short duration count, but are distinct from manual counts because they are collected by machine (i.e., Portable Traffic Recorder or PTR) and generally have a longer duration (e.g., several hours to multiple weeks)(FHWA 2013)[3]. This provides valuable count data for studying hourly, daily, and monthly traffic patterns, which would not be possible with manual counts alone (Nordback et al. 2015).

Short (manual or temporary automated, < 24 hours)

"Short" counts are short duration counts, either manual or temporary automated, taken for less than 24 consecutive hours. These counts are advantageous for collecting data from a greater variety of count sites within a large geographic extent. By increasing the number of counts at different locations within the

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[2] TMG, Section 4.1

[3] TMG, Section 4.2

network, researchers and practitioners are better able to understand spatial patterns across different geographies. The common use of volunteers for counting allows jurisdictions to collect large spatially diverse counts with little cost.

Mid-Length (temporary, automated, 24-hours to 1 month)

"Mid-length" counts are short duration counts lasting from 24-hours to 1 month collected continuously using temporary automated counters. These counts are typically taken from multiple locations in the network to compare and better understand what patterns are occurring at different short count sites. They are also useful in developing daily and weekly patterns.

Continuous (permanent, automated, 12+ months)

Continuous counts are collected 24 hours per day, 7 days per week by automated counters with the goal of collecting data for 365 days per year. Automated counters are often permanently installed at a location to capture continuous counts (Nordback et al. 2015). For motor vehicle count sites, (FHWA 2013) continuous count sites and permanent count sites are synonymous, but for non-motorized traffic continuous sites are usually, but not always, meant to be maintained permanently (Lindsey et al. 2015). In the TMG, a Continuous Count Station (CCS) may collect data for either all days of the year or for at least a seasonal collection (FHWA 2013)[4]. In some places, stations may be removed due to weather (e.g., snow) or road closures. Occasionally, gaps in the data may occur due to

[4] TMG, Section 1.2.2

special events detours, construction, and equipment failure (FHWA 2013)[5]. Researchers use continuous counts to analyze travel patterns by purpose, develop temporal adjustment factors, and estimate traffic volumes or annual average daily traffic for pedestrians and bicycles (AADNT) (Appendix A).

<u>Seasonal (temporary automated, 1 month to 11 months)</u>

"Seasonal" counts are continuous counts that range from 1 month to 11 months in length that gather data for at least one full season. These counts are collected using temporary automated counters such as passive infrared counters, for example. These are common in places where seasonal use due to weather or recreational travel patterns makes counts very low during off-season. For example, in places with snowy winters, such as in some mountain areas, jurisdictions may desire to protect their equipment from snow damage and remove it before winter sets in and covers bicycling trails with snow.

For the focus of this study, seasonal counts are not particularly useful for AADNT estimation, although can be used for seasonal AADNT estimation. Mid-length counts are sufficient for developing daily and weekly factors and continuous data for one full year are required for developing monthly factors. However, seasonal counts are good for seasonal annual daily traffic (SADT) computation and may be useful for recreational travel where bicycle and pedestrian use is completely or almost completely during a known season.

[5] TMG, Section 1.2.4

ERROR AND ACCURACY

Count Types

The TMG acknowledges that the technologies used for counting pedestrians and bicyclists are constantly evolving and the error rates associated with these technologies are not well known (FHWA 2013)[6]. Although it is not extensively discussed in this report, site selection may also factor into error rates. Selection criteria focuses on locations with the highest usage levels (i.e., times with lowest variability) or strategic locations of facility improvement, which may lead to bias estimates of overall usage.

Below is a discussion of error and accuracy associated with short duration and continuous count types.

Short Duration

Short duration manual and automated counts are affected by bias from seasonal and weekly variation, weather, and events (Ryus et al. 2014, FHWA 2013). Thus, determining when to conduct short duration counts is an important initial step in collecting reliable data, especially for 2-3 hour manual counts. These manual counts can be taken during the traditional peak hours in the morning or evening, off-peak hours, or during site-specific peak hours.

The TMG suggests a minimum of 7 days for automated counts and 4-6 hours for manual counts coinciding with the heaviest use (i.e., morning/evening for commute trips

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[6] TMG, Section 4.1

and mid-day for weekend/recreational trips)[7]. The TMG also suggests that 12 hour short-duration counts are preferable when resources are available, which allow for time-of-day use profiles to be calculated. If only manual counts are possible, the TMG encourages agencies to count at fewer locations for longer periods. Recent research confirms this guidance by demonstrating that average absolute percent error (AAPE) also known as the mean absolute percent error (MAPE) in AADNT estimation decreases as count duration increases (Voyt 2015, Nordback et al. 2013, El Esawey 2014, Budowski 2015, Figliozzi et al. 2014, Nordback & Sellinger 2014, El Esawey et al. 2013, Hankey et al. 2014).

Alternatively, the National Bicycle and Pedestrian Documentation Project (NBPDP) recommends short duration counts be taken a Tuesday, Wednesday, or Thursday during the traditional evening peak period (i.e., 5-7PM) for weekday counts and on Saturdays from noon to 2:00pm for weekend counts. The NBPDP encourages conducting these counts during a designated week in mid-May and mid-September. The NBPDP also suggests counting multi-hour periods between 1-3 times at every location on sequential days and weeks, depending on the approximate levels of use. Areas with high volumes (i.e., over 100 people/hour during mid-day periods) can typically be counted once for a weekday and weekend day, except when there is unusual activity or nearby land use (i.e., special events, irregular activity at sports facilities, etc.).

Additionally, recent research has explored estimation error for counting on different days of the week and different months or seasons. However, there is an apparent lack of research on estimation error for time-of-day. The estimation error associated with this day-of-year factoring method is also detailed in the discussion below.

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[7] TMG, Section 4.5.3

Nordback et al. (2013) provided estimates of error for various short duration count scenarios and offered recommendations for when and how long to count bicyclists for the most cost-effective accuracy in estimating annual average daily bicycle traffic (AADBT). The study found that counting during seasons with higher bicycle volumes and less variability result in better accuracy (e.g., May to October) (Nordback et al. 2013, Voyt 2015, El Esawey 2014). This period will vary with climate and location, but can be identified given one year of continuous count data. Nordback et al. found that to keep AADBT estimation error below 30% on average at least one week of count data was needed (Figure 2). The week of data also allows data users to accurately choose the correct peak periods and determine which travel patterns are common at the site in order to select appropriate daily and monthly adjustment factors. If collecting continuous count data for one week is not possible, conducting 12-hour counts on Tuesday, Wednesday, or Thursday provides sufficient information for indicating weekday traffic patterns and determining factor groups (commute vs non-commute patterns) within 30-46% MAPE. However, Nordback et al. also found that the season in which the short duration counts are collected can have a substantial impact on the accuracy. Even when only three peak hour counts were collected, error could be reduced to as little as 16% MAPE during the month of July. For this reason, further investigation into when short duration counts should be collected is warranted.

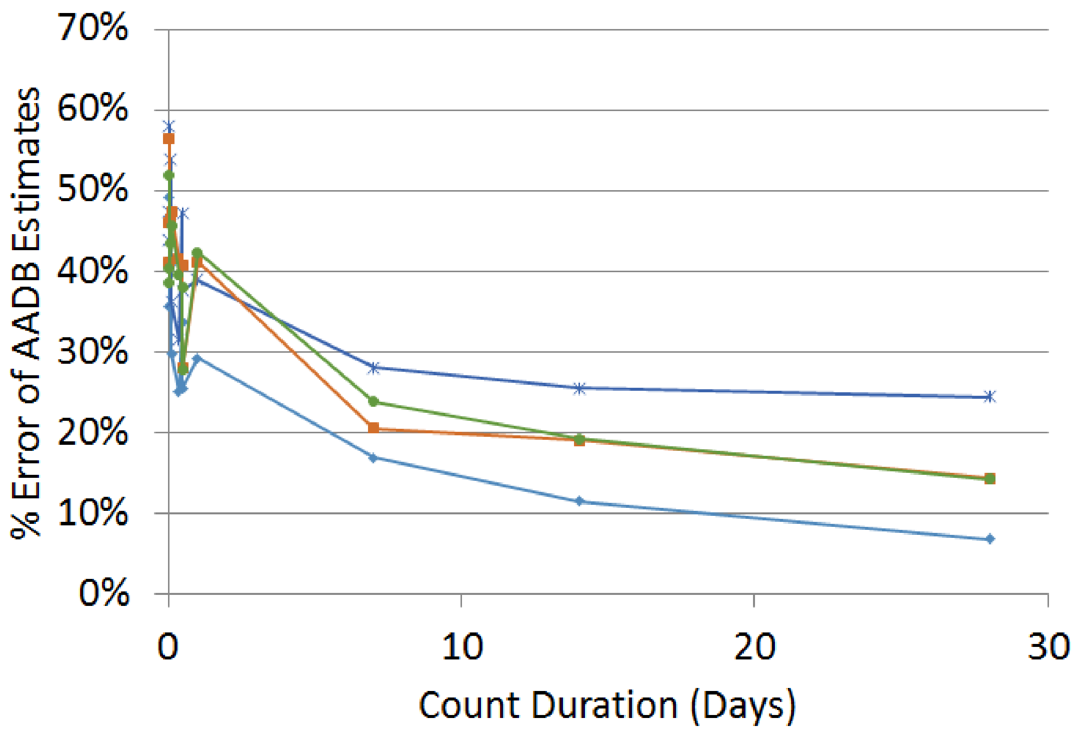


Figure 2 Error estimation as count duration increases.
Source: Nordback et al. 2013

Hankey et al. (2014) found that estimation error decreases as count duration increases, although only marginal gains in accuracy occur for counts longer than one week (Figure 3 and 4). In this Minneapolis study, the lowest error for AADNT estimation was found during summer months (or April through October). When using day-of-year factors, counting on consecutive days versus non-consecutive days results in minimal impact on estimation, although counting on consecutive days may help to reduce labor requirements (Figure 3). Additionally, this study found that day-of-year scaling factors have smaller error than day-of-week and month-of-year factors (Figure 4).

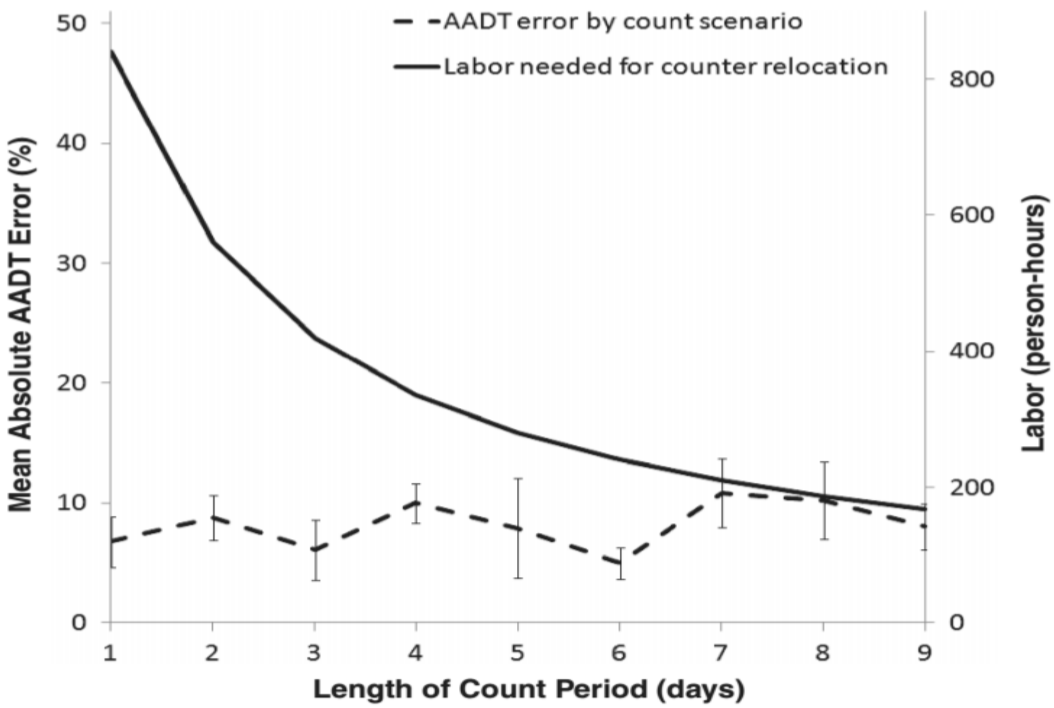


Figure 3 Mean Absolute AADNT estimation error and person-hours required to relocated monitors for each short-duration count scenario (bars = standard error).
Source: Hankey et al. 2014

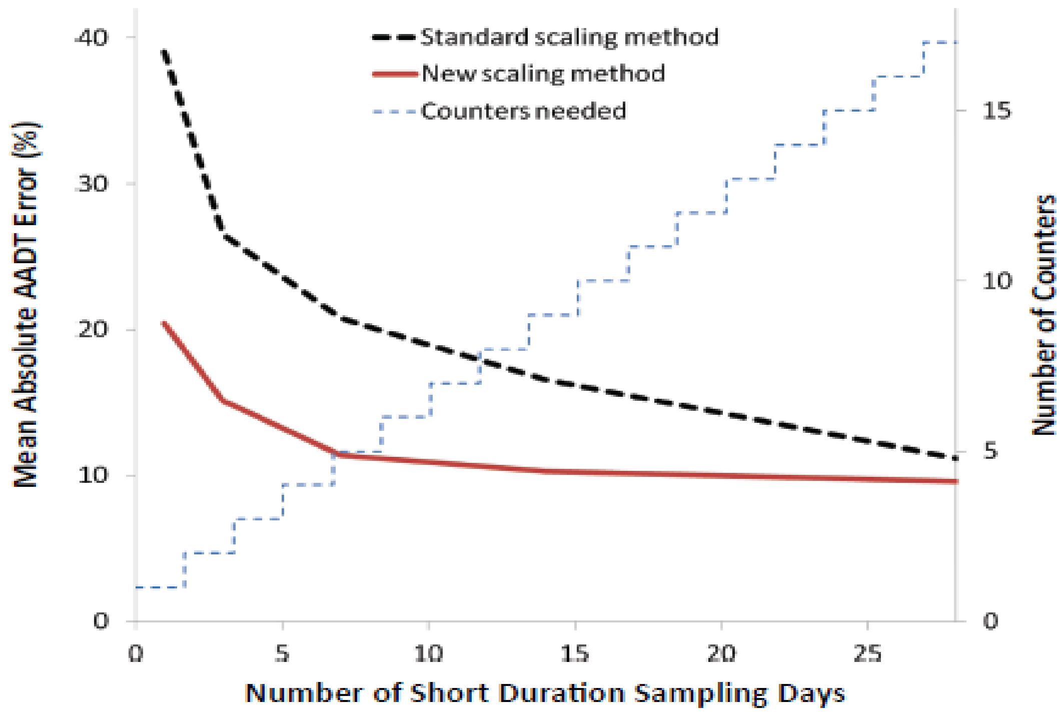


Figure 4 Mean absolute AADNT estimating error using standard (black dashed line) and new (red solid line) scaling methods (number of counters needed to complete design scenario (7-month sampling campaign) is denoted in staircase-shaped plot).

Source: Hankey et al. 2014

Nosal et al. (2014) found that disaggregate factors (i.e., day-of-year factors) had lowest estimation error (11% AAPE for weekdays) in comparison to the AASHTO method (traditional expansion factoring method), day-of-month method, and weather-based method using data from Montreal (Figure 5). This study determined that error and accuracy does not vary widely across different weekdays. It also found that Thursdays consistently produced the lowest AAPE, although the researchers concluded that this finding may only be applicable to conditions in Montreal or to the specific set of counters (Figure 5). Further, more accurate AADBT estimates were calculated using counts from summer months, which reinforces previous research and common data collection methods (Figure 6).

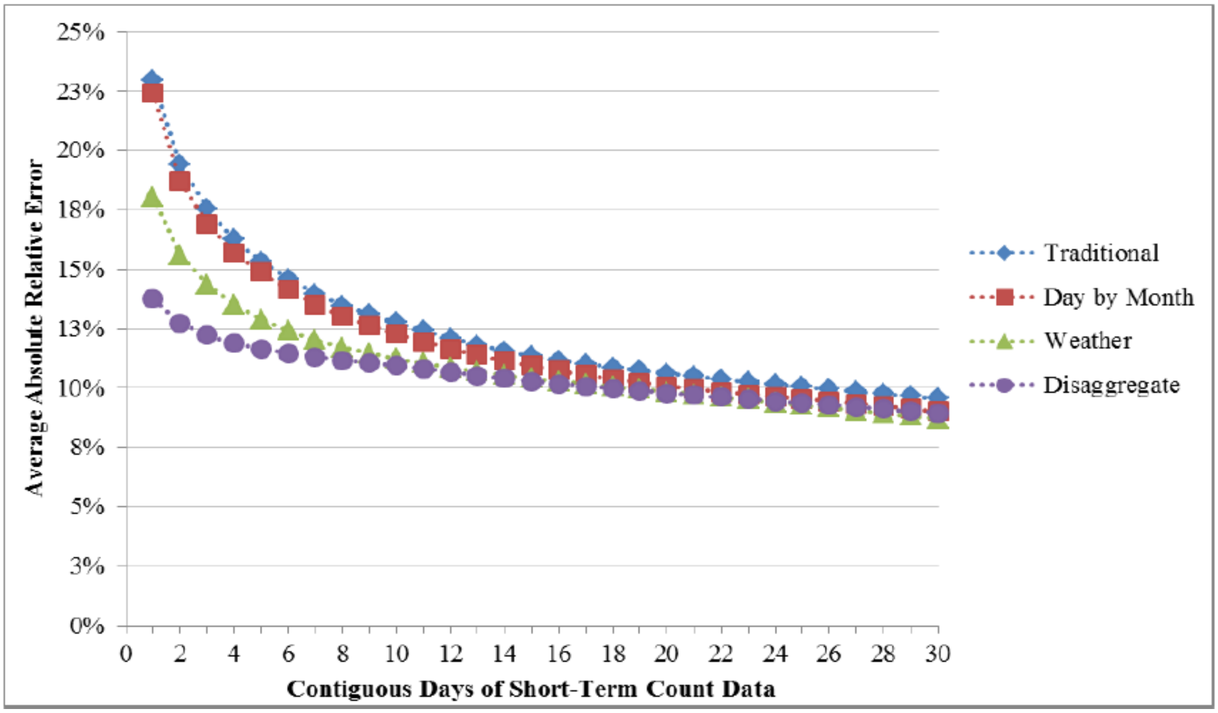


Figure 5 Effect of duration of short-term count on AARE by AADBT estimation method.

Source: Nosal et al. 2014.

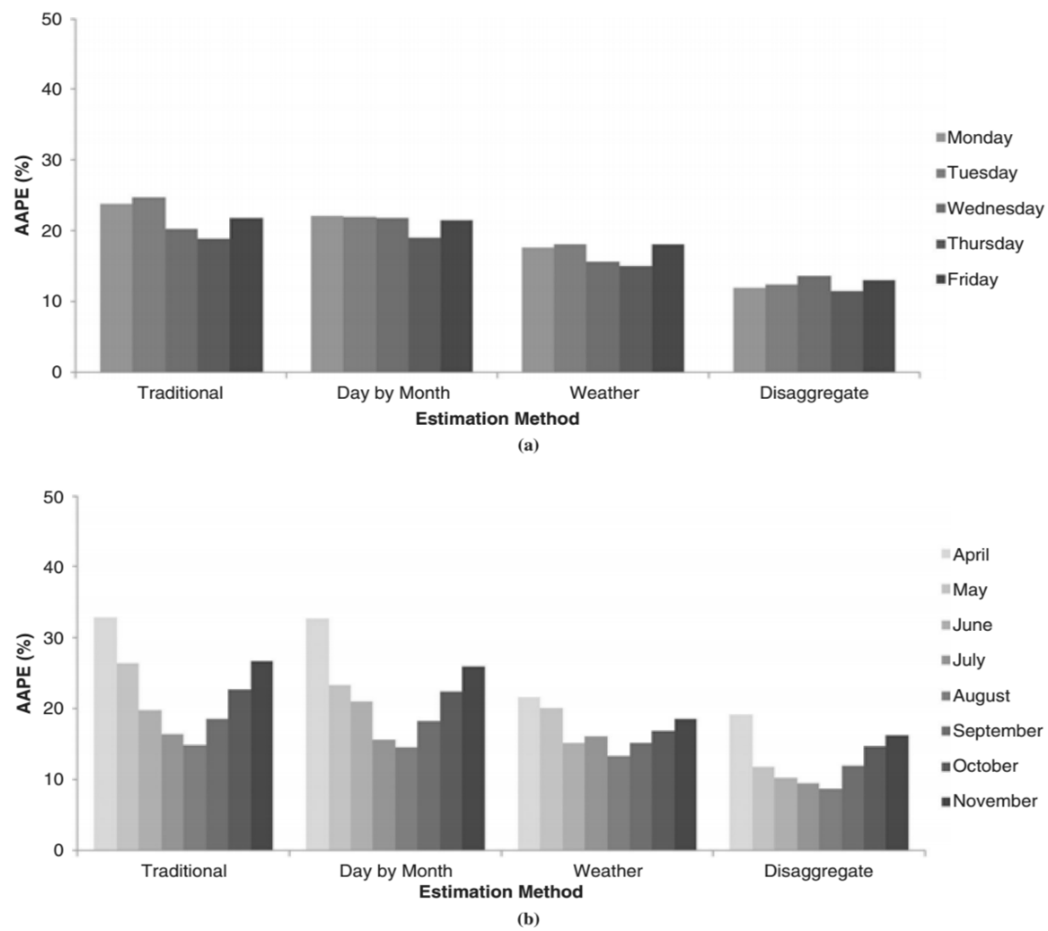


Figure 6 Effect of time of short-term count on AAPE value, by AADBT estimation method: (a) day of week and (b) month.
S*ource: Nosal et al. 2014.*

El Esawey (2016) supported that day-of-year factors were best suited for AADT estimation (17.5% MAPE). The study used data from Vancouver, British Columbia, and found that using count data from weekdays were better for estimation accuracy than weekends (e.g., average MAPE of 13.1% on weekdays vs 28.6% on weekends).

El Esawey (2014) used 2010 data and found that the lowest estimation error for estimating AADBT was an average MAPE of 4% when applying monthly and daily factors to 24-hour short duration counts. Applying the same 2010 data to estimate AADBT values for 2009 and 2011 shows the temporal transferability of monthly factors (MAPE 15% and

12%, respectively). The study found that summer months consistently provided lowest error (May-August), with the lowest MAPE of 7% in June. Further, MAPE estimated using AADBTs were relatively low when daily bicycle volume data from weekdays were used from July or August. The study recommends that Tuesday through Friday data in July or August be collected for estimation.

El Esawey et al. (2013) found that MAPE for estimating monthly average daily bicyclists was relatively low for weekdays (specifically Tuesdays and Wednesdays) (Table 1) and could be as low as 6-8% for Mondays through Thursdays in August. The study found the lowest MAPE in June, July, August (lowest was 10-16% in August) and highest MAPE in October, November, and December.

Table 1 MAPE Error for Each Day of Week

Day of week	Group_1 (%)	Group_2 (%)	Group_3 (%)	Group_4 (%)	Group_5 (%)	Group_6 (%)
Sunday	27	28	23	25	28	29
Monday	24	22	19	19	26	24
Tuesday	17	21	14	18	18	22
Wednesday	18	23	13	19	20	25
Thursday	23	23	18	18	24	25
Friday	23	22	17	19	24	23
Saturday	30	32	24	25	31	32
Average	23	24	18	21	24	26

Source: El Esawey et al. 2013

Figliozzi et al. (2014) determined from a year of continuous data from Portland, Oregon that days in the middle of the week (Tuesday-Friday) resulted in the lowest MAPE (14-16%) (Table 2). This data was taken from the Hawthorne Bridge, which demonstrates a commuter pattern to and from downtown Portland. Sundays and Mondays show a high

MAPE (≈25%), which is attributed to differences in traffic volumes on weekends and several holidays that fall on Mondays.

Table 2 MAPE by Day of Week

Day of week	MAPE (%)	Average DOW traffic
Sunday	25.4	2,609
Monday	25.6	4,982
Tuesday	15.8	5,354
Wednesday	14.4	5,186
Thursday	16.6	5,272
Friday	15.4	4,796
Saturday	19.5	2,885

Source: Figliozzi et al. 2014

Budowski (2015) found that using 2-hour count durations to estimate AADBT in Winnipeg resulted in 12-23% MAPE, and that the improvement in error for using 3- or 4-hour counts did not warrant the use of additional resources. This study determined that the best time of day to conduct short duration counts was influenced by the observed traffic pattern (e.g., commuter, post-secondary commuter, recreational, mixed). For segments classified as commuter, the best time was from 3-5PM, 4-6PM for recreational and mixed travel patterns (Figure 7). The study also confirmed the findings from Nordback et al. (2013) that one week of counts is optimal for short duration counts (7 of 8 study sites with <10% MAPE) (Figure 8). In addition, the study confirmed the findings of Nosal et al. 2014 and Hankey et al. 2014 that day-of-year factors yield lower AADNT estimation error than monthly and daily factors.

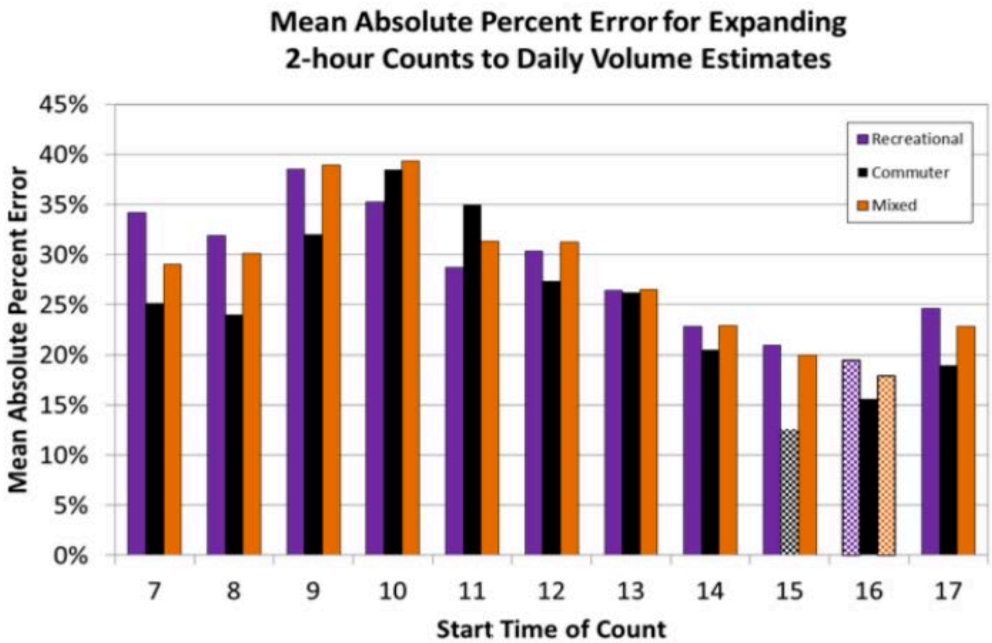
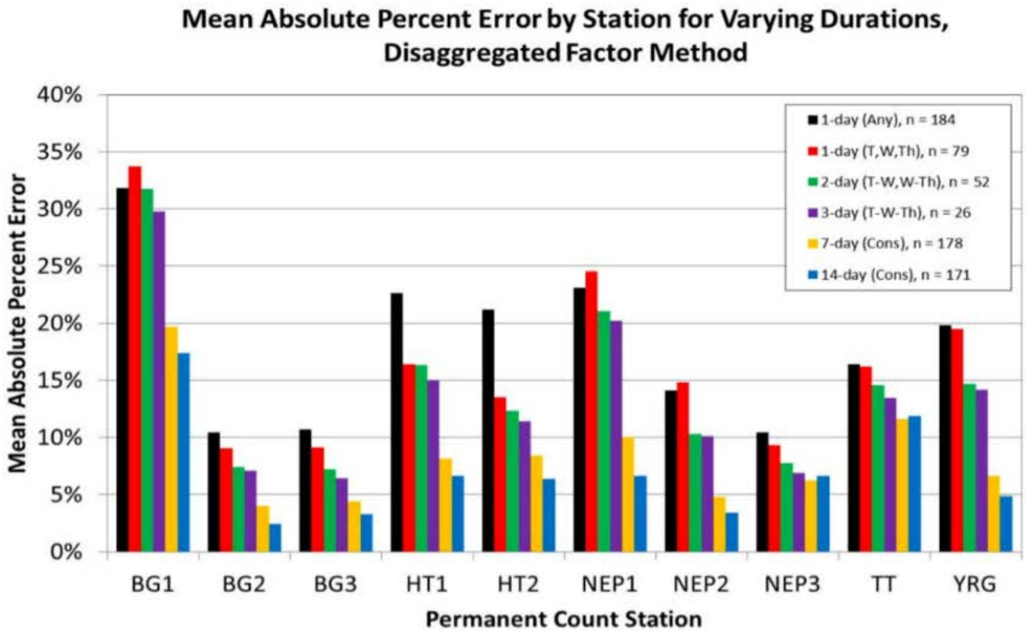


Figure 7 Hatched markings indicate the best times to start a 2-hour short duration count using data collected in Winnipeg, MB.
Source: Budowski 2015.



	1-day (Any)	1-day (T,W,Th)	2-day (TW,WTh)	3-day (TWTh)	7-day (Cons)	14-day (Cons)
BG1	32%	34%	32%	30%	20%	17%
BG2	10%	9%	7%	7%	4%	2%
BG3	11%	9%	7%	6%	4%	3%
HT1	23%	16%	16%	15%	8%	7%
HT2	21%	13%	12%	11%	8%	6%
NEP1	23%	25%	21%	20%	10%	7%
NEP2	14%	15%	10%	10%	5%	3%
NEP3	10%	9%	8%	7%	6%	7%
TT	16%	16%	15%	13%	12%	12%
YRG	20%	19%	15%	14%	7%	5%

Figure 5-8: Mean absolute percent error for calculating SADT when using the Disaggregated Factor Method for CCS in Winnipeg, MB, May to October, 2014.

Figure 8 Mean absolute percent error for calculating SADT when using the Disaggregated Factor Method for CCS in Winnipeg, MB, May to October, 2014.
Source: Budowski 2015.

Continuous

In contrast to short duration counts, continuous counts are collected year-round and are thus not affected by seasonality, unusual weather patterns, or special events. Although automated counts (temporary or permanent) are not affected by human bias, they may have significant biases due to occlusion, improper installation, and other systematic errors in relation to the site, traffic flow, and specific technology used (Ryus et al. 2014).

Data gaps may occur due to reconstruction, road closures, or equipment malfunction (Voyt 2015). A jurisdiction must establish a guideline for how much missing data compromises the data quality where it cannot be used without acceptable error (e.g., data is required from all 12 months to avoid seasonal biases). It is common practice to accept less than a year of daily volumes in calculating daily and monthly factors under the assumption that the equivalent of one month of missing data will not affect the true value of AADBT (El Esawey 2014).

Counting Methods

Manual

While manual counts tend to be more reliable than automated counts, they do not come without inaccuracies (Greene-Roesel et al. 2008). Since manual counts are often taken by volunteers, they may be subject to counter bias. This bias can be reduced through training of counters and careful monitoring of data sheets to identify incomplete data or potential errors due to misunderstanding instructions or fatigue (Jones et al. 2010). Another method to improve accuracy of manual counts is to reduce the number of characteristics being recorded by the observer (Diogenes et al. 2007, Greene-Roesel et al. 2008).

Ryus et al. (2014, 67-68) conducted a thorough literature review of pedestrian and bicycle data collection methods and technologies. In this review, the authors reported that accuracy for manual counts is highly dependent on the data collection behavior, which improves with training and decreases with count duration. Manual counts through smartphone applications have yet to be rigorously tested for accuracy. Manual counts using counting devices have different accuracy concerns depending on the different counters.

Diogenes et al. (2007) found that while video technology may be the most accurate manual count method, it is also the most expensive method given the need for specific technology and time to manually code each hour of video.

Automated

Research on accuracy and error estimation of various automated technologies are reviewed in recent research by Ryus et al. (2014), Hyde-Wright et al. (2014), Brosnan et al. (2015), Griffin et al. (2014), Nordback et al. (2013), Nosal et al. (2014), Hankey et al. (2014), and Hjelkrem & Giaever (2009).

Visual recognition software is an emerging automated technology that may be promising in the future, although more research is needed to investigate error and accuracy. Again, this type of video technology is expensive. While it is generally possible to calibrate the technology to accurately count bicycles and pedestrians at a specific site, some have found it difficult to move and re-calibrate equipment at multiple count locations.

Turner and Lasley (2013) discussed quality assurance principles and applications for reviewing counts from automated counters, including three key principles:

1. Quality assurance begins before you start collecting data

2. “Acceptable” data quality is determined by its use

3. Different data quality measures quantify different quality dimensions

The researchers recommended the creation of uniform accuracy evaluation procedures for pedestrian and bicycle counters and the adaptation of automated validity criteria that is specific to non-motorized traffic (similar to that already present in motorized traffic databases). Additionally, targeted visual review by trained staff is very valuable in assessing the quality of suspect data that might have passed through the automated quality checks unnoticed.

SHORT DURATION COUNT TYPES

Manual counting programs, which are often collected at intersections, are by far the most common. NCHRP 797 reports that of those agencies surveyed who count pedestrians, 93% do so manually and of those who count bicycles, 87% do so manually (Ryus et al. 2014). For this reason, optimizing and providing specific guidance for such programs is needed and would lead to higher quality data.

For motor vehicles short duration counts are collected on Tuesday, Wednesday, and Thursdays for 48 hours (FHWA 2013). Previous studies have found that 1 week of short duration bicycle counts is a good time frame for counting bicycling because there is not much reduction in error for longer count periods and having at least a week allows data users to see the travel patterns by day of week and by hour of the day (Nordback et al. 2013, Nosal et al. 2014, Hankey et al. 2014). While Nordback identified that AADBT estimation error could be lower than 20% with only three hours of count data if the data was collected in a month with low variability and high volume, further research is needed to understand if that applies to other data sets and to investigate which hours are most advantageous for reducing AADBT estimation for which travel patterns. Further, what are the most accurate months and days on which to count? How can a manual count program minimize AADNT estimation error and how much error is expected even with the optimal approach? These questions are addressed in this study.

State of the Practice

To better understand the state of practice for bike and pedestrian counting, the research team conducted a review of practice literature for guidance and interviewed practitioners in communities throughout Washington State and Portland. For the interviews, the extent of bike and pedestrian counting programs ranged from limited and short-term to extensive, continuous counting.

Practice Guidance

Guidebooks on bike and pedestrian counting are helpful in determining what practices are recommended for and commonly used by agencies and organizations for short duration count programs. The guidebooks reviewed provided some guidance on what counting technologies are recommended for short duration counts, and the timing and length of the count timeframe for short duration counts (Appendix B). Most of the literature recommends manual counts, pneumatic tubes, and active and passive infrared counting technologies. Additionally, most of the guidance literature agreed that generally spring and fall months were preferable because of higher, more consistent activity levels. Ryus et al. (2014) found that collecting short duration counts from different time periods may also be helpful in improving estimation accuracy when extrapolating AADNT using these data. In terms of the time length for short duration counts, 1- to 3-h counts are most common for manual counts (e.g., counts conducted by local jurisdictions in Colorado and Minnesota) and a minimum of 1-2 weeks for automated counts (e.g., Colorado DOT counts). Still, some agencies have yet to determine a minimum recommended length for short duration counts, but have research efforts underway to answer this question (e.g., Minnesota DOT and Oregon DOT)(Lindsey et al. 2014).

For the Washington State Bicycle and Pedestrian Documentation Project (WSDPDP), volunteers collect manual counts in late September or early October, which coincides with peak periods for walking and bicycle for work and school-related trips in Washington State. The counts are conducted on Tuesday, Wednesday, and Thursday during both the morning (7-9AM) and afternoon (4-6PM) peak travel times. These peak periods were selected because they typically have the highest volumes of pedestrian and bicycling use (Clinkscales 2015). In order to reduce the chance of weather-bias and offer scheduling flexibility, volunteers can choose to collect counts at each location on one of the three days and the morning and afternoon counts can occur on different days. While the NBPDP recommends Saturday counts, the WSBPDP does not currently collect these data.

The NBPDP recommends 2-hour manual counts conducted in mid-May and mid-September during the morning and afternoon peak-commute periods on consecutive weekdays (Tuesday, Wednesday, Thursday). A Saturday count typically precedes or follows the official count dates. If resources are limited, the afternoon peak on a weekday in mid-September is the preferred time to count. Twelve hour counts are also suggested for both a weekday and a Saturday from 7AM-7PM.

In a guidebook recently developed for the Utah Department of Transportation, Burbidge & Marriott (2016) recommended that if resources are limited and counts can only be conducted once per year that it is best to do so in mid-September to align with the NBPDP counts. The guidebook provided guidance on when to count on weekdays and weekends for peak-hour counts and 12-hour counts. Weekday peak-hour counts should be conducted from 7-9AM and 4-6PM on consecutive weekdays (Tuesday, Wednesday, Thursday). Weekday 12-hour counts should occur from 7AM-7PM, choosing one weekday and breaking the duration into shifts to avoid fatigue. For weekends, peak-hour counts on Saturday from 10AM-2PM and 12-hour counts on Saturday from 7AM-7PM are suggested. At a minimum, count durations on weekdays should be 2 hours and 3 hours on weekends.

Agencies in Seattle, Portland, and Victoria, BC also choose to count during the afternoon peak travel times on weekdays (Tuesday, Wednesday, Thursday) following the NBPDP methodology (Table 3). Seattle Department of Transportation (SDOT) has conducted counts quarterly and is the only agency to conduct 2-hour counts during the off-peak from 10AM-noon on weekdays. Portland Bureau of Transportation (PBOT) employs volunteers to count from June through September on good weather days, mid-week (Tuesday, Wednesday, Thursday) either during the morning (7-9AM) or afternoon (4-6PM) peak times. Similarly for trail counts in the Portland Metro area, volunteers are directed to conduct counts during the afternoon peak from 5-7PM on a weekday (Tuesday, Wednesday, Thursday) or on Saturday from 9-11am. In Victoria, BC, the Capitol Regional District also conducts quarterly counts during weekday morning (7-9AM) and afternoon (3-6PM) peak travel times.

Table 3 Recommended Times and Days for Conducting Short Duration Counts

Jurisdiction or Organization	Time	DOW	Month(s) or Season(s) Conducted
Washington State National Bike and Pedestrian Documentation Project [WSDOT, Cascade Bicycle Club]	7-9AM 4-6PM	T,W,Th	Sept 29-Oct 1 for 2015
National Bicycle and Pedestrian Documentation Project (NBPDP) [Alta Planning and Design, Institute of Transportation Engineers (ITE) Pedestrian and Bicycle Council]	**5-7PM**	**Weekday (Choose one T,W,Th)**	Mid-May and mid-Sept May 16-22 and Sept 13-18 for 2016
	12-2PM	Saturday	
	7AM-7PM	Weekday (Choose one T,W,Th)	
	7AM-7PM	Saturday	
Seattle, WA Manual Count Program [Seattle Department of Transportation (SDOT), NBPDP]	10AM-noon (off-peak)	Weekday (Choose one T,W,Th)	Jan, May, July, Sept
	5-7PM	Weekday (Choose one T,W,Th)	
	12-2PM	Saturday	
Portland, OR Manual Bike Counts [Portland Bureau of Transportation (PBOT)]	**4-6PM**	**Weekday (Choose one T,W,Th)**	June-Sept, excluding week of 4th of July
	7-9AM	Weekday (Choose one T,W,Th)	
Portland, OR Trail Counts [Metro, PBOT, NBPDP]	**5-7PM**	**Weekday (Choose one T,W,Th)**	Mid-Sept Sept 15-20 for 2015
	9-11AM	Saturday or Sunday	
Vancouver, BC Pedestrian Volume and Opinion Survey [City of Vancouver]	10AM-6PM, excluding 2-3PM	Weekdays	May-early June and Sept-Oct for 2013
Victoria, BC Regional Cycling Counts [Capitol Regional District, NBPDP]	7-9AM	Weekday (Choose one T,W,Th)	Jan, May, July, Oct
	3-6PM	Weekday (Choose one T,W,Th)	

Note: Bold indicates preferred times.

Jurisdiction or Organization	Time	DOW	Month(s) or Season(s) Conducted
Utah [Active Planning, Utah Department of Transportation]	7-9AM	Consecutive weekdays (T,W,Th)	Spring and Fall. If resources are limited and can only count once per year, do so in mid-Sept to coincide with NBPDP guidance.
	4-6PM	Consecutive weekdays (T,W,Th)	
	7AM-7PM	Weekday (Choose one T,W,Th)	
	10AM-2PM	Saturday	
	7AM-7PM	Saturday	
Minnesota [Minneapolis Department of Public Works, Transit for Livable Communities, NBPDP, Minnesota Department of Natural Resources (DNR), the Metropolitan Council, the Three Rivers Park District, and the Minneapolis Park and Recreation Board]	4-6PM	Weekday (Choose one T,W,Th)	Early to mid-Sept
	-	Saturday	
	Other times important locally	Other days important locally	

Note: Bold indicates preferred times.

The majority of jurisdictions reviewed in Table 4 agree that 2-hour counts should be conducted on weekday afternoon peak times (Tuesday, Wednesday, Thursday), although some choose to count from 4-6PM and others from 5-7PM. Four of the jurisdictions also suggested counting on weekdays during the morning peak travel times from 7-9AM (Tuesday, Wednesday, Thursday). Five of the nine jurisdictions suggest counting on Saturday either midday from 12-2PM (NBPDP; SDOT), during the morning peak from 9-11AM (Portland, OR Trail Counts), or from 10AM-2PM (Utah DOT). Overall, September is the most commonly suggested month for conducting counts amongst the reviewed jurisdictions, followed by May and June.

Washington

In Washington, municipality transportation planners and engineers, parks and recreation departments, and non-profits were contacted to ensure that every organization that may be involved in counting programs was reached out to (See Appendix C for complete contact list). People in 10 communities were interviewed following this project's questionnaire (Appendix D) to understand the state of the practice in bicycle and pedestrian counting. Bicycle and pedestrian counting programs range from temporary short-term, mid-term, and seasonal, to permanent continuous counting. For example, the City of Olympia has been conducting mid-term counts since 2008, three times a year for seven days. They have accrued extensive data and have found the value in counting. The City of Redmond has an extensive seasonal counting program. They installed 18 temporary counters that operated from March-June 2015. The City of Tacoma has three permanent, continuous counters where they have been collecting data since January 2015. The City of Seattle operated 10 permanent, continuous counters, with one installed as early as 2009. Finally, looking into the future, the City of Bellevue is in the process of securing funding to install 27 permanent, continuous counters over the next two years. For further information, see Table 4 below.

Communities throughout Washington are eager to conduct bicycle and pedestrian counts. However, not all have the funding or resources to do so. WSDOT has been able to fill this void and support short and long-term bicycle and pedestrian counting in Washington communities. In 2008, WSDOT created the Washington State Bicycle and Pedestrian Documentation Project. The inspiration behind this program was a goal set by the Washington State Bicycle Facilities and Pedestrian Walkways Plan to double the amount of people walking and biking by 2027. One of the key performance metrics to monitor that goal was bicycle and pedestrian counts. Since 2008, short-term counts are conducted every year in late September or early October. As of 2012, 38 communities participate in the program and eight of the 10 communities we interviewed are participating in the Washington State Bicycle and Pedestrian Documentation Project.

In addition to short-term counting, WSDOT also monitors permanent, continuous bicycle and pedestrian counters at 15 locations in Washington. These counters are located several cities, including Bainbridge Island, Bellevue, East Wenatchee, Olympia, Redmond, Seattle, and Spokane. WSDOT uses Eco-Counter counting equipment, with passive infrared, inductive loops, or a combination of both technologies. These counters have been installed from 2011-2016.

Table 4 Overview of Bike and Pedestrian Count Programs in Washington as of 2016

City	Count Types	Short Duration Participates in WSNBPDP	Continuous # of Non-WSDOT Counters	# of WSDOT Counters	Notes for Count Programs	Notes on Accuracy
Bellevue	Short Continuous	Y	0	2	Securing funding to install 27 permanent counters over the next two years.	*
Bellingham	Short	Y	0	Pending	Working with Washington Bikes and WSDOT to install permanent counters within the next year.	N/A
Mount Vernon	Short	Y	8	0	Had permanent counters in seven locations for eight years along trails in Mt. Vernon. However, permanent counting ended in 2013.	None given
Olympia	Short Mid Continuous	Y	0	1	Mid-term counting since 2008. Conducted three times a year for seven days.	*
Redmond	Short Seasonal Continuous	Y	0	1	Installed seasonal counters at 19 locations to count from March-June 2015.	Note: there are gaps in the data due to monitor memory maxing out and some false counts due to vegetation breaking the infrared beam.. - David Shaw *
Richland	N/A	N	0	0	No bicycle or pedestrian count program	N/A
Seattle	Short Continuous	Y	10	2	City of Seattle operates counters that were installed 2009-2016.	None given

City	Count Types	Short Duration Participates in WSNBPDP	Continuous # of Non-WSDOT Counters	# of WSDOT Counters	Notes for Count Programs	Notes on Accuracy
Spokane	Short Seasonal Continuous	Y	1	7	Washington Parks operates 1 continuous counter, which was installed in February 2014.	*
Tacoma	Short Continuous	Y	3	**	Operates three permanent, continuous counters, which were installed in January 2015.	There are some anomalies in the data … if there are some instances where the numbers do not make sense, it was likely that the Counter was acting up (I think 1 day in particular had an unreasonable high count). - Emily Campbell
Vancouver	Short	Y	0	0	-	N/A

** We received validation data from Ken Lakey (WSDOT) for permanent count locations at the Bellevue bike trail (Bellevue), Ben Burr Trail (Spokane), Centennial Trail (Snohomish County), Sammamish Trail (Redmond), Wenatchee Apple Capitol Loop (Wenatchee), and Woodland Trail-Chehalis Trail (Olympia).*

***Unable to determine given available information.*

Conclusion

In order to study the error for estimating AADNT from short duration counts, this analysis will use data from permanent counters and pretend that only a limited sample of one hour was collected. In this way both the actual and estimated AADNT can be estimated.

DATA DESCRIPTION

To study error for WSDOT specifically, continuous count data from the state of Washington was desired. Since that was limited as documented in Table 5, data from the the nearby city of Portland, Oregon was also included. A parallel FHWA project was also being conducted by the project team on a similar research question looking at data from three additional cities: Arlington, Virginia; San Diego, California; and Boulder, Colorado. Since these data were already formatted and prepared for study little additional work was required to include them in the study. Thus, this analysis includes data from 6 cities and 146 stations, a more extensive dataset than any previous analysis of non-motorized traffic data of this type.

Continuous count data were obtained from Arlington, Boulder, Mt. Vernon, Portland, San Diego, and Seattle from 2002 to 2016. To determine actual AADNT for a given year for a given site, at least one full 24-hours of count data representing each day-of-the-week in every month were needed. From this data set, 146 locations had sufficient data for the analysis, totaling 1,461,604 hourly observations. A data summary is presented in Table 5.

Table 5 Summary of Available Data

Community	Time Period	Type of Counters	Number of Sites Counted: Bikes Only	Number of Sites Counted: Peds Only	Number of Sites Counted: Bike-Ped Combined	Total # of Sites
Arlington, VA	2012-2016	Passive infrared and inductive loop combination	18	11	-	29
Boulder, CO	2002, 2004, 2007-2008, 2010-2012, 2016	Inductive loops	17	-	-	17
Mt. Vernon, WA	2009-2011	Passive infrared	-	-	6	6
Portland, OR	2009-2015	Passive infrared, inductive loops, pneumatic tubes	9	8	15	32
San Diego, CA	2013-2016	Passive infrared and inductive loop combination	33	13	-	46
Seattle, WA	2014-2016	Passive infrared and inductive loop combination, pneumatic tubes	9	7	-	16
Total			86	21	39	146

Note: "–" denotes no data of a given type.

SEATTLE, WA

The Seattle data was provided by Washington State Department of Transportation (WSDOT) and the Seattle Department of Transportation (SDOT).

Location and Facility Type

WSDOT has two counters in Seattle located at the University of Washington Transit Center (North and South), which were installed in February and March 2016.

SDOT maintains 12 counters, which are located on multi-use trails, protected bike lanes, neighborhood greenways, the Fremont Bridge and SW Spokane Street.

Table 6 Seattle Bicycle and Pedestrian Continuous Count Locations

Facility Type	Facility Name	Mode
Multi-Use Trails	Elliott Bay Trail in Myrtle Edward Park	Bicycles and pedestrians separately
	Burke-Gilman Trail north of NE 70th St.	Bicycles and pedestrians separately
	Chief Seattle Trail north of S Thistle St.	Bicycles and pedestrians separately
	Mountains to the Sound Trail west of the I-90 floating bridge	Bicycles and pedestrians separately
Protected Bike Lanes	Broadway between Pike St. and Union St.	Bicycles only
	2nd Ave. south of Madison	Bicycles only
	Linden Ave. N south of N 135th St.	Bicycles only
Neighborhood Greenways	26th Ave. Southwest at SW Oregon St. in Delridge	Bicycles only
	39th Ave. Northeast at NE 62nd St. in Wedgewood	Bicycles only
	NW 58th St. at 22nd Ave. Northwest in Ballard	Bicycles only
Bridges	Fremont Bridge	Bicycles only
	SW Spokane St. Bridge	Bicycles only

Source: Author's analysis of Seattle Department of Transportation information

Table 7 Seattle Count Sites Used in Analysis by Mode and AADNT

			AADNT			
ID	Site	Mode	2013	2014	2015	2016
172	SEA-26th-Ave-SW-Greenway-S-of-SW-Oregon-St	bicycle				80
173	SEA-39th-Ave-NE-Greenway-south-of-NE-62nd-St	bicycle		246	257	221
174	SEA-520-Trail-South-of-NE-23rd-Pl	bicycle				117
175	SEA-520-Trail-South-of-NE-23rd-Pl	pedestrian				148
176	SEA-Broadway-btw-Pike-St-and-Pine-St	bicycle		348	289	313
177	SEA-Burke-Gilman-Trail-North-of-NE-70-Ave	bicycle		1,104	1,113	1,108
178	SEA-Burke-Gilman-Trail-North-of-NE-70-Ave	pedestrian		219	4,568	1,369
179	SEA-Chief-Sealth-Trail-North-of-Thistle-St	bicycle		19	39	
180	SEA-Chief-Sealth-Trail-North-of-Thistle-St	pedestrian		53	38	
181	SEA-Elliot-Bay-Trail-bw-Bay-St-and-Broad-St	bicycle		1,143		1,123
182	SEA-Elliot-Bay-Trail-bw-Bay-St-and-Broad-St	pedestrian		2,287		2,414
183	SEA-Fremont-Bridge	bicycle	2,531	2,742	2,683	2,685
184	SEA-I-90-Trail-S-of-SE-34th-bw-108th-109th	bicycle				543
185	SEA-I-90-Trail-S-of-SE-34th-bw-108th-109th	pedestrian				117
186	SEA-MTS-Trail-West-of-I-90-Bridge	bicycle		676	687	
187	SEA-MTS-Trail-West-of-I-90-Bridge	pedestrian		205	204	
188	SEA-NW-58th-St-Greenway-E-of-22nd-Ave	bicycle		567	173	
189	SEA-Sammamish-Trail-bw-90th-and-85th-E-river	bicycle				911
190	SEA-Sammamish-Trail-bw-90th-and-85th-E-river	pedestrian				760

Figure 9 Map of SDOT Counters
Source: SDOT

Equipment Type

Both SDOT and WSDOT utilize Eco-Counter technologies for collecting data in Seattle. WSDOT uses the Urban MULTI counter, which differentiates between pedestrians and bicyclists using a combination of passive infrared (PYRO model) and an inductive loop (ZELT model).

SDOT collects non-motorized traffic counts using inductive loops, infrared, and pneumatic tubes. SDOT uses pneumatic tubes along three neighborhood greenways to count bicycles bi-directionally. At two locations with protected bike lanes, SDOT continuously counts bikes bi-directionally using pneumatic tubes. On multi-use trails, SDOT counts a mix of bicycles and pedestrians using inductive loops and infrared counters. These counters collect bi-directional traffic data for bicycles and pedestrians at four locations. At the Fremont Bridge and SW Spokane Street, Eco-Totem counters are used to count bicyclists, which combine inductive loops (ZELT) with a totem display. The funding and installation of these counters were supported by SDOT and the Cascade Bicycle Club.

Figure 10 UW Transit Center Urban MULTI.
Source: WSDOT

Figure 11 Fremont Bridge Eco-Totem
Source: SDOT

Time Period

Data was provided from 2013 to 2016. The data from automated feeds updates at 5am every morning to Eco-Counter's website to allow for the continuous data to be accessible to the present day.

Specific Quality Control Issues

The accuracy of the detectors in Seattle have not been confirmed by SDOT or WSDOT and neither agency has provided accuracy adjustment factors. The data was quality checked for unusual patterns, spikes, zeroes, and unusually low counts using graphs of the total daily volume over time.

MT. VERNON AND SKAGIT COUNTY, WA

From 2008-2012, Skagit Healthy Communities collected continuous count data from 13 sites in Mount Vernon and Skagit County. This data was provided in per vehicle format, which includes a timestamp and direction for each pedestrian, bicyclist, or other warm body which enters the detection zone. The data was processed in Excel by binning the counts by hour and combining both flow directions. There is no evidence to suggest that these data are reliable by direction. There was no documentation of counter validation or testing.

Location and Facility Type

Ten count sites had continuous count data for a full calendar year. Nine of the sites were located on multi-use trails and one site was located on a shared sidewalk on the Berentson Bridge adjacent to SR-20.

Table 8 Mt. Vernon Count Sites, 2008-2012

Facility Name	Available Data Range
Berentson (Swinomish) Bridge	2/25/2010 - 5/29/2012
Kulshan Creek Trail (18th St West Side)	1/11/2008 - 2/27/2009, 7/29/2009 - 7/4/2012
Kulshan Creek Trail (by the middle school)	2/7/2008 - 1/24/2009
Maddox Creek	7/29/2009 - 7/22/2011*
Padilla Bay Shore Trail (South Gate)	7/30/2009 - 11/26/2010, 5/13/2011 - 5/21/2012
Padilla Bay Shore Trail (North Gate)	7/30/2009 - 2/7/2012
Port of Skagit Trail (Crosswinds Drive)	7/30/2009 - 2/9/2011
Port of Skagit Trail (Higgins Airport and Ovenell)	1/24/2009 - 3/10/2011*
Port of Skagit Trail (Josh Wilson and HAR PORT)	1/24/2009 - 11/21/2010
Port of Skagit Trail (Ovenell Rd and FTM PO)	1/24/2009 - 5/19/2012
Skagit Playfields (Martin Road West)	4/7/2009 - 3/22/2011
Skagit Playfields (Martin Road East)	1/10/2008 - 8/16/2011*
Trumpeter Trail (Off Division)	7/29/2009 - 7/7/2010

**Cannot use for analysis because there is not a full calendar year of data currently available*

Table 9 Mt. Vernon Count Sites Used in Analysis by AADNT

		AADNT			
ID	**Site**	**2008**	**2009**	**2010**	**2011**
196	MVN-Berentson-Bridge				22
197	MVN-Kulshan-Creek-Trail-18th-St	75		75	
199	MVN-Padilla-Bay-Shore-Trail-North-Gate			126	116
201	MVN-Port-of-Skagit-Crosswind-Drive			54	
202	MVN-Port-of-Skagit-Josh-Wilson-Har-Port		34		
203	MVN-Port-of-Skagit-Ovenell-Rd-FtM-Rd		15	14	9
204	MVN-Skagit-Play-Fields-Martin-Rd			163	

Note: All Mt. Vernon sites recorded bicycle-pedestrian combined counts.

Equipment Type

The Scanner, a passive infrared counter manufactured by JAMAR Technologies, was used to collect counts for these 13 sites. This is an older model that JAMAR no longer sells that can either display a total volume or provide timestamped per vehicle data.

Time Period

The data provided was available from January 2008 to May 2012.

Specific Quality Control Issues

According to email correspondence with the manufacturer, The Scanner does not automatically adjust the data for Daylight Savings Time (DST). However, The Scanner user manual indicates that when The Scanner is connected to a computer, it will use the computer's date and time automatically, unless this feature is disabled. Therefore, the shuttle file that includes the switch to DST in early March would still be in Pacific Standard Time (UTC-8:00), but the following shuttle file would be in Pacific Daylight Time (UTC-7:00) it would be updated with the computer's clock during the data upload. The reverse would happen in early November for the switch back to Pacific Standard Time. The data was adjusted to indicate the corresponding time zone for every shuttle file using either (UTC-8:00) or (UTC-7:00) at the end of the date and time stamp.

The data was quality checked for unusual patterns, spikes, zeroes, and unusually low counts using graphs of the total daily volume over time in Excel and the hourly volumes over time in Bike-Ped Portal (Appendix F). The most common data problems found were repeating zeroes and unusually high counts, likely from equipment malfunction.

OTHER COMMUNITIES IN WASHINGTON STATE

Location and Facility Type

WSDOT maintains permanent, continuous counters at 15 locations along multi-use paths throughout Washington State including in Bainbridge Island, Bellevue, East Wenatchee, Olympia, Redmond, Seattle, and Spokane.

During this project, the research team learned that the City of Tacoma has data for 3 continuous counters for the Flume Line Trail (multi-use trail), Park Avenue at 56th (shared street), and Wright Park (bike lane). However, of the data provided by the city, only the Wright Park site had sufficient data to include in the analysis.

Similarly, Washington Parks has continuous data from the Kardong Bridge in Spokane that the research team was unable to procure for this project. This data was collected using TRAFx counting equipment starting in February 2014.

For this analysis, a full calendar year of data was needed. Because many of the continuous counters were recently installed in late 2015 and early 2016, they do not provide enough data for the analysis, although they did provide long-term data.

Table 10 Count Sites in Other Communities in Washington State, 2011-2017

City	Facility Name	Available Data Range
Bainbridge Island	Bainbridge Island Winslow Way	4/27/2015 - Present
Bellevue	Bellevue I-90 Trail Bellevue SR 520 Trail 1	3/3/2015 - Present 3/2/2015 - Present
East Wenatchee	Apple Trail Capitol Loop by Old Wenatchee Bridge	10/15/2015 - Present
Olympia	Woodland Trail West	7/28/2015 - Present
Redmond	Sammamish River Trail East Sammamish River Trail	6/23/15 - Present 4/5/2016 - Present*
Spokane	Ben Burr Trail Altamont Centennial Trail - Kendall Yards Children of the Sun Trail FREYA Children of the Sun Trail Parksmith Kendall Yards EB Kendall Yards WB	8/26/2015 - Present 8/26/2015 - Present 12/14/2015 - Present 10/26/2011 - Present 8/26/2016 - Present 8/27/2016 - Present

**Cannot use for analysis because there is not a full calendar year of data currently available*

Table 11 Count Sites in Other Communities in Washington State by Mode and AADNT

		AADNT	
Site	**Mode**	**2015**	**2016**
Apple Capitol Loop Trail	bicycle		220
Ben Burr Trail Altamont	pedestrian		84
Ben Burr Trail Altamont	bicycle		13
Centennial Trail - Kendall Yards	pedestrian		408
Centennial Trail - Kendall Yards	bicycle		231
Children of the Sun Trail-Freya	pedestrian		31
Children of the Sun Trail-Freya	bicycle		29
Parksmith Total_Children of the Sun Trail	pedestrian	13	12
Parksmith Total_Children of the Sun Trail	bicycle	30	38
Woodland Trail West	bicycle		221

Note: These sites were used in creating factors for the guidebook for Washington State, however, they were not used in the hourly error analysis.

Figure 12 Apple Capitol Loop Trail, Old Wenatchee Bridge.
Source: WSDOT

Equipment Type

For these count locations, WSDOT uses Eco-Counter software, with passive infrared, inductive loops, or a combination of both technologies. The City of Tacoma data was collected using Eco-Counter inductive loops (ZELT).

Time Period

Data from WSDOT was provided from 2011-2016. Automated feeds update the data to Eco-Counter's website to allow for the continuous data to be accessible to the present day. Data from the City of Tacoma was provided from January 1, 2015- June 5, 2016 as .csv file downloaded from Eco-Counter.

Specific Quality Control Issues

Validation data from Ken Lakey (WSDOT) is available for permanent count locations at the Bellevue bike trail (Bellevue), Ben Burr Trail (Spokane), Centennial Trail (Snohomish County), Sammamish Trail (Redmond), Wenatchee Apple Capitol Loop (Wenatchee), and Woodland Trail-Chehalis Trail (Olympia).

PORTLAND, OR

The Portland data was provided by the Portland Bureau of Transportation (PBOT), Metro, the regional metropolitan planning agency for Portland, the Oregon Department of Transportation (ODOT), and TriMet.

Location and Facility Type

Since the early 1990s, PBOT has been collecting non-motorized traffic counts from locations including the Hawthorne Bridge, the Broadway Bridge, Riverwalk (lower deck of the Steel Bridge), SW Moody Avenue, and various locations with bike lanes throughout the city.

The Hawthorne Bridge, the Broadway Bridge, and Riverwalk are separated from motor vehicle traffic and are shared space for bicyclists and pedestrians. On the Hawthorne Bridge, painted bicycle and pedestrian emblems on the sidewalk suggest the space each mode should occupy to prevent conflicts. SW Moody Ave. is a bidirectional separated bike lane at the same grade as the sidewalk for pedestrians, but is grade separated from motor vehicle traffic. The separated bike lane is painted green and the bicycle and pedestrian emblems are used differentiate the spaces. PBOT also provided continuous count data from inductive loops in bike lanes throughout the city from 44 locations, however only about four locations, including NW Lovejoy and 9th Ave., were of sufficient accuracy to be used for this analysis due to QC concerns. These loops are largely quadrupole inductive loops used for advance detection of bicycles for the purposes of signal actuation.

Figure 13 Quadrupole inductive loop in bike lane at NW Lovejoy and 9th Ave.
Source: James Lindsey

Table 12 Examples of Portland Bicycle and Pedestrian Continuous Count Locations

Facility Type	Facility Name	Who is Counted
Shared use sidewalk	Hawthorne Bridge	Bicycles only
	Broadway Bridge	Bicycles only
Shared use pedestrian- and bicycle-only bridge	Riverwalk	Bicycles only
Separated Bike Lane	SW Moody Ave.	Bicycles only
Bike lane	NW Lovejoy and 9th Ave.	Bicycles only

Source: Author's analysis of Portland Bureau of Transportation information

Metro provided data from 64 off-street trails using trail counters that are maintained by several jurisdictions including Metro, Tualatin Hills Park and Recreation District, Washington Park TMA, City of Portland, and City of Tualatin.

Portland also has three unique count locations at the Eastbank Esplanade, I-205 multi-use path, and Tilikum Crossing, which are discussed in more detail in this section.

The Eastbank Esplanade is located adjacent to the Willamette River and provides a scenic bike- and pedestrian-only connection along the east waterfront. The counter at this location is found just north of the Hawthorne Bridge and is maintained by PBOT. This counter is the first piezoelectric and infrared combination counter in the west coast of the U.S. installed in 2016.

Figure 14 Piezoelectric and passive infrared combo on the Eastbank Esplanade.
Source: Krista Nordback

The I-205 multi-use path was completed in 1982 and extends 16.5 miles from the Clackamas River in Gladstone to Vancouver, Washington. At its intersection with SE Yamhill, are two diamond inductive loops maintained by the Oregon Department of Transportation (ODOT).

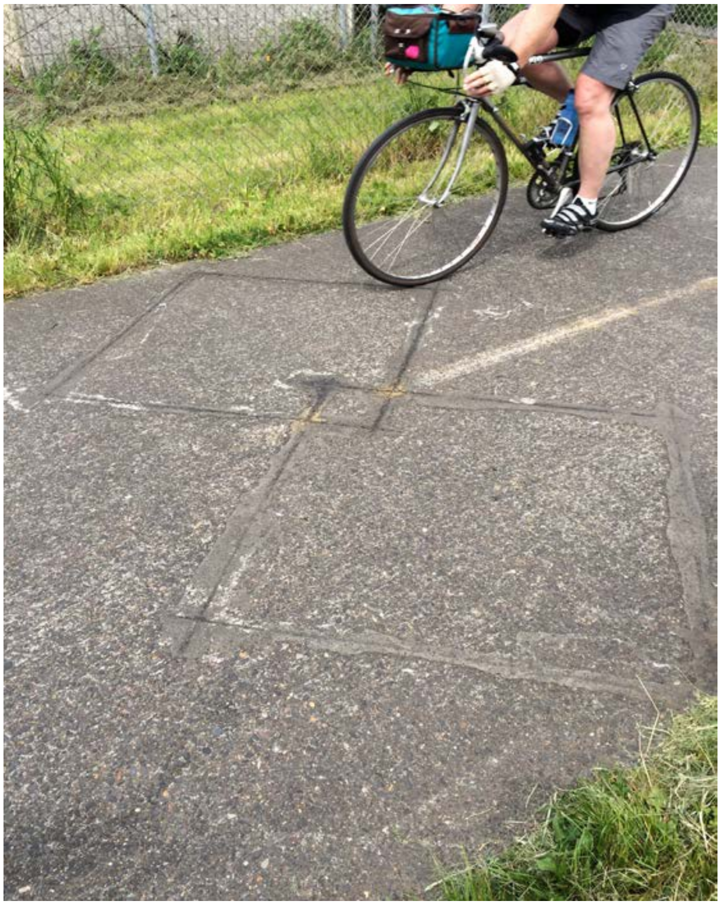


Figure 15 I-205 multi-use path inductive loops.
Source: Krista Nordback

Tilikum Crossing is a bridge that stretches across the Willamette River between SW and SE Portland that is solely used by transit, bicyclists, and pedestrians. One each side of the bridge is approximately a 14-foot-wide path that is used by bicyclists and pedestrians with paint used to separate the different uses.

Figure 16 Tilikum Bridge Eco-Display

Source: Dylan Johnstone

Table 13 Portland Count Sites Used in the Analysis by Mode and AADNT

			AADNT								
ID	**Site**	**Mode**	2009	2010	2011	2012	2013	2014	2015	2016	Type
1	PDX-Hawthorne-Bridge	bicycle				4,286	4,645	4,657	4,582	3,235	Tube
105	PDX-Broadway-Bridge	bicycle						2,666			Tube
112	PDX-Eastbank-Esplanade	bicycle						717			Tube
113	PDX-Glendoveer-Fitness-Trail	pedestrian			315	304			639		PI
114	PDX-Graham-Oaks-1	pedestrian							223		PI
118	PDX-Graham-Oaks-5	pedestrian				55					PI
121	PDX-I-205-Multi-Use-Path-on-Yamhill-St	bicycle							251		Loop
123	PDX-Lone-Fir-1	pedestrian					228				PI
124	PDX-Lone-Fir-2	pedestrian					107				PI
126	PDX-Mt-Talbert-1	pedestrian	90	92	85	101	112	133	45		PI
132	PDX-NE-Broadway-St-E-of-N-Williams-Ave-WB	bicycle					386		111		Loop
133	PDX-NE-Broadway-St-Weidler-St-Couplet-at-2nd-Ave	bicycle					274		95		Loop
135	PDX-NE-Cully-Blvd-at-NE-Killingsworth-St	bicycle					12		55		Loop

			AADNT								
ID	**Site**	**Mode**	2009	2010	2011	2012	2013	2014	2015	2016	Type
144	PDX-NW-9th-Ave-N-of-NW-Lovejoy-St-SB	bicycle					529		534		Loop
153	PDX-Scouters-Mountain-2	pedestrian							30		PI
155	PDX-SE-122nd-Ave-at-SE-Market-St	bicycle							447		Loop
158	PDX-Smith-and-Bybee-Interlakes	pedestrian	57	55	62	59	61	65	68		PI
160	PDX-Steel-Bridge-Street-Level	bicycle						153			
163	PDX-SW-Moody-Ave	bicycle						1,035	1,223		Tube
170	PDX-Wildwood-at-MAC	pedestrian							262		PI
206	PDX-Commonwealth-Lake	bike-ped-combined			336	306	319	330	382		PI
207	PDX-Cooper-Mountain-Loop	bike-ped-combined			226	255	275	306	361		PI
208	PDX-Fanno-Creek-at-92nd	bike-ped-combined			260	319	325	371	367		PI
209	PDX-Fanno-Creek-at-Allen	bike-ped-combined						132	138		PI
210	PDX-Fanno-Creek-at-Hall	bike-ped-combined				488		336			PI
211	PDX-Fanno-Creek-at-Scholls	bike-ped-combined			302	274		303	345		PI
213	PDX-Hazeldale-Park	bike-ped-combined			149	143					PI
214	PDX-Hyland-Woods-Southwest-Corner	bike-ped-combined			77	68	80				PI
216	PDX-Rock-Creek-Regional-Trail	bike-ped-combined				370	412	453			PI
217	PDX-Rock-Creek-Regional-Trail-Junction	bike-ped-combined				370	411	452			PI
218	PDX-Tualatin-Hills-Nature-Center	bike-ped-combined						381	403		PI
219	PDX-Tualatin-Hills-Nature-Park	bike-ped-combined				550	576	601			PI
225	PDX-Waterhouse-North-at-Walker	bike-ped-combined				104	138				PI

ID	Site	Mode	AADNT 2009	2010	2011	2012	2013	2014	2015	2016	Type
226	PDX-Waterhouse-South-at-Walker	bike-ped-combined							234		PI
230	PDX-Westside-Murrayhill-2	bike-ped-combined							214		PI

PI= Passive Infrared

<u>Equipment Type</u>

PBOT uses inductive loop counters for its bike lanes and pneumatic tube counters on its bridges, shared use paths, and the SW Moody Ave. separated bike lanes. Metro provided data from off-street trails collected using TRAFx passive infrared counters. On the Eastbank Esplanade, PBOT uses a piezoelectric and passive infrared combination counter that was manufactured by TDC and is distributed by JAMAR Technologies.

Inductive loops (Phoenix) from Diamond Traffic Products are used on the I-205 multi-use path, which are the same detectors used by ODOT for counting motor vehicle traffic. This equipment would have trouble counting in a mixed traffic location with motor vehicles and bikes, but since the loops are separated from motor vehicle traffic, ODOT can count bicycles more accurately. ODOT validated the counter in 2013 and found that overall the equipment failed to count 20% of the 757 bicycles manually counted from video during 51 hours of observation.

At Tilikum Crossing, Eco-Counter's Eco-Display is a visual interface displays the number of cyclists that cross daily and cumulatively since the bridge opened in 2015. Inductive loops (ZELT) detect cyclists at this location.

Time Period

Data from PBOT was provided from 2008 to 2016. The data from the Hawthorne Bridge and SW Moody Ave. have automated feeds that update daily to Eco-Counter's website to allow for the continuous data to be accessible to the present day. The data from the inductive loops in bike lanes are collected and stored in PORTAL, an online database for motorized and non-motorized traffic counts in Portland. These counts automatically feed through TransSuite software to PORTAL's website.

Data from Metro was provided from 2010 to 2016. This data from the trail counters must be collected manually collected from the field by connecting a computer to the counter's dock and downloading the shuttle files. Therefore, this data is updated as staffing allows.

The Eastbank Esplanade piezoelectric/infrared counter was installed in February 2016 and the available data ranges from February 2016 to present-day.

For the I-205 multi-use path, the inductive loops were originally installed in the 1980s with four other sites in Oregon by ODOT. However, in the late 1980's the count program ended. In 2011-2012, ODOT began counting at this location again, although only data from 2014-2016 was provided for this project.

For Tilikum Crossing, data is available from the opening of the bridge on September 11, 2015 to 2016 (present-day) and can be publicly assessed through Eco-Counter's website at http://portland-tilikum-crossing.visio-tools.com/.

Specific Quality Control Issues

The data provided by PBOT for the inductive loops in bike lanes had inconsistencies due to equipment malfunction (e.g., repeating zeroes). For some counters, these inconsistencies were sporadic, one-day events and for others the strings of zeroes lasted for multiple days at a time. In terms of accuracy, the counts were validated using manual counts from PBOT's summer bike counts in 2016 for six locations. The research team validated another ten locations in August and September 2016. It was found that each site had a mean percent error (MPE) over ±25% due to overcounting or undercounting, and thus these sites were not included in the analysis. Emails from PBOT indicated that four detectors on N Broadway were damaged by a utility company grounding out the detectors during paving projects in October 2016. These sites had high MPEs of 60-85% and are set to be replaced by the City.

Additionally, for the PBOT data that was collected using pneumatic tubes, there are different quality control concerns. For the SW Moody Ave. data, the inconsistencies found included unusually low counts before repeating zeroes and one instance of a single day data gap a few days before repeating zeroes. Both are indicative of a detector malfunction, possibly associated with the battery. These data were collected using Eco-Counter pneumatic tubes and did not include any unusually high counts or spikes. At another site, the Riverwalk on the lower deck of the Steel Bridge, data gaps were observed from a few days up to three weeks in length and low counts over a period of two days that could be due to a temporary closure. The Broadway Bridge data did not appear to have any inconsistencies during visual inspection. Inconsistent data were removed from the analysis.

For the data provided by Metro, several issues emerged due to Daylight Savings Time (DST) and the counters. Based on email correspondence with the manufacturer, it is our understanding that the counters must be adjusted by the user to account for DST in the spring and fall. However, based on email correspondence with data providers, Robert Spurlock (Metro) and JP McNeil (Explore Washington Park), it is our understanding that due to staffing and budget constraints the counters were not adjusted after they were originally set up. Because of this, the data should be adjusted instead. To do this, the research team used the date when the counter was installed to determine whether the data corresponded to Pacific Standard Time (UTC-8:00) or Pacific Daylight Time (UTC-7:00). This adjustment was made under the assumption that the clock on the counter's dock had not been changed by the user since it was initially set up, which had been confirmed via email by Robert Spurlock (Metro) and JP McNeil (Explore Washington Park). However, the clock would be reset when the battery on the unit is replaced. According to Spurlock, this would be evident by a time period without data and is likely to occur about once every three years.

The Metro trail data had inconsistencies including spikes, repeated zeroes, and data gaps. Spikes that occur at the beginning or end of the data were removed from the analysis as they were potentially caused by installation or detector malfunction. Approximately 70% of the series of repeated zeroes that were observed in all of the Metro data occurred for three weeks or less, about 50% of those series were for less than 7 days. A majority of the Metro trail sites were located where lower volumes were expected, often in suburban or rural locations. For low volume sites (<200 users per day), spikes were defined as >1,000 users per hour and were often observed in clusters of unusually high counts (>100 users per hour) for those sites. Often these clusters are found a few days or even a couple of weeks before data gaps, which indicated a detector malfunction. For high volume sites (>200 users per day), spikes used the same definition as low volume sites (>1,000 users per hour), but unusually high counts were flagged for review if counts occurred overnight, before a data gap or repeated zeroes, or in series of high counts over a period of days.

Robert Spurlock (Metro) provided 2-hour validation counts for 8 sites. From these counts, the error of the trail counters varies from roughly 60% undercount to 40% overcount for an individual hour for hours with over 35 people. This shows the variability of the counts, indicating that the count for a specific hour may not be accurate, but on average, a net undercount is expected. For this reason, factors developed from this data are more likely to be accurate if they are based on an average of hours than on a single hour on a single day. JP McNeil (Explore Washington Park) and Bruce Barbarasch (Tualatin Hills Park and Recreation District) did not provide documentation for validation counts they had completed.

ODOT's I-205 multi-use path inductive loopshad no detectable QC problems based on visual checks aside from a few data gaps.

A spike in the data for Tilikum Crossing occurs on September 27, 2015 because of the route for PBOT's Sunday Parkways, an open streets event, included the bridge. This data set did not have data gaps or inconsistencies.

ARLINGTON, VA

Location and Facility Type

The Arlington data set includes continuous counts taken from bike lanes, shared-use paths and bridges. For at least 12 of these sites, bicyclists and pedestrians are counted as separate traffic flows. Other sites are bicycle-only count sites. For the purposes of this analysis, the sites were divided by mode into 29 sites: eighteen bicycle-only and 11 pedestrian-only.

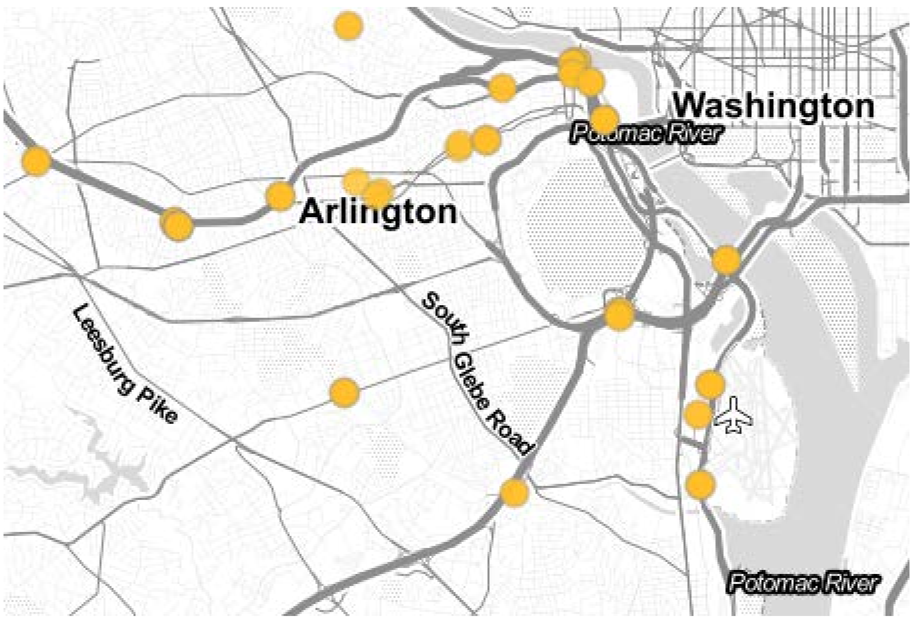


Figure 17 Count locations in Arlington County
Screenshot from Bike-Ped Portal.

Table 14 Arlington Count Sites Used in the Analysis by Mode and AADNT

						AADNT			
ID	**Site**	**Mode**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
2	Arl-CustisTrail-Bon-Air-Park	bicycle				794	780	776	821
3	Arl-CustisTrail-Bon-Air-Park	pedestrian				424	448	461	454
4	Arl-Ballston	pedestrian				353	309	328	349
5	Arl-Ballston	bicycle				229	213	226	237
6	Arl-Military-Rd-2500-SB	bicycle				81	75	71	67
7	Arl-Bon-Air-Park	bicycle				1,155	1,138	1,151	1,183
8	Arl-Bon-Air-Park	pedestrian				659	549	649	641
9	Arl-East-Falls-Church	bicycle							287
10	Arl-East-Falls-Church	pedestrian							676
11	Arl-Quincy-St-1100-SB	bicycle					75		
12	Arl-Fairfax-3700	bicycle				246	206	112	
13	Arl-Mt-Vernon-Airport-South	bicycle			1,756	1,716	1,579		1,676
14	Arl-Mt-Vernon-Airport-South	pedestrian			431	420	350		270
15	Arl-Crystal-2200	bicycle				113	202		
16	Arl-Custis-Rosslyn	bicycle	959	1,022	1,145	1,107	1,025	1,036	1,189
17	Arl-Custis-Rosslyn	pedestrian	364	377	391	386	375	375	441
18	Arl-Columbia-Pike	bicycle				602	625	636	646
19	Arl-Columbia-Pike	pedestrian				510	618	505	525
20	Arl-Bluemont-Connector	bicycle					154	157	169
21	Arl-Bluemont-Connector	pedestrian					265	283	306
22	Arl-Crystal-City-Connector	bicycle			412	509	541	530	
23	Arl-Crystal-City-Connector	pedestrian			462	575	547	498	
24	Arl-South-Joyce-SB	bicycle				22	47	40	43
25	Arl-South-Joyce-NB	pedestrian				103	169	156	149
26	Arl-Rosslyn-Bikeometer	bicycle						976	1,066
27	Arl-Key-Bridge-West	bicycle				1,425	1,575	1,428	1,454
28	Arl-Key-Bridge-West	pedestrian				3,419	3,588	3,269	3,182
29	Arl-Theodore-Roosevelt-Island-Bridge	bicycle			1,018	726	1,034	1,022	1,054
30	Arl-Theodore-Roosevelt-Island-Bridge	pedestrian			1,113		913	845	840
103	Arl-Clarendon-Blvd-Wilson-Blvd-2500	bicycle				387	363	350	359

Equipment Type

The Arlington data was collected primarily using passive infrared and inductive loop combination counting equipment at 18 sites along multi-use paths and bridges, including Eco-Counter Eco-Multi, Pyro Box, and Eco-Combo. These models count bicycles and pedestrians separately. At one site along Four Mile Run Trail counts are collected using a combination of a piezoelectric counter (MetroCount MC 5720) and a passive infrared counter. Along five streets, single inductive loop counters are used to collect counts on bi-directional bike lanes.

Time Period

Data from Arlington County was provided from 2012 to 2016.

Specific Quality Control Issues

For the Arlington data set, pedestrians and bikes are counted separately using automated counters. When one mode counts repeated zeroes, the other mode may also record repeated zeroes or spikes in the data. About 90-95% of what the researchers categorized as suspect data were repeated zeroes.

Further, the Arlington data was cleaned by the counter manufacturer at the request of the City. This cleaning included estimating data for missing counts and removing erroneous high counts.

BOULDER, CO

Location and Facility Type

For the Boulder data set, continuous bicycle-only counts were collected along multi-use trails, sidewalks, shared lanes, and bike lanes.

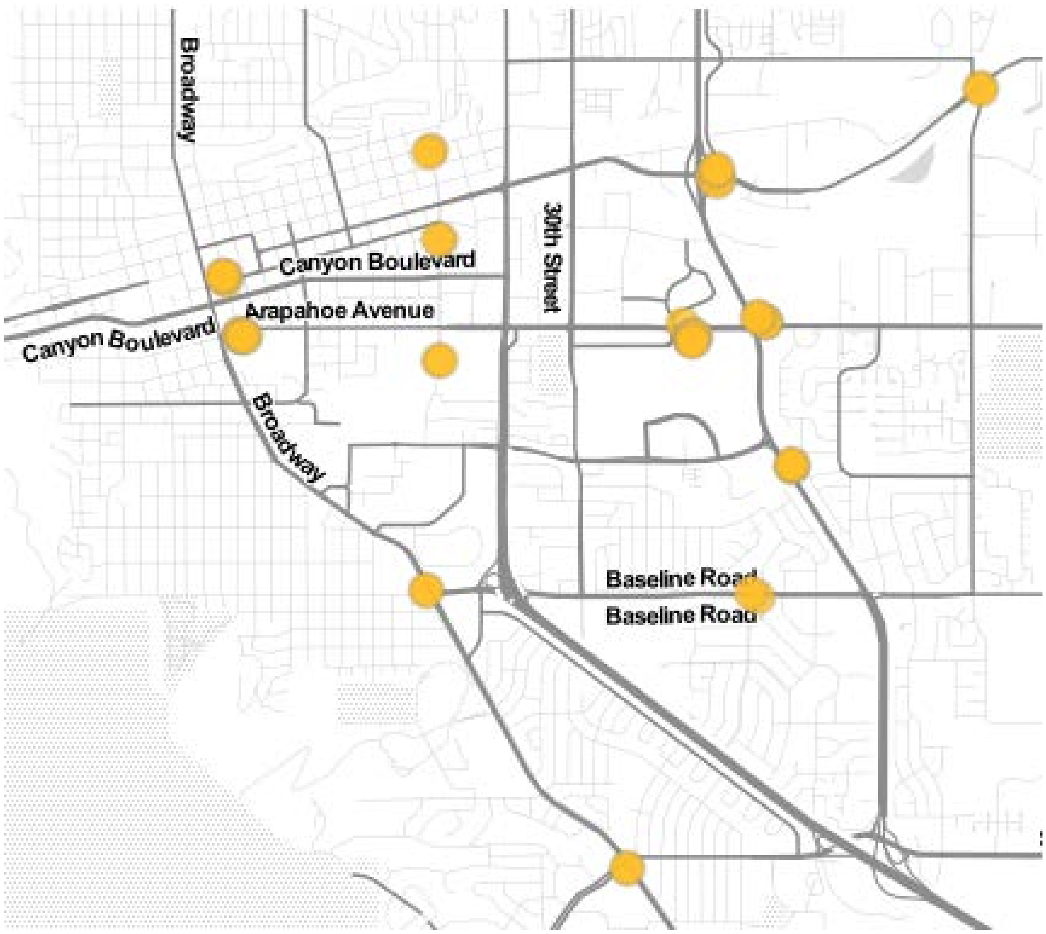


Figure 18 Count locations in Boulder County
Screenshot from Bike-Ped Portal.

Table 15 Boulder Count Sites Used in the Analysis by AADNT

		AADNT											
ID	**Site**	**2002**	**2003**	**2004**	**2007**	**2008**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
77	Bou-Folsom-South-Arapahoe								742		546	676	692
78	Bou-Folsom-North-Pine												585
79	Bou-Folsom-South-South												638
81	Bou-13th-North-Walnut							595	776	687	537	660	671
82	Bou-Boulder-Creek-4000-Arapahoe			602	731	735							
83	Bou-Skunk-Creek-Research-Park			365	459	434							
84	Bou-Boulder-Creek-West-Skunk-Creek			676	796	845							
85	Bou-Arapahoe-Path-4000-Arapahoe			74	71	91							
86	Bou-Arapahoe-East-38th		91	82	100		164						
90	Bou-Arapahoe-East-Foothills						122						
91	Bou-Foothills-North-Arapahoe						368						
92	Bou-Broadway-South-Table-Mesa							439	544				
93	Bou-Pearl-Between-Foothills-Ramps					36							
96	Bou-Pearl-East-Foothills-Off-Ramp					9							
98	Bou-Broadway-Path-South-Arapahoe-13th				391	451							
99	Bou-Broadway-Path-South-Boulder-Creek				619	657							
100	Bou-Boulder-Creek-East-Broadway				887	944							
101	Bou-Pearl-East-55th	46							126				
102	Bou-55-South-Pearl	60							151				

Note: All Boulder sites recorded bicycle-only counts.

Equipment Type

The data used are all from inductive loop bicycle counters. Data from the older (2012 and earlier) counters were collected using inductive loop counters (Global Traffic Technologies' Canoga C900 and C800 series loop amp cards located in signal controller cabinets) on paths and sidewalks (Nordback et al. 2010). The newer counters (2011 to present) are Eco-Counter Zelt inductive loop counters located in bike lanes and one in a shared roadway (Nordback et al. 2011).

Time Period

Data from the City of Boulder was provided from 2002 to 2016.

Specific Quality Control Issues

The researchers observed higher than usual counts in the winter and low counts in February and March for one site, Broadway Path S of Arap Ave. and 13th but considered this a natural traffic pattern for the site

SAN DIEGO, CA

Location and Facility Type

Counts were conducted along multi-use paths, bike lanes, shared roadways, and sidewalks across San Diego County (Figure 19). For at least 10 of these sites bicyclists and pedestrians are counted as separate traffic flows. For the purposes of this analysis the sides were divided by mode into 47 sites: 33 bicycle-only counts and 14 pedestrian-only.

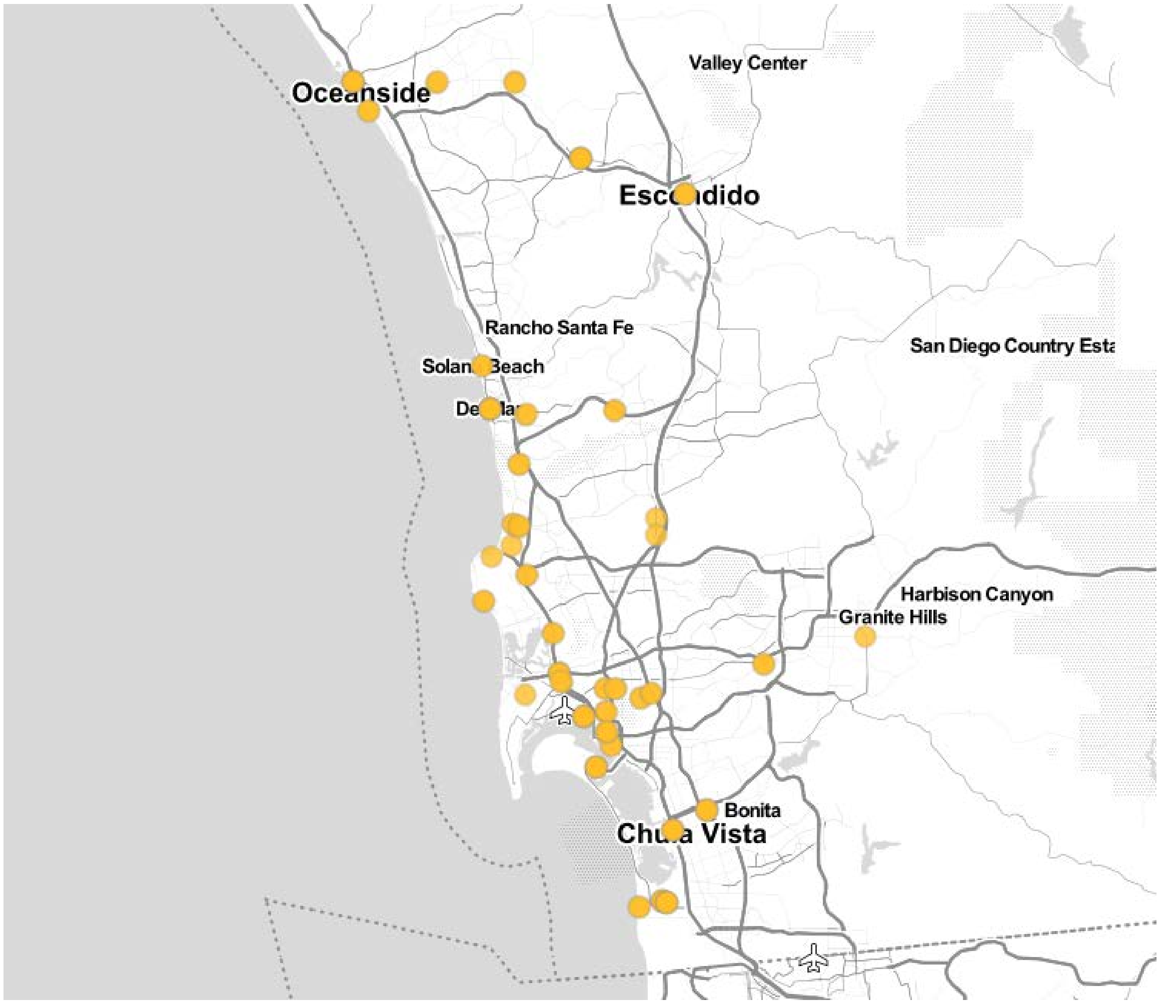


Figure 19 Count locations in San DiegoCounty
Screenshot from Bike-Ped Portal.

Table 16 San Diego Count Sites Used in the Analysis by Mode and AADNT

			AADNT			
ID	**Site**	**Mode**	**2013**	**2014**	**2015**	**2016**
31	SD-El-Cajon-Washington-EB	bicycle	20	21		19
32	SD-Del-Mar-Camino-SB	bicycle	415	397	368	173
33	SD-Del-Mar-Camino	pedestrian	2,225	2,169	1,853	1,957
34	SD-Escondido-Inland-Rail-Trail-EB-WB	bicycle	93	102	98	
35	SD-Escondido-Inland-Rail-Trail-EB-WB	pedestrian	267	102	156	
36	SD-Imperial-Beach-Bayshore-EB-WB	bicycle			777	
37	SD-Imperial-Beach-Bayshore-EB-WB	pedestrian			130	
38	SD-Imperial-Beach-Palm-EB-WB	bicycle		129	128	
39	SD-La-Mesa-University-WB	bicycle	30	26	25	25
40	SD-Oceanside-Blvd-WB	bicycle			28	18
41	SD-Oceanside-Pacific-SB-NB	bicycle			506	
42	SD-Oceanside-SLR-River-Trail-EB-WB	bicycle			647	561
43	SD-Oceanside-SLR-River-Trail-EB-WB	pedestrian			92	
44	SD-San-Marcos-Inland-Rail-Trail-EB-WB	bicycle	164	163		121
45	SD-San-Marcos-Inland-Rail-Trail-EB-WB	pedestrian	351	453		1,270
46	SD-30th-St-SB-NB	bicycle	64	4	90	
47	SD-Broadway-EB-WB	pedestrian	2,474	3,148	6,117	15,354
48	SD-Del-Mar-Heights-WB	bicycle		44	41	43
49	SD-Mission-Bay-SB-NB	bicycle	162	178	-	
50	SD-Gilman-SB	bicycle		285	288	289
51	SD-Kearney-Villa-SB	bicycle		91	84	29
52	SD-La-Jolla-Blvd-SB-NB	bicycle	141	141	139	57
53	SD-Landis-EB-WB	bicycle	36	19	66	52
54	SD-River-Bike-Path-EB-WB	bicycle				171
55	SD-River-Bike-Path-EB-WB	pedestrian				172
56	SD-Harbor-Dr-Bridge-SB-NB	pedestrian	5,655	9,216		
57	SD-Chula-Vista-Bayshore-SB-NB	bicycle	442	436	408	
58	SD-Chula-Vista-Bayshore-SB-NB	pedestrian	54	58	54	
59	SD-Pac-Hwy-SB	bicycle	75	92	88	86
60	SD-Rose-Canyon-SB-NB	bicycle	268	289		
61	SD-Sorrento-Valley-SB-NB	bicycle		235	230	60
62	SD-Torrey-Pines-WB	bicycle		32	32	32
63	SD-Solana-Beach-Coast-Hwy-SB-NB	bicycle	53	672	693	82

ID	Analysis Area Name	Mode	2013	2014	2015	2016
				Year		
64	SD-Vista-Village-Dr-WB	bicycle	44	45	43	24
65	SD-SR56-EB-WB	bicycle				422
66	SD-National-City-Sweetwater-EB-WB	bicycle	294	287	290	
67	SD-National-City-Sweetwater-EB-WB	pedestrian	2	155	152	
68	SD-Torrey-Pines-UCSD-SB-NB	bicycle		145	136	
69	SD-1037-BB	bicycle	101			
70	SD-1037-BB	pedestrian	19			
71	SD-Coronado-Bayshore-SB-NB	bicycle			1,018	
72	SD-Coronado-Bayshore-SB-NB	pedestrian	420		442	
73	SD-University-Ave-EB-WB	pedestrian	2,156	1,782	687	1,125
74	SD-University-Ave-WB	bicycle	266	229	231	183
75	SD-Harbor-Dr-Multi-EB-WB	bicycle	732	744	690	
76	SD-Harbor-Dr-Multi-EB-WB	pedestrian	41	746	445	
104	SD-4th-Ave-SB-5th-Ave-NB	bicycle	89	46	123	70

Equipment Type

The San Diego data was collected using Eco-Counter passive infrared and inductive loop counters, including Eco-Multi, Pyro Box, and Zelt, models.

Time Period

Data from Sherry Ryan at San Diego State University was provided from 2013 to 2016.

Specific Quality Control Issues

After review, the researchers found that spikes and repeated zeroes were the most common issues found with the San Diego data set.

ACCURACY OF DATA

Quality control was conducted by the research team to remove inconsistencies in the data provided by various agencies and organizations. The data were both manually checked by the research team and checked using an automated code in Bike-Ped Portal that flagged repeating zeroes, repeating non-zeroes, and high counts. Suspicious data was excluded from analysis. Due to an oversight, partial count days were included in the analysis, but since there are few such days in the datasets, the results and findings not significantly impacted.

Inconsistencies included unusual patterns (e.g., duplicate data), spikes (e.g., detector malfunction with counts >1000 per hour), low counts, and repeating zeroes using graphs of the total volume over time (Appendices F-G). Unusually low counts and repeating zeroes where there appeared to be temporary closures to the facility (e.g., holidays, snow events) were not removed. Spikes that appeared to be potentially caused by equipment malfunction, vandalism, or insect or other wildlife activity, were removed from the analysis. However, spikes that appeared due to special events that genuinely increased pedestrian or bicycle activity were included.

If counts spiked for just one or a few hours and the counts were below 1,000 per hour, we considered this an actual event, even if we could not find the event listed on the internet. However if such a spike was followed by a data gap or repeating zeroes, we felt this was indicative of a counter malfunction and excluded such spikes. If the high volumes (>200 per hour) continued into late and night and went on for days, we considered this a malfunction of some sort and excluded these data from analysis.

The 1,000 per hour threshold was determined after a review of bicycle and pedestrian capacity and saturation flow rate studies (Tables 17-19). This threshold was considered to be flexible for the person conducting the quality checks to use discretion in determining if the data appeared to be real or a malfunction. This discretion was necessary in order to not over clean the data at higher volume sites. The threshold was also loosely based off the peak hourly volumes found for one bicycle flow direction on the Hawthorne Bridge, a site with some of the largest bicycle volumes in the U.S. (e.g, roughly 5,000 riders daily)(Figure 20). Since many of the sites checked had much lower daily volumes than this, it would be an anomaly for 1,000 users to pass within one hour given demonstrated travel patterns and volumes.

Table 17 Review of Bicycle-Only Capacity and Saturation Flow Rate Studies

Location or Reference	Author	Study Year	Path Width	Saturation Flow (Bicycles/h)	Saturation Flow Rate Bicycles/h/ft	Assuming an 8 ft Path
Netherlands	Stembord, H.	1991	0.78 m (2.6 ft)	3,000-3,500	1,346	10,769
Canada	Navin, F.B.D.	1994	1.25 m (4.1 ft)	5,000	1,220	9,756
Canada	Navin, F.B.D.	1994	2.5 m (8.2 ft)	10,000	-	-
Netherlands	Botma, H.	1995	1 m (3.3 ft)	3,200	970	7,758
Netherlands	Botma, H.	1995	2 m (6.6 ft)	6,400	-	-
Netherlands	Botma, H.	1995	3 m (9.9 ft)	9,600	-	-
Davis, CA	Homburger, W.S.	1976	1.0 m (3.3 ft)	2,600	788	6,303
China	Yang, J.M.	1985	2 m (6.6 ft)	4,400-4,500	682	5,455
China	Yang, J.M.	1985	3 m (9.9 ft)	6,600-6,700	677	5,414
China	Lui et al.	1993	1 m (3.3 ft)	1,800-2,100	636	5,091
Swedish Capacity Manual	Vagverk, S.	1977	1.2 m (4 ft)	1,500	375	3,000
US (Highway Capacity Manual)		1994	2 lanes (6.6 ft)	2350*	356	2,848
US (Highway Capacity Manual)		1994	1 lane (3.3 ft)	500*	152	1,212

**Assumptions about the range of data and the size of the lanes were made and put in (). Analysis of data from Allen et al. 1998.*

Source: Author's analysis from Allen et al. 1998, Johnson 2014, and Hummer et al. 2006

Table 18 Summary of Bicycle-Only Capacity and Saturation Flow Rate Studies

Summary by Region	Assuming an 8 ft Path
Netherlands	7,700-11,000
Canada	9,700
China	5,000-5,400
Swedish Capacity Manual	3,000
Davis, CA	6,300

Source: Author's analysis from Johnson 2014 and Hummer et al. 2006

Table 19 Review of Pedestrian-Only Capacity and Saturation Flow Rate Studies

Author, Year	Study Name	Capacity	Assumed Speed	Pedestrian Buffer Zone
FHWA, 1998	Recommended Procedures for Chapter 13 "Pedestrians" of the Highway Capacity Manual	4,000-5,000 pedestrians/h/m, for simplicity 4,500 ped/h/m (75 ped/min/m)	0.75 m/s	0.75 m^2/ped
TRB, 1994	Highway Capacity Manual	LOS E up to 82 ped/min/m or 4920 ped/h/m		
Fruin, 1971	Pedestrian Planning and Design	LOS E up to 82 ped/min/m or 4920 ped/h/m		
Pushkarev Zupan, 1975b	Urban Space for Pedestrians	LOS F up to 82 ped/min/m or 4920 ped/h/m		

Source: Rouphail et al. 1998

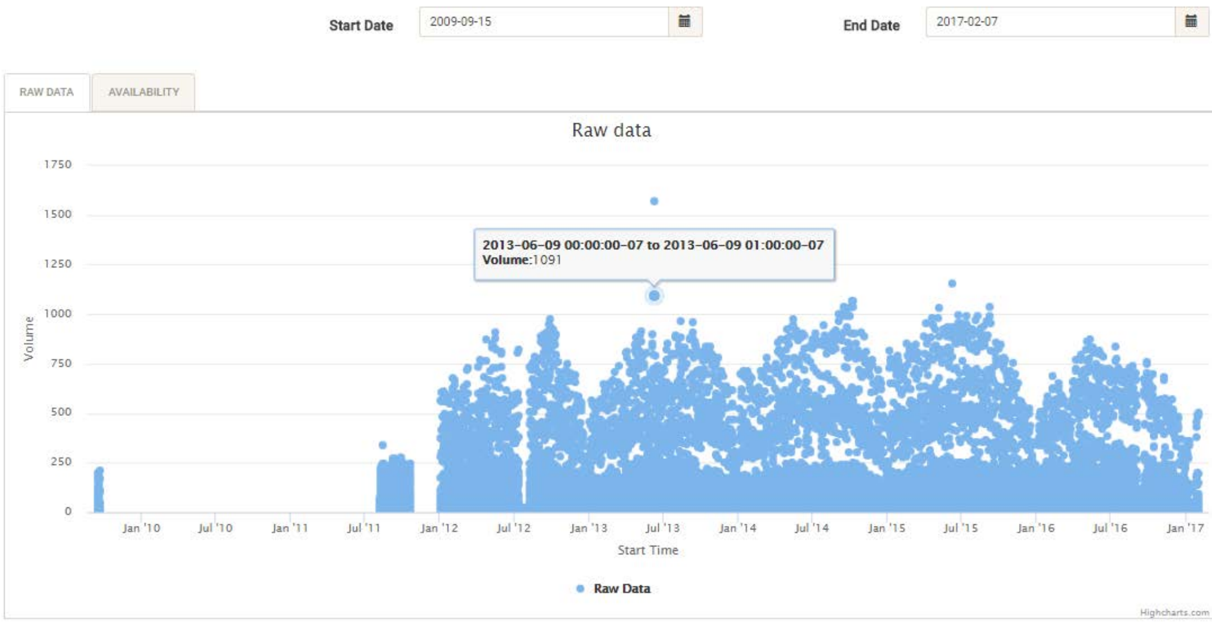


Figure 20 Hawthorne Bridge, North Sidewalk Westbound Bicycle Flow
Source: Bike-Ped Portal

VALUES OF AADNT

Another aspect of data quality is the known undercount bias of passive infrared and some inductive loop automated counters, discussed in detail in NCHRP 797 and its companion Web-only document 205 (Ryus et al. 2014). This aspect of error was not accounted for in this study, so for the sites studied the AADNT discussed herein is likely to be an underestimate of actual bicycle and pedestrian traffic on the trails.

Despite this, it is still interesting to look at the magnitude of the volumes observed in the different cities. Figures 21 and 22 show AADNT by mode. Looking at the bicycle volumes, San Diego has the most bicycle counters, these sites see 1,000 bicyclists per day or less on average, while Portland has fewer counters, but the highest volumes (up to 4,500 AADBT). Seattle shows the next highest volumes, but also has fewer counters. As shown in Table 20, sites that average 200 AADBT and lower represent about 40% of the sites counted. Sites over 600 AADBT represent about a third of the count sites counted.

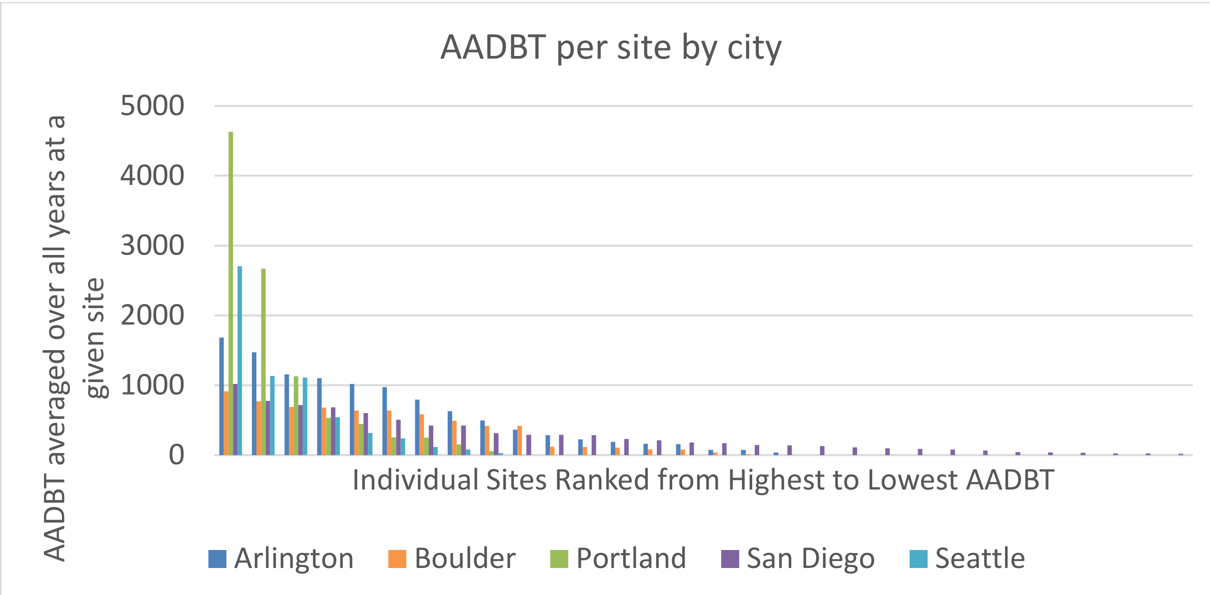


Figure 21 AADBT per Site By City

Table 20 AADBT By city

AADBT Range	Arlington	Boulder	Port-land	San Diego	Seattle	Total	Percent	Cumula-tive %
0-200	14	13	3	38	4	**72**	38%	38%
201-400	12	2	2	12	6	**34**	18%	55%
401-600	4	7	3	5	1	**20**	10%	66%
601-800	8	10	0	6	0	**24**	13%	78%
801-1000	2	3	0	0	0	**5**	3%	81%
1001-1200	14	0	1	1	5	**21**	11%	92%
1201-1400	0	0	1	0	0	**1**	1%	92%
1401-1600	5	0	0	0	0	**5**	3%	95%
1601-1800	3	0	0	0	0	**3**	2%	96%
>1800	0	0	4	0	3	**7**	4%	100%
Total	**62**	**35**	**14**	**62**	**19**	**192**	**100%**	

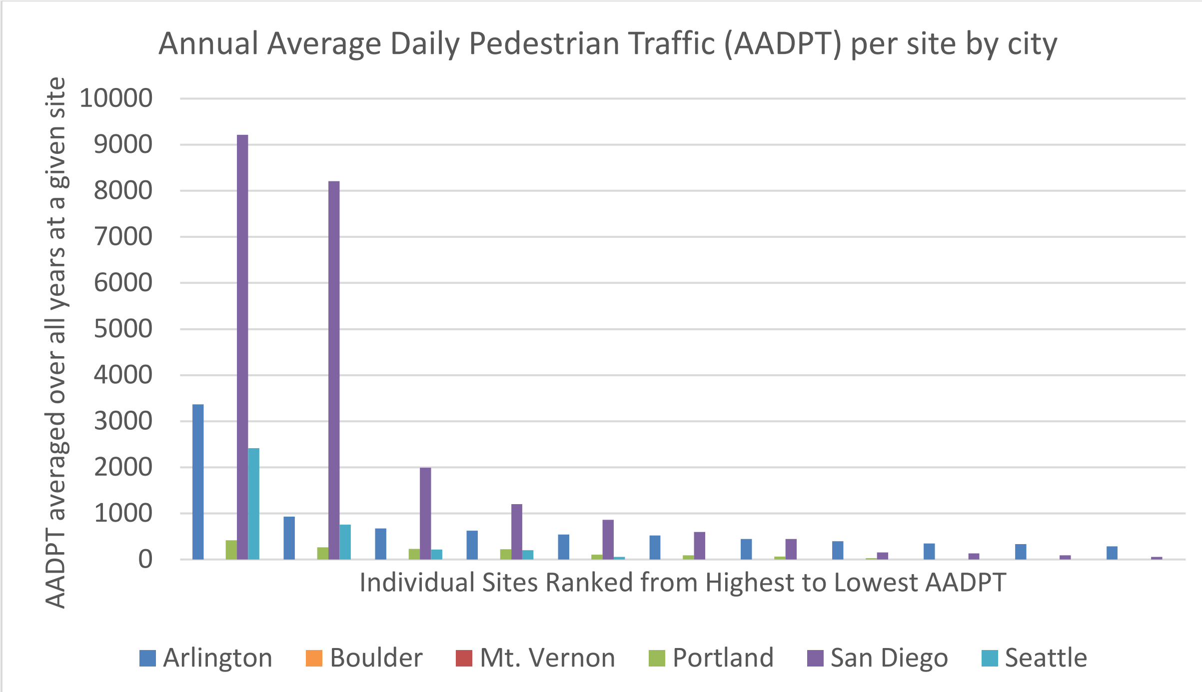


Figure 22 AADPT per Site By City

Table 21 AADPT by City

AADPT Range	Arlington	Portland	San Diego	Seattle	Total	Percent	Cumula-tive %
0-200	0	16	6	1	**23**	26%	26%
201-400	13	5	0	2	**20**	23%	49%
401-600	14	0	3	0	**17**	19%	68%
601-800	5	1	2	1	**9**	10%	78%
801-1000	3	0	0	0	**3**	3%	82%
1001-1200	1	0	1	0	**2**	2%	84%
1201-1400	0	0	1	0	**1**	1%	85%
1401-1600	0	0	0	0	**0**	0%	85%
1601-1800	0	0	1	0	**1**	1%	86%
>1800	4	0	7	1	**12**	14%	100%
Total	**40**	**22**	**21**	**5**	**88**	**100%**	

For pedestrians, a quarter of the sites had volumes less than 200 people per day on average, while another quarter have volumes greater than 800 AADPT. This means that roughly half of the sites counted between 200 and 800 AADPT. For pedestrian travel, San Diego has the highest volumes (as high as 9,000 AADPT on average) and as many count sites as Arlington (11 sites). Arlington has the next highest volume sites. Portland has multiple lower volume sites, which make sense since these count sites are mostly on unpaved trails.

METHODOLOGY

The analysis included four main parts described in the sections and flowchart below in Figure 23: grouping sites, calculating non-motorized traffic adjustment factors (e.g., hourly factors), AADNT estimation and error analysis, and a comparison of count scenarios.

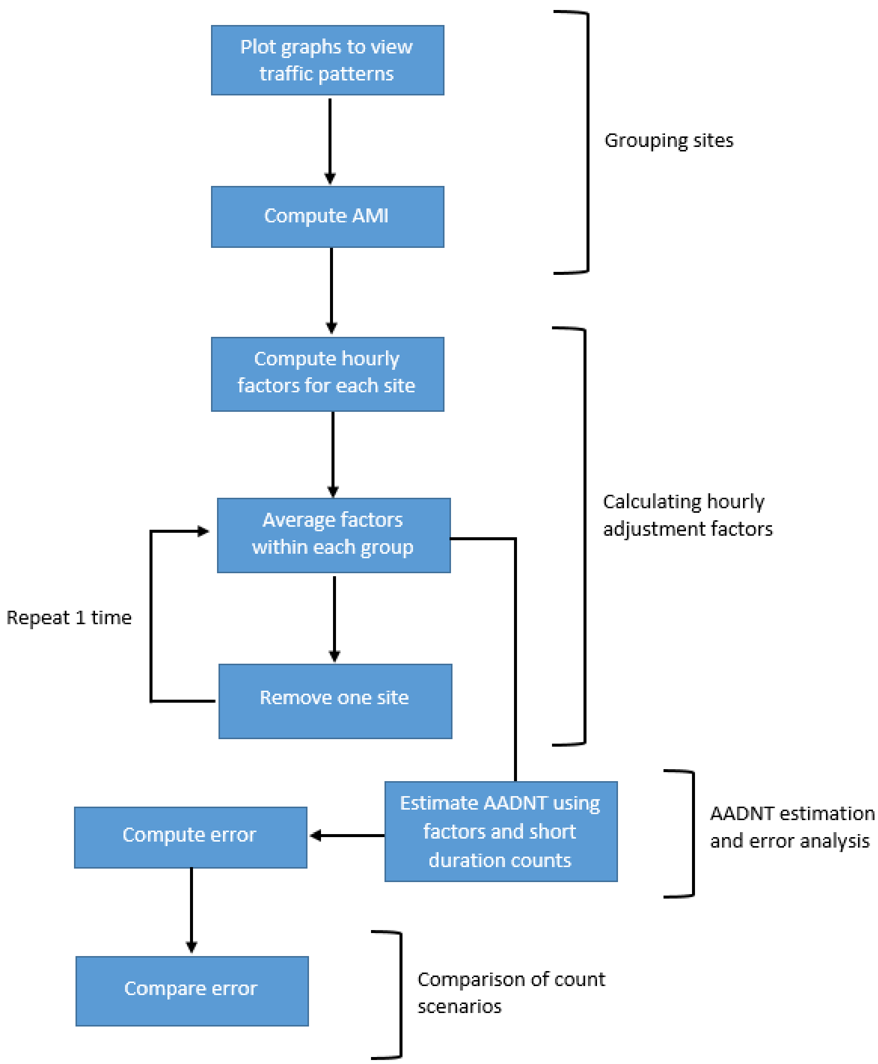


Figure 23 Flowchart showing steps following in the analysis

Due to the extensive dataset, the analysis was conducted using the Bike-Ped Portal database (Nordback et al. 2015). The analysis was conducted using Python scripts and SQL queries to compute estimates of AADNT if only one hour of count data at a given site were provided. This produced actual and estimated AADNT values for each site for each hour studied. The error for the scenarios of interest were then computed in Microsoft Excel.

GROUPING SITES

Graphs of daily, weekly, and yearly temporal variations were plotted for each site. The sites were then grouped into three factor groups based on these patterns and a traffic distribution index proposed by Miranda-Moreno et al. (2013), the Average Morning/Midday Index (AMI). The AMI is a ratio of morning to midday traffic. Average AMI is calculated using the following equation:

$$AMI = \frac{\sum_{7}^{8} v_h}{\sum_{11}^{12} v_h} \qquad \text{(Equation 1)}$$

Where:

AMI = Average Morning/Midday Index

v_h = Average weekday hourly count for hour (*h*)

The calculated AMI values were grouped using the following criteria: Hourly Noon Activity (AMI <= 0.7), Hourly Multipurpose (0.7< AMI <=1.4), Hourly Commute (AMI > 1.4). This grouping was based on the distribution of AMI, presented in Figure 24. Sites with noon activity have peak counts between the morning and evening peak hours.

Sites demonstrate a commute pattern when the morning and evening peak hours are higher than the noon peak hour. Sites with multipurpose patterns generally have traffic patterns that mix both weekday commute and weekend recreational use patterns. The factor groups are further separated by region and mode. A summary of this grouping is provided in Table 22.

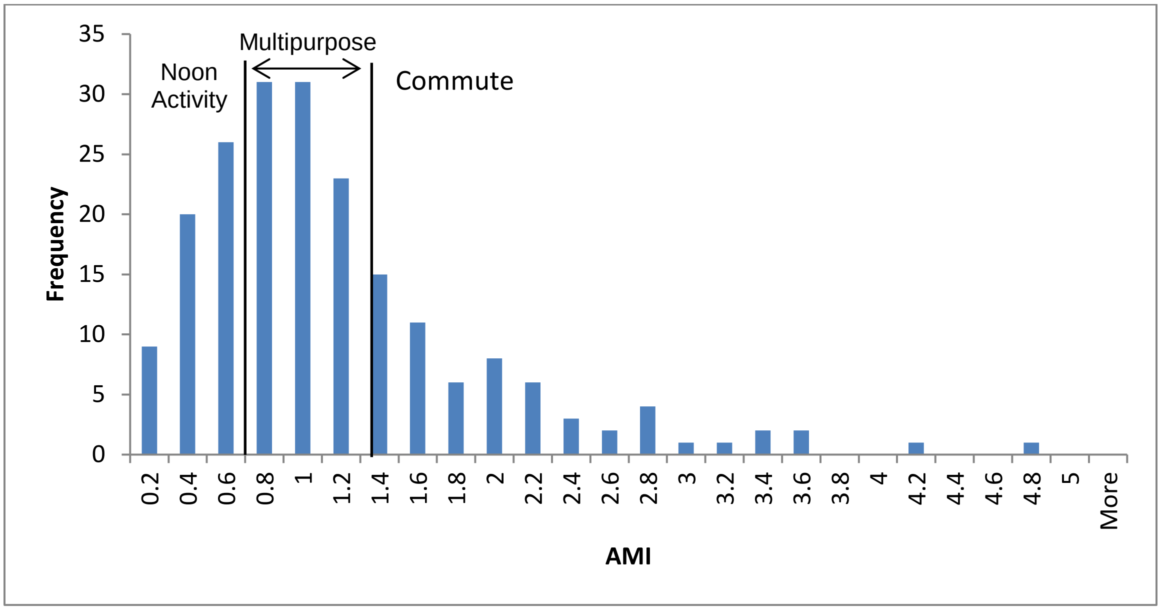


Figure 24 Histogram of AMI distribution

Table 22 also includes ranges of AADNT values for each city and group. This table shows that all the cities have low volume sites (less than 200 AADNT) and all cities, except Mt. Vernon, have high volume sites (greater than 600 AADNT). Mt. Vernon is the smallest city with fewer than 40,000 people, so it is not surprising that none of the count sites record above 200 AADNT.

Table 22 Summary of Factor Groups and AADNT

Community	Number of Sites (n)	Hourly Commute		Hourly Multipurpose		Hourly Noon Activity	
		Range of AADNT	n	Range of AADNT	n	Range of AADNT	n
Arlington	29	67-1,756	22	22-3,588	7	-	-
Boulder	17	-	-	9-944	17	-	-
Portland	32	111-4,657	6	55-453	8	30-639	18
San Diego	46	128-289	3	18-9,216	22	19-15,354	21
Seattle	16	19-2,742	9	53-219	3	205-2,414	4
Mt. Vernon	6	-	-	-	-	14-163	6
Total	146	-	40	-	57	-	49

Note: "–" denotes missing data or non-applicable totals.

CALCULATING ADJUSTMENT FACTORS

Hourly adjustment factors for every day of the week and month for a given year were computed. Since manual count programs collect less than 24 hours of counts, an hourly factor is needed to adjust the hourly count up to an annual total. This hourly factor is calculated by dividing the average hourly traffic volume for that month and day of week by the AADNT.

$$\text{AADNT}y = \frac{1}{12}\sum_{m=1}^{12}\left[\frac{1}{7}\sum_{j=7}^{1}\left[\frac{1}{n}\sum_{i=1}^{n} V_{ijmy}\right]\right] \quad \text{(Equation 2)}$$

Where:

V_{ijmy} = total traffic volume for i^{th} occurrence of the j^{th} day of the week within the m^{th} month, for year y.

n = the count of the j^{th} day of the week during the m^{th} month for which traffic volume is available (a number between 1 and 5)

The average hourly traffic volume is calculated using each hour from 7:00AM-7:00PM for 7 days of the week for non-holiday weeks in a given year to produce 1,008 factors per year for each site. For example, counts for a given site from the hour between 7:00AM and 8:00AM for all Tuesdays in May were averaged and divided by AADNT for that year and site. For this study, holidays are defined as only federal holidays. Weeks are defined to start on Monday and end on Sunday.

Each hourly factor represents a unique temporal state and this method inherently accounts for weather variations from day-to-day and month-to-month. Therefore, these hourly factors can be applied directly to estimate AADNT without applying daily or monthly factors.

$$H_{h,j,m,y,k,s} = \frac{V_{h,j,m,y,k,s}}{AADNT_{y,k,s}} \quad \text{(Equation 3)}$$

Where:

$H_{h,j,m,y,k,s}$ = Hourly factor for a given hour of the day, h, day of the week, j, month of the year, m, year, y, mode, k, and site, s.

$AADNT_{y,k,s}$= Actual annual average daily non-motorized traffic for year, *y*, mode, *k*, and site, *s*.

$V_{h,j,m,y,k,s}$ = Average hourly peak bicycle traffic volume

h = hour of the day (7:00AM to 7:00PM)

j = day of the week (1 = Sunday, 7 = Saturday)

m = month of the year (1 = January, 12 = December)

y = year

k = mode (bicycle, pedestrian, or bicycle-pedestrian-combined)

s = site

Next, factors are computed by factor group (AMI groups). Then factors are recomputed by after removing the trial site and recomputed again after removing one additional site. This resulted in 1,008 factors per year per group.

AADNT ESTIMATION AND ERROR ANALYSIS

To calculate the estimated AADNT error for manual count sites using the factors discussed, the analysis pretended that one of the continuous counters is actually a short duration site (trial_short_duration). This made it possible to know the actual AADNT for that site and also investigate an error estimate if only one hour that year had been counted manually. For each hour of the day (7:00AM-7:00PM in non-holiday weeks) for each trial short duration site, the estimated AADNT is computed using:

$$Estimated\ AADNT = \frac{(\text{trial\_short\_duration}V_{h,d,k,s})}{\text{trial\_group}H_{h,j,m,y,k,g})} \qquad \text{(Equation 4)}$$

Where:

trial_short_duration$V_{h,d,k,s}$ = Volume for a particular hour, *h*, date, *d*, and mode, *m*, for the trial short duration site, *s*.

trial_group$H_{h,j,m,y,k,g}$ = Hourly factor for a given hour of the day, *h*, day of the week, *j*, month of the year, *m*, year, *y*, mode, *k*, and for the trial group, *g*. The trial group, *g*, is composed of the sites in the factor group <u>except</u> the trial short duration site, *s*.

The trial group, *g*, does not include the trial short duration site, *s*, because the researchers do not want to estimate AADNT at a site using data from that site. The study is trying to simulate the situation where the full year of data are not available, so including such data in the factor would reduce the error, and not be a good test of the method. These calculations are repeated for all sites.

$$Error_{yskhdg} = \frac{(Estimated\ AADNT_{yskhdg} - AADNT_{ysk})}{AADNT_{ysk}}$$

(Equation 5)

Where:

$AADNT_{ysk}$ = the actual annual average daily bicyclists and/or pedestrians for the site, *s*, year, *y*, and mode, *k*.

$Estimated\ AADNT_{yskhdg}$ = the annual average daily bicyclists and/or pedestrians estimated for a given trial short duration site, *s*, year, *y*, mode, *k*, for the hour of the day the trial short duration count, *h*, for trial short duration count date, *d*, and for trial factor group, *g*.

SHORT DURATION COUNT SCENARIOS

Several short duration count scenarios are examined in this study as shown in Table 23. Most of the scenarios are selected from recommended timeframes from various count programs found in the United States and Canada. All of the scenarios assumed that counts are collected during April to September. Several of the scenarios assumed weekday counts are collected on Tuesday, Wednesday, or Thursday (TWorTh), Tuesday, Wednesday, and Thursday (TWandTh) and weekend counts are collected on Saturday, which are recommended by previous research and common data collection methods.

Table 23 Short Duration Count Scenarios

Duration of Count	Time Frame	Days of the Week (DOW)	Source
2 h	7-9AM	TWorTh	WSBPDP
2 h	3-5PM	TWorTh	1-hour analysis found lower error in Table 24
2 h	4-6PM	TWorTh	WSBPDP
2 h	5-7PM	TWorTh	NBPDP
2 h	12-2PM	Saturday	NBPDP
2 h	4-6PM	Any day	1-hour analysis found lower error in Table 24
4 h	7-9AM, 4-6PM	TWorTh	WSBPDP
4 h	5-7PM 12-2PM	TWorTh Saturday	NBPDP
6 h	7-9AM	TWandTh	Utah DOT
6 h	4-6PM	TWandTh	Utah DOT
8 h	7-9AM, 4-6PM 10-2PM	TWorTh Saturday	Utah DOT
8 h	7-9AM, 11AM-1PM, 5-7PM 12-2PM	TWorTh Saturday	Proposed new count scenario for WSBPDP
12 h	7AM-7PM	TWorTh	NBPDP, Utah DOT
24 h	7AM-7PM	TWorTh Saturday	NBPDP, Utah DOT

Note: WSBPDP = Washington State Bicycle and Pedestrian Documentation Project, NBPDP = National Bicycle and Pedestrian Documentation Project, Utah DOT = Utah Department of Transportation

One purpose of this study is to investigate error estimation for different hours throughout the day. Thus, many of the 2-hour count scenarios are derived timeframes recommended by existing count programs or guidance to represent various hours from 7:00AM to 7:00PM. Several 2-hour scenarios represent times when the highest counts for different travel patterns are expected (e.g., PM peak hours for commute patterns, midday Saturdays for recreational patterns). Two 2-hour scenarios are included because the initial error analysis determined that counts in the afternoon produced the lowest error estimations regardless of other variables (e.g., day of week, hourly factor group, city).

The 4-hour count scenarios were modeled from the Washington State Bicycle and Pedestrian Documentation Project (WSBPDP) and the National Bicycle and Pedestrian Documentation Project (NBPDP). Because both 4-hour scenarios sample days throughout April to September, rather than specific days in late September or early October, the corresponding errors are likely to be lower than that of the actual WSBPDP or NBPDP counts.

The 6-hour count scenarios are based on guidance from the Utah Department of Transportation (Utah DOT), which recommends counting on consecutive weekdays (Tuesday, Wednesday, and Thursday) during morning and evening commute peak hours. The 8-hour count scenarios are combinations of 2-hour scenarios previously discussed. One 8-hour scenario expands upon the 4-hour NBPDP scenario by adding a midday period on the weekdays from 11:00AM-1:00PM and a midday period on Saturday from 12:00-2:00PM. This scenario allows for an estimation of AMI to be computed. Estimations of AMI can be used to determine the correct factor group, and thus calculate more accurate error estimates. This scenario is the research team's proposed new count scenario for WSBPDP.

The 12-hour and 24-hour count scenarios are both modeled from the NBPDP and Utah DOT guidance. Counts are assumed to be collected from 7:00AM-7:00PM on Tuesday, Wednesday, or Thursday only for the 12-hour scenario. The 24-hour scenario counts during these same times and additionally from 7:00AM-7:00PM on Saturday. It is possible to collect these counts using manual counters by dividing the time period into shifts to avoid fatigue. However, it is typical that these counts would be taken using automated, continuous counters specifically calibrated to bicycles and/or pedestrians.

The comparison of count scenarios calculated the mean percentage error (MPE), mean absolute percentage error (MAPE), and standard deviation of the MAPE using the actual AADNT and the estimated AADNT. The equations below show how these computations were made:

$$MPE = \frac{AADNT_{estimated} - AADNT_{actual}}{AADNT_{actual}} * 100 \qquad \text{(Equation 6)}$$

$$MAPE = \left| \frac{(AADNT_{estimated} - AADNT_{actual})}{AADNT_{actual}} * 100 \right| \qquad \text{(Equation 7)}$$

FINDINGS AND DISCUSSION

The mean absolute percentage error for AADNT estimation for 1-hour counts by day of week are shown in Table 24. The findings reveal that the lowest observed errors cluster from 2:00-6:00PM on Tuesday, Wednesday, Thursday, and Friday. The highest errors are found mostly in the morning hours from 7:00-9:00AM throughout the week and evening hours after 5:00PM for weekends. Lower error is observed on Sunday rather than Saturday, which is contrary to what other research has found. However, because it is not common practice to conduct weekday counts on Friday or weekend counts on Sunday, these days are not included in many of the count scenarios.

As shown in Table 25, the commute factor group has the lowest error for 1-hour counts for all of cities except San Diego. This high error in San Diego is likely due to having only 3 sites in that factor group, all with error above 90%. The errors presented in Table 26 for 1-hour counts by mode indicate the lowest error for bicycle-only counts.

Table 24 Mean Absolute Percentage Error (MAPE) for 1-Hour Counts by Day of Week

Hour	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Avg.
7	160	134	110	111	106	109	127	122
8	103	82	72	78	73	78	86	82
9	76	82	**65**	66	72	69	76	72
10	74	79	66	66	66	69	94	73
11	71	74	**65**	66	67	68	96	72
12	67	76	79	**65**	71	76	69	72
13	67	76	66	73	67	73	69	70
14	69	75	**63**	**64**	**63**	**64**	68	67
15	66	66	**61**	**61**	**61**	**60**	**65**	63
16	66	**63**	**59**	**60**	**62**	**59**	68	62
17	73	**61**	**59**	**65**	66	67	84	68
18	95	**65**	73	70	69	75	147	85
Average	82	78	70	70	70	72	87	

Note: The hours with the lowest errors are in bold.

Table 25 Mean Absolute Percent Error (MAPE) from 1-Hour Counts by Factor Group

		Hourly Commute		**Hourly Multipurpose**		**Hourly Noon Activity**		
Community	**Number of Sites (n)**	**MAPE (%)**	**n**	**MAPE (%)**	**n**	**MAPE (%)**	**n**	**Weighted Average (%)**
Arlington	29	48	22	69	7	-	-	53
Boulder	17	-	-	61	17	-	-	61
Portland	32	43	6	46	8	83	18	66
San Diego	46	108	3	59	22	76	21	70
Seattle	16	55	9	112	3	101	4	77
Mt. Vernon	6	-	-	-	-	125	6	125
Total	146	-	40	-	57	-	49	-
Average (%)	**-**	**63**	**-**	**69**	**-**	**96**	**-**	**75**

Note: "–" denotes missing data or non-applicable totals or averages.

Table 26 Mean Absolute Percent Error (MAPE) from 1-Hour Counts by Mode

Community	Number of Sites (n)	Bicycle MAPE (%)	Bicycle n	Bike-Ped Combined MAPE (%)	Bike-Ped Combined n	Pedestrian MAPE (%)	Pedestrian n	Weighted Average (%)
Arlington	29	54	18	-	-	49	11	52
Boulder	17	60	17	-	-	-	-	60
Portland	32	45	9	58	15	109	8	67
San Diego	46	62	33	-	-	88	13	69
Seattle	16	55	9	-	-	106	7	77
Mt. Vernon	6	-	-	125	6	-	-	125
Total	146	-	86	-	21	-	39	-
Average (%)	**-**	**55**	**-**	**92**	**-**	**88**	**-**	**75**

Note: "–" denotes missing data or non-applicable totals or averages.

SCENARIO COMPARISON

The MAPE for AADNT estimation for each of the count scenarios by city is provided in Table 27. The 12-hour and 24-hour count scenario produce the lowest MAPE for April to September of 32% and 30% error, respectively. This is likely because these scenarios average more hours of data, which result in more accurate estimate of AADNT. Both the 12-hour and 24-hour scenarios provide enough data to observe a daily travel pattern for a weekday (TWorTh), and the 24-hour scenario expands the dataset to also include a daily travel pattern for a Saturday. Both scenarios demonstrate the lowest standard deviation of MAPE (43% and 40%, respectively) found in Table 28, indicating the least variability in error estimates. The Table 27 errors are plotted in Figure 25 to show that error usually decreases as more hours are counted, although not always as in the case of the 12-hour count for Mt. Vernon.

For jurisdictions without resources to conduct 12-hour counts, the 8-hour scenario with count periods from 7-9AM, 11-1PM, and 5-7PM TWorTh and 12-2PM Saturday results in the next lowest error of 33%. The Arlington test data demonstrates the lowest error across all scenarios, and Mt. Vernon the highest.

Table 27 Mean Absolute Percentage Error (MAPE) for Short Duration Count Scenarios

		Mean Absolute Percentage Error (%)						
Scenario	**Hours**	**ARL**	**BOU**	**MVN**	**PDX**	**SAN**	**SEA**	**Avg.**
12-2PM Saturday	2	36	48	91	44	62	77	50
7-9AM TWorTh	2	32	54	175	56	59	52	50
4-6PM Any day	2	38	45	93	53	54	49	48
4-6PM TWorTh	2	37	44	90	55	50	43	47
3-5PM TWorTh	2	38	40	71	48	53	44	46
5-7PM TWorTh	2	35	46	83	55	48	37	45
7-9AM and 4-6PM TWorTh	4	27	40	119	40	44	40	38
5-7PM TWorTh and 12-2PM Saturday	4	25	37	58	38	44	45	36
7-9AM TWandTh	6	28	48	196	46	54	50	44
4-6PM TWandTh	6	29	36	63	47	43	38	39
3-5PM TWandTh	6	29	32	60	39	47	37	38
7-9AM and 4-6PM TWorTh and 10-2PM Saturday	8	25	34	60	30	43	45	34
7-9AM, 11AM-1PM, 5-7PM TWorTh and 12-2PM Saturday	8	24	33	58	29	45	43	33
7AM-7PM TWorTh	12	25	31	83	30	40	29	32
7AM-7PM TWorTh and 7AM-7PM Saturday	24	21	31	58	25	41	40	30
Average		30	41	93	43	49	45	

Note: Available data used in this analysis were collected from April to September.
ARL = Arlington, BOU = Boulder, MVN = Mt. Vernon, PDX = Portland, SAN = San Diego, SEA = Seattle

Table 28 AADNT Estimation Error for Short Duration Count Scenarios

		AADNT Error as Mean Percentage Error (MPE)		AADNT Error as Mean Average Percentage Error (MAPE)	
Scenario	**Hours**	**MPE (%)**	**SD of MPE (%)**	**MAPE (%)**	**SD of MAPE (%)**
12-2PM Saturday	2	14	85	50	70
7-9AM TWorTh	2	20	99	50	88
4-6PM Any day	2	14	86	48	73
4-6PM TWorTh	2	13	85	47	72
3-5PM TWorTh	2	13	78	46	64
5-7PM TWorTh	2	12	84	45	71
7-9AM and 4-6PM TWorTh	4	15	64	38	54
5-7PM TWorTh and 12-2PM Saturday	4	13	60	36	50
7-9AM and 4-6PM TWorTh and 10-2PM Saturday	8	16	53	34	43
7-9AM, 11AM-1PM, 5-7PM TWorTh and 12-2PM Saturday	8	15	54	33	46
7AM-7PM TWorTh	12	14	51	32	43
7AM-7PM TWorTh and 7AM-7PM Saturday	24	16	47	30	40

Note: SD = standard deviation

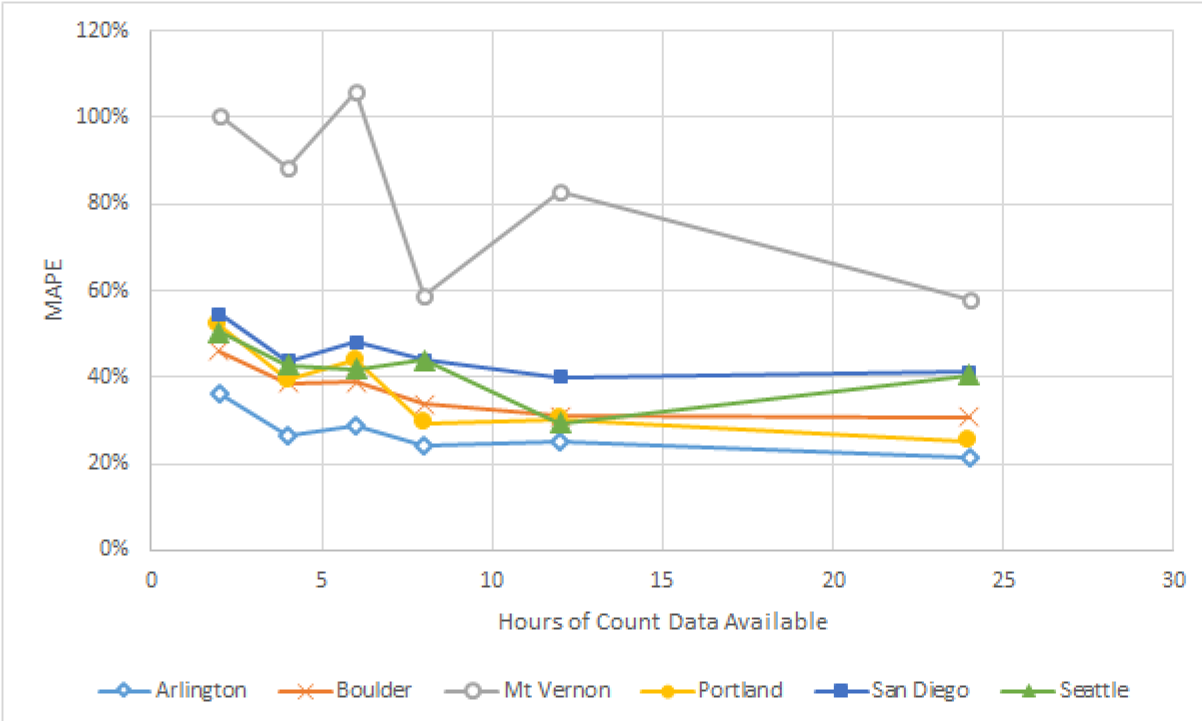


Figure 25 Mean Absolute Percentage Error (MAPE) as a Function of Hours Counted

<u>Discussion</u>

As others have found, estimating AADNT from less than 24-hours of count data results in high error. The 2-hour count error estimates are similar to Budowski's Seasonal Average Daily Bicyclist error estimates using the TMG method (32% MAPE and 44% standard deviation) for 10 bicycle counters in Winnipeg. For some purposes, such error is unacceptably high, but since little other information on bicycle and pedestrian volumes are available, practitioners may choose to use such estimates despite the error. This report provides valuable estimates of the error for such estimates so that practitioners may make informed choices.

Error for some cities is higher than others as illustrated in Figure 25. For example, Mt. Vernon had exceptionally high error. This is likely due to the low number of count sites (only six sites total), the high variability of the counts (possibly due to inaccuracies in the equipment) and low volumes. However, volume does not clearly correlate with error in this dataset of all the cities overall. Similarly, San Diego also had data quality problems, likely due to lack of equipment maintenance budget, most, but not all, of which were identified during our data quality process. Such problems may have caused the relatively high error. Error for Arlington is the lowest of the six cities studied, likely due to the higher number of count sites (22 total, leading to at least seven per factor group) and the consistent data quality. It should be noted that Arlington data has been cleaned to an extent that data for the other cities were not. This cleaning was conducted by the counter manufacturer at the request of the city and included estimating data where counts were missing and removing erroneous high counts. This resulted in data being more consistent than other datasets.

Another source of error is the number of permanent counters used to create the adjustment factors. Error (MAPE) was 54% lower from estimates where two permanent counters were used to create the factors compared to estimates where only one permanent counters was used. This illustrates the importance of installing multiple counters per factor group. The TMG recommends at least three counters. In this study the number of counters per factor group ranged from 1 to 14. Future study of these data will investigate this source of error further.

It is likely that because more special events occur on weekends than weekdays, there is more variability in weekend counts, and thus higher error. However, it is unclear why Sunday produced less error than Saturday. This study was unable to determine whether more events happen on Saturday or Sunday, but this does impact the error and warrants further study.

As shown in Table 26, error for bicycle counts seems lower than for pedestrian and combined bicycle-pedestrian counts, overall, but this may be a factor of variability and data quality rather than actually associated with pedestrians. In fact, Arlington which has relatively good data quality and relatively high volumes shows slightly lower AADNT estimation error for pedestrians than bicycles.

As shown in Figure 25, MAPE for the 8-hour manual count strategy (7-9AM, 11AM-1PM, 5-7PM TWorTh and 12-2PM Saturday) is relatively lower than other scenarios with similar durations. This indicates that if manual counts are to be collected this is a good scenario.

CONCLUSIONS

This research demonstrates that using manual counts to estimate annual average daily non-motorized traffic (AADNT) is likely to result in errors higher than 20%. However, since this is common practice, the report presents estimates of this error using common estimation methods applied to count data from six cities using frequently used manual count scenarios. For example, Mean Absolute Percent Error (MAPE) averages 45% for the often used 5:00-7:00PM 2-hour count period on Tuesday, Wednesday, or Thursday.

Error varies by number of count sites in the factor group, month, time of day, day of week, and city. It is also likely to vary by variability and volume at the count sites, and quality of the data. The commute factor group demonstrates the lowest error. Afternoon counts seem to be best for reducing error (2:00-6:00PM). While Monday is associated with high error, Friday is closer to the other weekdays in terms of reducing error. Sunday is often as good if not better than Saturday in terms of error contrary to what others have found. Likely due to data quality but also non-motorized traffic volume, Arlington had the lowest AADNT estimation error (mean absolute percent error) and Mt. Vernon, Washington had the highest. Average AADNT estimation errors for the studied short duration count scenarios ranged from 30% to 50%. Error is lower for scenarios in which more peak hours are counted and when more than one permanent counter was available to estimate adjustment factors.

RECOMMENDATIONS

Recommendations for the Washington State Bicycle and Pedestrian Documentation Program (WSBPDP):

- Communities are urged to use counting equipment to count longer than 24 hours (preferably <u>one week</u>) in order to reduce the error.
- If manual counting is continued, the <u>8-hour peak hour count scenario (7-9AM, 11AM-1PM, 4-6PM on a Tuesday, Wednesday or Thursday and 12-2PM Saturday) during a nonholiday week and good weather from May through September is recommended for potential future WSBPDP use</u>. The average error of 33% (MAPE) for this scenario, this error is relatively low for manual count-based estimate. Also, this scenario provides information on how weekend and weekday travel compare and provides some basis for understanding weekday travel patterns.
- Conduct segment (screenline) counts for manual short duration counts
- <u>Install more than one continuous counter per factor group</u>. Error (MAPE) decreases over 50% for factors groups with two continuous counters rather than one. Each of the four regions (Coast Range, Puget Lowlands, Cascades, and Eastern Washington) are expected to have separate factor groups, which are likely to each include the commute, noon-activity, and mixed pattern groups discussed herein. In addition, bicycle and pedestrian modes should be grouped separately. This indicates a minimum of 24 groups in the state (4 regions X 3 pattern groups X 2 modes), though there are likely to be more groups if, for example, rural and urban areas have different noon activity patterns or different cities have different patterns. Adding

counters in the Coast Range and Cascades is especially needed as these areas had not counters at the time of analysis.

- Maintain and calibrate continuous counters and short duration counting equipment at initialization and annually thereafter.
- Collect data from both continuous and short duration coverage count sites for a network-wide count program.

Detailed recommendations from this research are included in a guidebook for communities in the WSBPDP included in Appendix J of this report. This guidebook, incorporates results from this research as well as those of a companion project by Dr. Michael Lowry at University of Idaho. This following sections details how decisions for the guidebook were made and supported by available analysis.

WHEN TO COUNT

From the hourly analysis of Mean Absolute Percentage Error (MAPE) by day of week in Table 29 demonstrates that the lowest errors were mostly found in the afternoon and the highest errors in the mornings. In order to maintain consistency with grouping methods outlined in previous research by Miranda-Moreno (2013), manual counts would need to be collected during weekday mornings from 7-9AM and midday from 11AM-1PM, despite the high error in the mornings. This allows for adaptations of the Weekday/Weekend Index and Average Morning/Midday Index for manual counts to be calculated (referred to as Weekend Ratio and Midday Ratio, respectively). These indices are useful for determining travel patterns for count sites to group them.

In the count scenario comparison, the 4-6PM TWorTh had slightly lower error than the 5-7PM TWorTh scenario. Considering this, the researchers chose to recommend counting during the 4-6PM evening period. This maintains consistency with the WSBPDP but is not consistent with the National Bicycle and Pedestrian Documentation Project current count timeframe (5-7PM). Similarly, the analysis found lower error to be observed on Sunday rather than Saturday, which is contrary to what other research has found. However, because it is not common practice to conduct weekday counts on Friday or weekend counts on Sunday, these days are not recommended in the guidebook or included in many of the analyzed count scenarios.

Table 29 Mean Absolute Percentage Error (MAPE) for 1-Hour Counts by Day of Week

Hour	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Avg.
7	160	134	110	111	106	109	127	122
8	103	82	72	78	73	78	86	82
9	76	82	**65**	66	72	69	76	72
10	74	79	66	66	66	69	94	73
11	71	74	**65**	66	67	68	96	72
12	67	76	79	**65**	71	76	69	72
13	67	76	66	73	67	73	69	70
14	69	75	**63**	**64**	**63**	**64**	68	67
15	66	66	**61**	**61**	**61**	**60**	**65**	63
16	66	**63**	**59**	**60**	**62**	**59**	68	62
17	73	**61**	**59**	**65**	66	67	84	68
18	95	**65**	73	70	69	75	147	85
Average	82	78	70	70	70	72	87	

Note: The hours with the lowest errors are in bold. The hours in gray shading were chosen by the research team as a proposed new count scenario for WSBPDP in the guidebook.

The thresholds for the Weekend and Midday Ratios were determined after reviewing literature on WWI and AMI, and seek to maintain consistency with previously used methods. For the example Weekend Ratio and Midday Ratio calculations from manual counts in the guidebook, continuous count data were obtained from the Seattle Department of Transportation. Continuous data were used instead of manual counts for two reasons. First, the researchers only had access to manual count data from 7-9AM and 4-6PM TWorTh, which was not sufficient to complete the calculations. Second, continuous data were necessary to verify if the ratios were accurately placing each site into its appropriate group. To do this, actual WWI and AMI were calculated for each site for 2016 using continuous data, and these groups were compared to the groups from the computed Weekend and Midday Ratios from manual counts.

ADJUSTMENT FACTORS AND AADNT

To create WBPDP-specific factors, a different method was used that used for the previous analysis. Based on the literature review, the disaggregate factoring method (also known as “day-of-year” factors) results in the lowest AADNT estimation error (Nosal et al. 2014, Hankey et al. 2014, Budowski et al. 2017). For this reason a disaggregate hour-of-year factoring approach as proposed by Budowski was used to create factors for the State of Washington. The method was applied to Washington State continuous count data for 2015 and 2016, the only years in which sufficient continuous count data were available for the state. In order to make the factors useful, they were tailored to the dates of the 2015 and 2016 WBPDP. These hour-of-year factors are simply calculated as the average of the counts in the hours of interest divided by the AADNT for that year, mode and site (equation provided in Guidebook, page 34). When multiple sites are available in that factor group for that set of hours, the resulting factors are averaged together. All of the factor reported in Table 30 are based on data from at least two continuous counters. To estimate AADNT at a two-hour count site, the average hourly bicycle or pedestrian volume counted should be divided by the appropriate factor from the table. An example is given in the guidebook.

The estimated error based on a two-hour count alone is high. According to the analysis results in Table 28, the error is 45% to 50% MAPE with 64% to 88% standard deviation, indicating a wide range of error using TMG-style factors. Using the hour-of-year disaggregate factoring approach, the error (MAPE) averages at 38% with 41% standard deviation and -2% MPE indicating a slight bias toward under estimating. This is an improvement on the TMG-style method included in the analysis, but still less than the desired accuracy. Overall, for the disaggregate hour-of-year method there is about an 80% chance that the error will be within plus or minus 60%. As summarized in Table 31 the error for 4-6PM Bicycle counts is much lower, with MAPE from 3% to 34% for the Puget Lowland Region. This is an area where more continuous counters and may indicate that with more counters factors are more robust.

Table 30 Adjustment Factors by Factor Group for Washington State 2015 and 2016

		Eastern Washington		Puget Lowlands			
		Noon Activity		Mixed	Noon Activity		Commute
Date	Hour	Bicycle	Pedestrian	Bicycle	Bicycle	Pedestrian	Bicycle
Tuesday, 9/29/15	7-9AM	-	-	-	0.06	-	0.14
	4-6PM	-	-	-	0.12	-	0.17
Wednesday, 9/30/2015	7-9AM	-	-	-	0.07	-	0.15
	4-6PM	-	-	-	0.07	-	0.16
Thursday, 10/1/2015	7-9AM	-	-	-	0.07	-	0.14
	4-6PM	-	-	-	0.12	-	0.16
Tuesday, 9/27/2016	7-9AM	0.15	0.03	0.10	-	0.18	0.26
	4-6PM	0.19	0.16	0.16	-	0.34	0.21
Wednesday, 9/28/2016	7-9AM	0.07	0.08	0.10	-	0.07	0.25
	4-6PM	0.24	0.10	0.17	-	0.12	0.20
Thursday, 9/29/2016	7-9AM	0.07	0.05	0.09	-	0.07	0.31
	4-6PM	0.24	0.12	0.14	-	0.08	0.18

Notes: "-" denotes insufficient data to calculate factors. There were insufficient data for calculating factors for the Eastern Washington Commute (Pedestrian and Bicycle), Eastern Washington Multipurpose Bicycle, and Puget Lowland Commute Pedestrian factor groups. Factors were not calculated for the midday (11AM-1PM TWorTh) and weekend (12-2PM Saturday) counts for 2015 and 2016 because the WSBPDP did not count during those time periods.

Table 31 MAPE for Disaggregate Factors

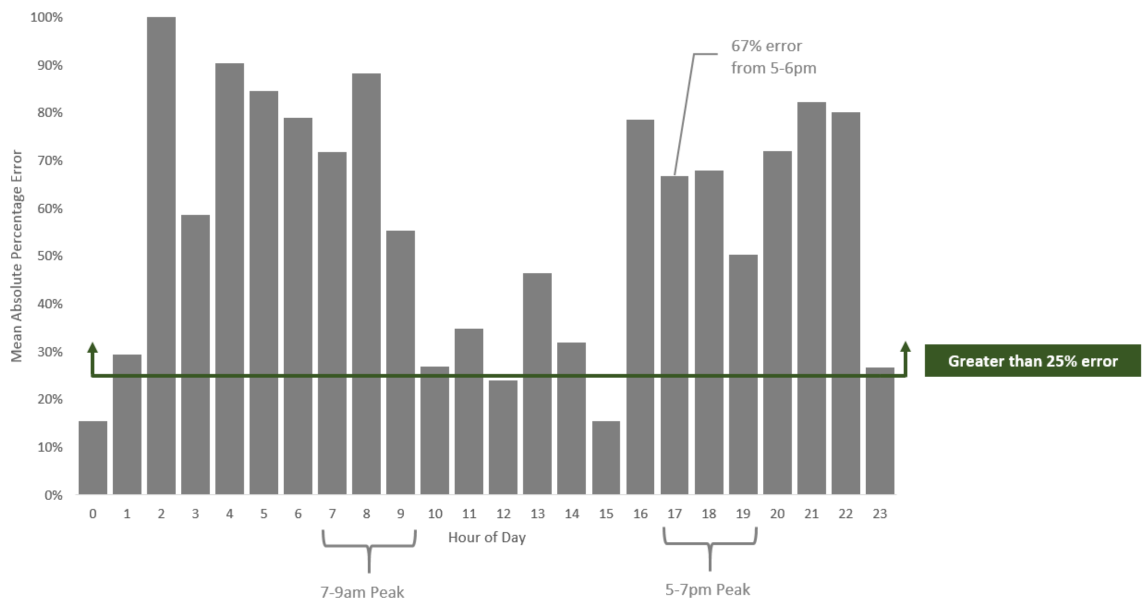
		Eastern Washington		Puget Lowlands			
		Noon Activity		Mixed	Noon Activity		Commute
Year	Hour	Bicycle	Pedestrian	Bicycle	Bicycle	Pedestrian	Bicycle
2015	7-9AM	-	-	-	15%	-	21%
2015	4-6PM	-	-	-	34%	-	15%
2016	7-9AM	47%	39%	34%	-	77%	69%
2016	4-6PM	36%	29%	3%	-	52%	14%

Notes: "-" denotes insufficient data to calculate factors.

Only six factor groups are listed in Table 30. In the future the number of factor groups should expand as more continuous count data become available for the State of

Washington. The four regions for Washington were used from previous research by Nordback et al. (2017): Coast Range, Puget Lowland, Cascades, and Eastern Washington. At the time of the analysis, no continuous count sites were located in the Coast Range or Cascades regions. Each are likely to have their own commute, noon-activity, and mixed pattern groups identified in this research. Factor groups are expected to be different for each mode and may differ by other variables such as land use. This indicates a minimum of 24 groups in the state (4 regions X 3 pattern groups X 2 modes), though there are likely to be more groups if, for example, rural and urban areas have different noon activity patterns or different cities have different patterns.

When factors from the incorrect factor group are applied to a count site, there is greater error. In an example, Figure 26 uses factors for bicycles from the Fremont Bridge in Seattle, a commute pattern in the Puget Lowlands, and test data from the Apple Capitol Loop Trail in Wenatchee, a non-commute pattern in Eastern Washington. This produced highly erroneous results. Even at peak hours, significant undercounting occurs (absolute errors greater than 50%).



The figure above shows AADBT estimation error for Wednesday September 28, 2016 for the Apple Capitol Loop Trail (Eastern Washington, non-commute pattern). When the Fremont Bridge hourly factors from a different factor group (Puget Lowland, commute pattern) are applied to the Apple Capitol Loop data to estimate AADBT, this produces highly erroneous results. For this example, AADBT estimation error is greater than 25% for most hours of the day when the incorrect factor group is used, even at peak hours.

Figure 26 Error from Choosing Incorrect Factor Group

Next Steps

The grouping of the sites is an aspect of the method that might impact the error. In this analysis sites were grouped only by the morning to midday ratio (AMI), but in the future using the Weekend/Weekday Index to group sites with high weekend activity and high weekday activity is likely to also decrease error (Miranda-Moreno et al. 2013).

When the correct morning/midday patterns and weekend/weekday patterns are known, one can group the site appropriately, but how much does the error increase when the incorrect group is chosen, or it changes from year to year? Grouping short duration sites in the wrong factor group is another source of error that should be investigated further.

Another area of future work is examination of the number of continuous counters needed for reducing error.

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APPENDIX A

Review of Estimation and Adjustment Literature

APPENDIX A
REVIEW OF ESTIMATION AND ADJUSTMENT LITERATURE

Author(s), Year	***Summary***	***Facilities***	***Temporal/ Seasonal Adjustment Factors***	***Short-term (<24 hrs)***	***Mid-length (1 day - 1 mo)***	***Long (1 mo-11 mo)***	***Continuous (12+ mo)***	***Permanent (Y/N)***
El Esawey, 2016	Compared methods for computing adjustment factors by AASHTO, El Esawey, and Hankey et al. using the same data set from Vancouver, BC. Proposed a model to determine daily adjustment factors at any region according to the local characteristics of any day. Found that the day-of-year method to be the best of the three methods with 17.5% mean absolute percent error (MAPE).	street network	daily monthly seasonal day-of-week day-of-month day-of-year				x	Y
Fournier et al., 2016	This paper developed and validated a simply calibrated mathematical model for seasonal bicycle demand using a sinusoidal function that generally fits locations with seasonal change.	multi-use trails street network	one month in winter/ summer		x	x	x	Y
Budowski, 2015	Used 10 continuous counters on 5 paths in Winnipeg, Manitoba to develop adjustment factors for short duration bicycle counts.	multi-use trails	hourly day-of-season	x			x	Y
Lindsey, 2015	Installed and validated permanent automated sensors, used portable sensors for short duration counts, developed methods for extrapolating counts, and integrated continuous counts into MnDOT traffic monitoring databases.	multi-use trails street network	day-of-year	x	x	x	x	Y

Author(s), Year	Summary	Facilities	Temporal/ Seasonal Adjustment Factors	Short-term (<24 hrs)	Mid-length (1 day - 1 mo)	Long (1 mo-11 mo)	Continuous (12+ mo)	Permanent (Y/N)
El Esawey, 2014	Developed daily and monthly adjustment factors (DFs and MFs) to estimate accuracy of annual average daily bicycle (AADBT) traffic volumes using 12 continuous count locations in Vancouver, BC. Found that MFs (11.5% error) were superior to using seasonal factors (17% error) and lowest errors were achieved when factors were applied to data from the same year as the development data. Estimating AADBT using only 1 day of bicycle volume using DFs (15% error), MFs (11% error).	street network	daily monthly			x	x	Y
Figliozzi et al., 2014	This project developed a methodology to correct for the use of daily and monthly adjustment factors for bicycle traffic. Used 1 year data on bicycle volume from Portland, Oregon and a linear regression model to express the relationship between estimation error for AADB with adjustment factors and the characteristics of the day of the count, previous days, and weather variables.	separated bikeways	daily monthly	x			x	Y
Gosse & Clarens, 2014	Proposed a framework where a small city with no permanent counting infrastructure and some manual volunteer bicycle counts can reasonably estimate an edge-specific bicycle usage network-wide. Models use spatial, temporal, and weather factors.	street network	hourly weather-related commute-day	x		x		N

Author(s), Year	*Summary*	*Facilities*	*Temporal/ Seasonal Adjustment Factors*	*Short-term (<24 hrs)*	*Mid-length (1 day - 1 mo)*	*Long (1 mo-11 mo)*	*Continuous (12+ mo)*	*Permanent (Y/N)*
Hankey et al., 2014	Proposed reasons to use day-of-year adjustment factors for estimating AADNT. Found that day-of-year factors have less error than the standard scaling method (day of week and month of year) and that error is reduced as the length of short-duration counts is increased, although it reported only marginal increases in accuracy for counts longer than 1 week. Reported that counting on consecutive or nonconsecutive days minimally influences AADNT estimation while reducing labor demands.	multi-use trails	day-of-year month-of-year	x			x	N
Nordback & Sellinger, 2014	The first and second phases of creating a method to calculate Bicycle and Pedestrian Miles Traveled (BMT/PMT) in Washington state. Recommendations for improvements to existing Washington State Bicycle and Pedestrian Documentation Program to provide data for BMT/PMT estimates.	multi-use trails street network	seasonal daily hourly day-of-week monthly weekday	x			x	Y
Nosal et al., 2014	Expansion factor method produces estimates with considerable error. Proposes two AADBT estimation methods using weather and disaggregate models and compares these methods to traditional expansion factor methods. These methods resulted in an average absolute relative error of 11% using 1 day of short-term data.	separated bikeways street network	monthly day-of-week day-of-month weather-related day-of-year (disaggregate)	x	x		x	Y

Author(s), Year	*Summary*	*Facilities*	*Temporal/ Seasonal Adjustment Factors*	*Short-term (<24 hrs)*	*Mid-length (1 day - 1 mo)*	*Long (1 mo-11 mo)*	*Continuous (12+ mo)*	*Permanent (Y/N)*
El Esawey et al., 2013	Discusses grouping bicycle count data using daily factors by weekday/ weekend, weather-specific factors, and different road class factors. Analyzed a large data set from Vancouver, BC and found that the best estimation results of the monthly average cycling volumes were achieved when using daily factors that are disaggregated by weather conditions. Reported that grouping factors by weekdays and weekends provided similar estimation errors. Found that daily adjustment factors degrade in reliability over time, which calls up regular updates every few years.	street network	day-of-week weekday/ weekend weather-related	x	x	x	x	Y
Lindsey et al., 2013	Project included analyses of continuous counts from six locations on multi-use trails in Minnesota using inductive loop detectors and active infrared monitors. Integrated continuous counts with data from vehicular monitoring programs.	multi-use trails	day-of-week monthly	x			x	Y

Author(s), Year	Summary	Facilities	Temporal/ Seasonal Adjustment Factors	Short-term (<24 hrs)	Mid-length (1 day - 1 mo)	Long (1 mo-11 mo)	Continuous (12+ mo)	Permanent (Y/N)
Miranda-Moreno et al., 2013	Analyzed a large data set of cycling volumes from 5 North American cities (Montreal, Ottawa, Vancouver B.C., Portland OR, and San Francisco) and along the Route Verte. Bicycle volume patterns at any location could be classified as utilitarian, mixed utilitarian, mixed recreational, and recreational. Calculated hourly and daily expansion factors. Found seasonal patterns across the four categories and cities were identified. MFs were developed separately for each city. No testing or evaluation of developed factors. Analysis lacked a full year of cycling volume data (only April-November data).	multi-use trails street network separated bikeways cycle tracks	hourly daily monthly				x	Y
Nordback et al., 2013	Used continuous count data and a factoring method to estimate AADBT and AADPT from short-term counts for the Colorado DOT. Found that applying motorized factors to non-motorized counts will likely lead to high estimation error, except in specific situations. Determined 20% average error for one week of short term counts, which can be reduced by counting from May to October when volumes are highest.	multi-use trails street network	hourly daily monthly weather-related	x			x	Y

Author(s), Year	*Summary*	*Facilities*	*Temporal/ Seasonal Adjustment Factors*	*Short-term (<24 hrs)*	*Mid-length (1 day - 1 mo)*	*Long (1 mo-11 mo)*	*Continuous (12+ mo)*	*Permanent (Y/N)*
Nordback et al., 2013	Used continuous bicycle counts from Boulder, CO to estimate AADBT and analyze estimation errors. Found 15% error with 4 weeks of continuous count data to 54% when using only 1 h of data. Analysis recommended one full week of automated counts are the most cost-effective length for short-term counts when the devices are specifically calibrated for bicycle counting. Found that seasons with higher bicycle volume have less variation in bicycle counts and thus more accurate estimates.	multi-use trails street network	hourly daily monthly	x			x	Y
Roll, 2013	Used count data from Eugene, OR and surveys (National Household Travel Survey and Oregon Household Activity Survey) to create and validate time-of-day factors for estimation.	multi-use trails street network	time-of-day		x			N
Lindsey et al., 2012	Proposed reasons to use day-of-year adjustment factors for estimating AADT for non-motorized traffic. Found that day-of-year factors have less error than the standard scaling method (day of week and month of year) and that error is reduced as the length of short-duration counts is increased, although only marginal increases in accuracy for counts longer than 1 week. Reported that counting on consecutive versus nonconsecutive days minimally influences AADT estimation while reducing labor demands.	multi-use trails	day-of-week month-of-year	x			x	Y

Author(s), Year	Summary	Facilities	Temporal/ Seasonal Adjustment Factors	Short-term (<24 hrs)	Mid-length (1 day - 1 mo)	Long (1 mo-11 mo)	Continuous (12+ mo)	Permanent (Y/N)
Niska et al., 2012	Recommended methods for estimating annual change in pedestrian and bicycle traffic using data from Lund and Jönköping, Sweden. Used 200 short-term counts and one permanent counter, supplemented with travel surveys. Reported error for predicting year-to-year change based on the number of randomly selected count sites.	*	weather-related	x			x	*
Nordback, K.L., 2012	Dissertation on estimating AADBT using factoring methods and developing a method to analyze safety at urban intersections using counts from Boulder, Colorado.	multi-use trails street network	hourly daily monthly weather-related peak-hour	x			x	Y
Ginger et al., 2011	Analyzed and validated bicycle count data to determine adjustment factors that could be applied to peak period counts to estimate whole-day and off-peak periods.	multi-use trails street network	day-of-week peak-hour	x	x	x		N
Jones et al., 2010	Includes a literature review, primary data collection, count and survey results, and the development of a predictive model. This project was coordinated with the National Bicycle & Pedestrian Documentation Project.	multi-use trails street network	monthly	x			x	N

Author(s), Year	***Summary***	***Facilities***	***Temporal/ Seasonal Adjustment Factors***	***Short-term (<24 hrs)***	***Mid-length (1 day - 1 mo)***	***Long (1 mo-11 mo)***	***Continuous (12+ mo)***	***Permanent (Y/N)***
Burbidge, 2016	Created a structured approach to conducting non-motorized traffic counts that were most appropriate for counting in Utah. Evaluated existing count methodologies and compiled findings into a guidebook.	multi-use trails street network	N/A	x		x		Y
Vogt, 2015	Thesis examining the effect of missing data from permanent counters on the accuracy of AADT and an analysis of short duration counts on accuracy of AADT estimates using data from Manitoba, Canada.	street network	day-of-week monthly	x			x	Y

* Unable to determine based on available information.

APPENDIX B

Review of Short Duration Counts in Guidebooks

APPENDIX B
REVIEW OF SHORT DURATION COUNTS IN GUIDEBOOKS

Author(s), Year	***What count technologies are recommended for short duration counts?***	***When are counts conducted?***	***How long are short duration counts?***	***Summary***
Clinkscales, 2015	Manual	Sept 29-Oct 1 for 2015 (T,W,Th) Weekday, 7-9am Weekday, 4-6pm	2 hrs	Washington State's bicycle and pedestrian data collection program overview of count dates and times, methodology, and how to complete and submit forms.
Alta Planning + Design, 2004	Manual	Mid-May and mid-September Morning and afternoon "peak-commute" periods on weekdays (T,W,Th). A Saturday count precedes or follows the official count dates.	2 hrs 12 hrs	Established a consistent methodology for bicycle and pedestrian data collection that is used nationwide by planners, governments, and advocates. Created a national database of bicycle and pedestrian survey data and offers free summary reports of annual automatic count data.
Louch et al., 2016	Pneumatic Tubes Video Imaging Infrared (Active and Passive)	-	-	A review of emerging technology and their applications for bicycle and pedestrian counting for transportation professionals to use to guide decision-making.
Huff et al., 2014	Pneumatic Tubes (EcoCounter TUBES used) Passive Infrared (EcoCounter ECOPYRO used)	Sept 5- Sept 25, 2014	20 days	Report presenting automated counts from six locations in the City of Cudahy, CA.

Author(s), Year	***What count technologies are recommended (for short duration counts)?***	***When are counts conducted?***	***How long are short duration counts?***	***Summary***
Burbidge & Marriott, 2016	Manual (Tally sheets, mechanical counting devices, electronic counting devices, video observations) Pneumatic Tubes Video Imaging Infrared (Active and Passive) Radio Beams Laser Scanning (Limited use in US)	Spring and Fall If resources are limited and can only count once per year, do so in mid-September to coincide with NBPDP guidance. Weekday peak, 7-9am and 4-6pm on consecutive weekdays (T,W,Th) Weekday 12-hour, 7am-7pm (choose one weekday, broken into shifts to avoid fatigue) Weekend peak, 10am-2pm on Saturday Weekend 12-hour, 7am-7pm on Saturday (broken into shifts)	Minimum 2 hrs on weekdays and 3 hrs on weekends	Created a structured approach to conducting non-motorized traffic counts that were most appropriate for counting in Utah. Evaluated existing count methodologies and compiled findings into a guidebook.
Griffin et al., 2014	Manual Pneumatic Tubes Infrared	-	2 hr manual counts (NBPDP) 7 days (Nordback) 2 weeks (VTI)	Reported on current projects research and techniques in active transportation monitoring, specifically for studying traffic volumes and behavioral data.

Author(s), Year	*What count technologies are recommended (for short duration counts)?*	*When are counts conducted?*	*How long are short duration counts?*	*Summary*
Lindsey et al., 2014	*Colorado* DOT - Portable Counters and Infrared Local jurisdictions - Boulder County: Pneumatic Tubes *Minnesota* DOT - Manual and automated counts Local jurisdictions - 2h counts following NBPDP protocols, Three Rivers Park District uses Passive Infrared *Oregon* DOT - Encourages only the use of automated counters; does not support manual counts Metro - Manual counts	-	*Colorado* DOT - Recommends minimum 1 week; does not use counts less than 24 h; on-street 48-h bike tube counts planned Local jurisdictions - mostly 1- to 3-h counts; Boulder County: 24-h to 1-week bike counts *Minnesota* DOT - No determined minimum length, research underway Local jurisdictions - mostly 1- to 3-h counts *Oregon* DOT - No determined minimum length, research underway	Detailed efforts by the Colorado, Minnesota, and Oregon Departments of Transportation (DOTs) to establish non-motorized traffic monitoring programs.

Author(s), Year	What count technologies are recommended (for short duration counts)?	When are counts conducted?	How long are short duration counts?	Summary
Ryus et al., 2014	Manual Video Imaging Pneumatic Tubes Temporary Inductive Loops Infrared (Active and Passive) Radio Beam Laser Scanners (battery-powered)	Times with higher activity levels (e.g., summer months on days with good weather). Collecting short counts from different time periods can also improve estimation accuracy.	Extrapolating short-term counts from 2-h counts can provide highly inaccurate results. Recent research suggests 4-7 days of counts will reduce error in an annual volume estimate to >20%.	A comprehensive guidebook on methods (data collection and analysis) and technologies for counting pedestrians and bicyclists. Includes case studies from various U.S. locations.
Ryus et al., 2014	Manual Video Imaging Pneumatic Tubes Temporary Inductive Loops Infrared (Active and Passive) Radio Beam Laser Scanners (battery-powered)	Months representative of average or typical use levels, generally spring and fall. Mid-May and mid-September (NBPDP)	Manual counts for 1- to 3-h on sequential days (NBPDP) Automated counts for 7-14 days	A web-report detailing findings on accuracy and consistency of a range of automatic count technologies. Determined that it is critical for practitioners to calibrate and evaluate accuracy of counters at specific sites to better understand the effectiveness of the counters in capturing non-motorized traffic volumes under site-specific conditions. Includes guidance on how to best collect pedestrian and bicycle volume data.

APPENDIX C

Washington State Contact List for Questionnaires and Interviews

APPENDIX C

WASHINGTON STATE CONTACT LIST FOR QUESTIONNAIRES AND INTERVIEWS

City	Organization	Contact Person
Bellevue	**City of Bellevue Transportation Department**	**Franz Loewenherz**
Bellevue	City of Bellevue Transportation Department	Kyle Potuzak
Bellevue	City of Bellevue Parks and Rec	Geoff Bradley
Bellingham	**City of Bellingham**	**Kim Brown**
Bellingham	Belingham Parks and Recreation	Elizabeth Haveman
Bellingham	Belingham Parks and Recreation	Josh Neyman
Mount Vernon	**Skagit Healthy Communities**	**Elizabeth McNett Crowl**
Olympia	City of Olympia	Sophie Stimson
Olympia	**City of Olympia**	**John Lindsay**
Olympia	City of Olympia	Michelle Swanson
Redmond	**City of Redmond**	**Joel Pfundt**
Redmond	**City of Redmond Parks**	**David Shaw**
Richland	Richland Parks and Recreation	
Seattle	Department of Transportation	Craig Moore
Seattle	Seattle DOT	Brian Dougherty
Spokane	**City of Spokane Street Department**	**Bobby Halbig**
Spokane	Bicycling Advisory Board	Bradley Bleck
Tacoma	Puyallup Watershed Initiative	Liz Kaster
Tacoma	Tacoma Metro Parks	Debbie Terwilleger
Tacoma	City of Tacoma	Josh Diekmann
Tacoma	City of Tacoma	Emily Cambell

City	Organization	Contact Person
Turnwater	City of Turnwater	Paula Reeves
Vancouver	City of Vancouver	Jennifer Campos
Vancouver		**Haley Heath**
Vancouver	City of Vancouver Parks and Recreation	
Yakima	Yakima Parks	
N/A	Washington Bikes	Blake Trask
N/A	Cascade Bicycle Club	Jeff Aken
N/A	**WSDOT**	**Ken Lakey**
N/A	Washington State Parks	Moose Hempel
Note: Bold indicates individuals who were interviewed following the questionnaire.		

APPENDIX D

Washington State Permanent Bike Counter Questionnaire

APPENDIX D

WASHINGTON STATE PERMANENT BIKE COUNTER QUESTIONNAIRE

TREC at Portland State University (PSU) is working with Washington State DOT on a study to understand when is the best time to count bicyclists and pedestrians. For this reason, we are looking for permanent bicycle and pedestrian count data in or near the State of Washington. Have you installed a permanent (installed for at least a year), continuous bike counter in your community? (If not, do you know any other agencies who have one?)

If so, when was the counter installed?

Are you planning to install a permanent, continuous bike counter within the next year?

Which types of bike counter have or are you planning to install?

a. Pneumatic tubes
b. Inductive loop
c. Passive infrared
d. Piezoelectric
e. Video image with automotive conversion
f. other

What is the make and model of the device?

If you have or are planning to install a bike counter, where is it located?

On which type of facility is it located?

a. Across an entire road

b. Within a bike lane

c. On a multi-use paved trail

d. On a soft surface trail

e. On a sidewalk or sidepath adjacent to a street

What are you counting?

just bicyclists

bicyclists and pedestrians together

bicyclists and pedestrians separately

just pedestrians

Has it been validated for accuracy? If so, how? Have you documented this?

Would you be willing to let PSU use your count data for a study sponsored by WSDOT to understand when to conduct short duration bicycle and pedestrian counts?

Do you know of any other jurisdictions who are collecting continuous bicycle and pedestrian count data?

APPENDIX E

Oregon Contact List

APPENDIX E

OREGON CONTACT LIST

City/County	Organization	Contact Person
Portland	Explore Washington Park	JP McNeil
Portland	City of Portland	Peter Koonce
Portland	Metro	Robert Spurlock
Portland	ODOT	Jessica Horning
Portland	TriMet	Jeff Owen
Portland	City of Portland	Tom Jensen
Portland	City of Portland	Roger Geller
Washington County	Washington County	Shelley Oylear

APPENDIX F

Quality Control Reports for Mt. Vernon, WA

Mt. Vernon, WA QC Report

The Mt. Vernon data was collected using The Scanner, a passive infrared detector by JAMAR Technologies[8]. It was provided in per-vehicle format, which includes a timestamp and direction for each pedestrian, bicyclist, or other warm body which enters the detection zone.

The data was processed in Excel by binning the data by hour. Next, a time series was created for the missing bins (e.g., overnight when you expect to observe zeroes) and the counts for these bins were set to zero. Data gaps (e.g., gaps between shuttle files that do not overlap) were excluded from the time series to prevent false zeroes. A single UTC time zone offset was applied to each timestamp as The Scanner does not account for Daylight Savings Time. This processing was necessary to upload the data to Bike-Ped Portal, which does not currently support per-vehicle data types. Since there is no evidence to suggest that these data are reliable by direction, the different flows were combined into a total count for each site.

The data was quality checked for unusual patterns, spikes, zeroes, and unusually low counts using graphs of the total daily volume over time in Excel and the hourly volumes over time in Bike-Ped Portal. Unusually low counts and zeroes where there appeared to be temporary closures to the facility (e.g., holidays, snow events) or other events that we could not explain definitely were not removed. The research team excluded data that appeared to be due to equipment malfunction, vandalism, or insect or other wildlife activity (e.g., spikes at night), but not when they appeared due to special events that genuinely increased pedestrian or bicycle activity. If counts spiked for just one or a few hours and the counts were below 1,000 per hour, we considered this an actual event, even if we could not find the event listed on the internet. However if such a spike was followed by a data gap, we felt this was indicative of a counter malfunction and excluded such spikes. If the high volumes (>200 per hour) continued into late and night and went on for days, we considered this a malfunction of some sort.

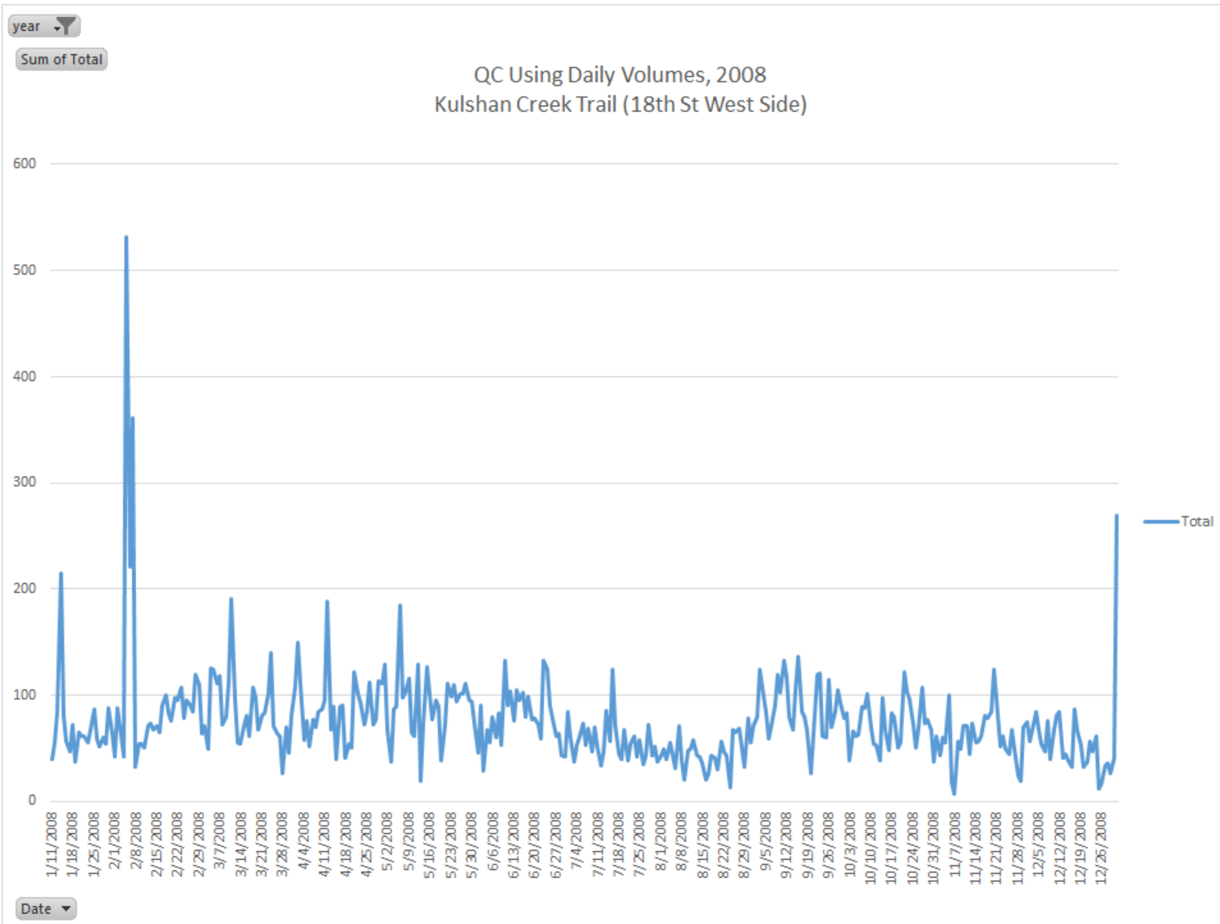
Below are examples of common issues we came across when completing QC for these data sets.

[8] The Scanner Manual. Retrieved from http://www.jamartech.com/files/The_Scanner_Manual.pdf

KULSHAN CREEK TRAIL (18TH ST WEST SIDE)

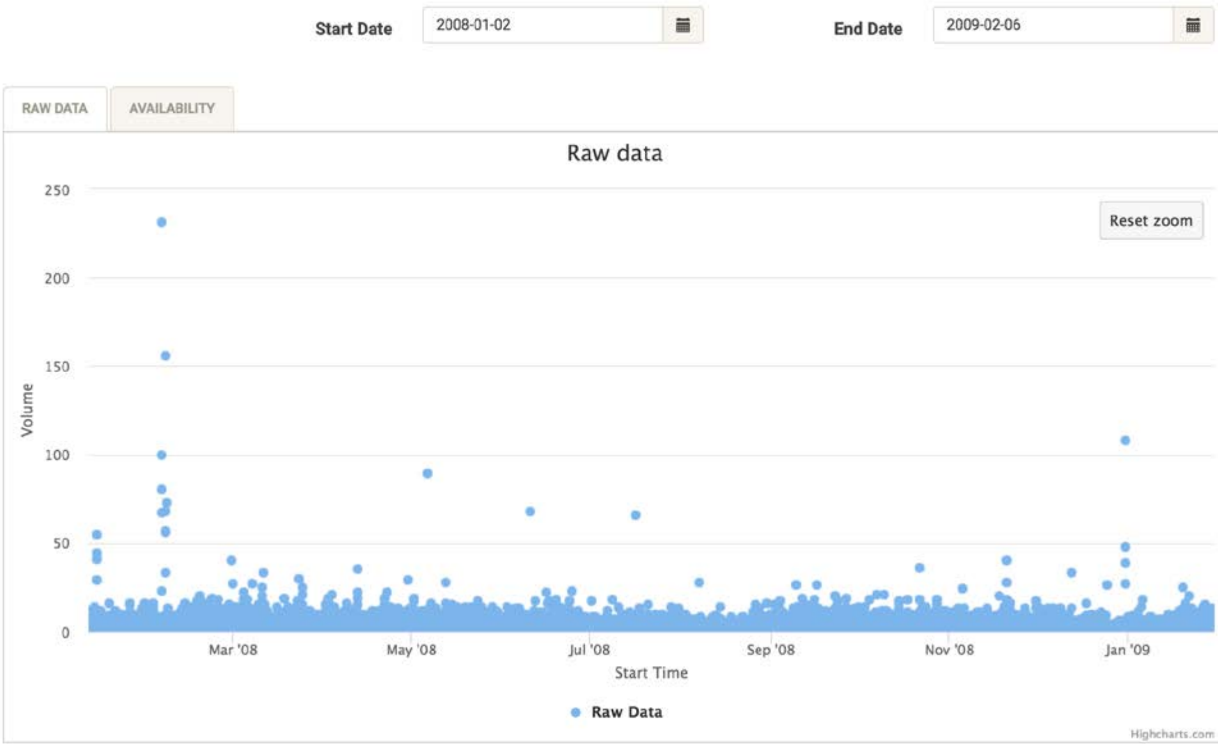
This is a multi-use, paved trail that connects downtown Mt. Vernon with residential and commercial areas to the east. It is 2.5 miles in length, which passes next to several schools, salmon rearing ponds, and parks. Bike commuters, walkers/joggers, and skaters enjoy this trail.[9]

Daily Counts in Excel, Kulshan Creek Trail (18th St West Side)



[9] Mt. Vernon Chamber of Commerce. Retrieved from http://www.mountvernonwa.gov/index.aspx?NID=622

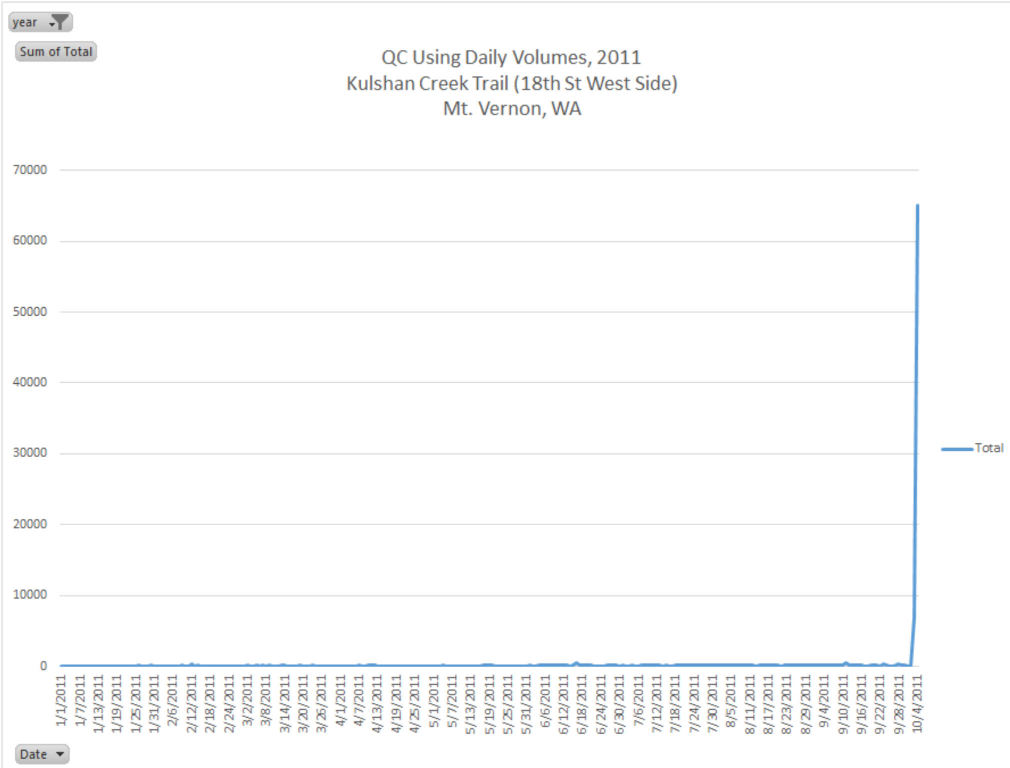
Hourly Counts on Bike-Ped Portal, Kulshan Creek Trail (18th St West Side)



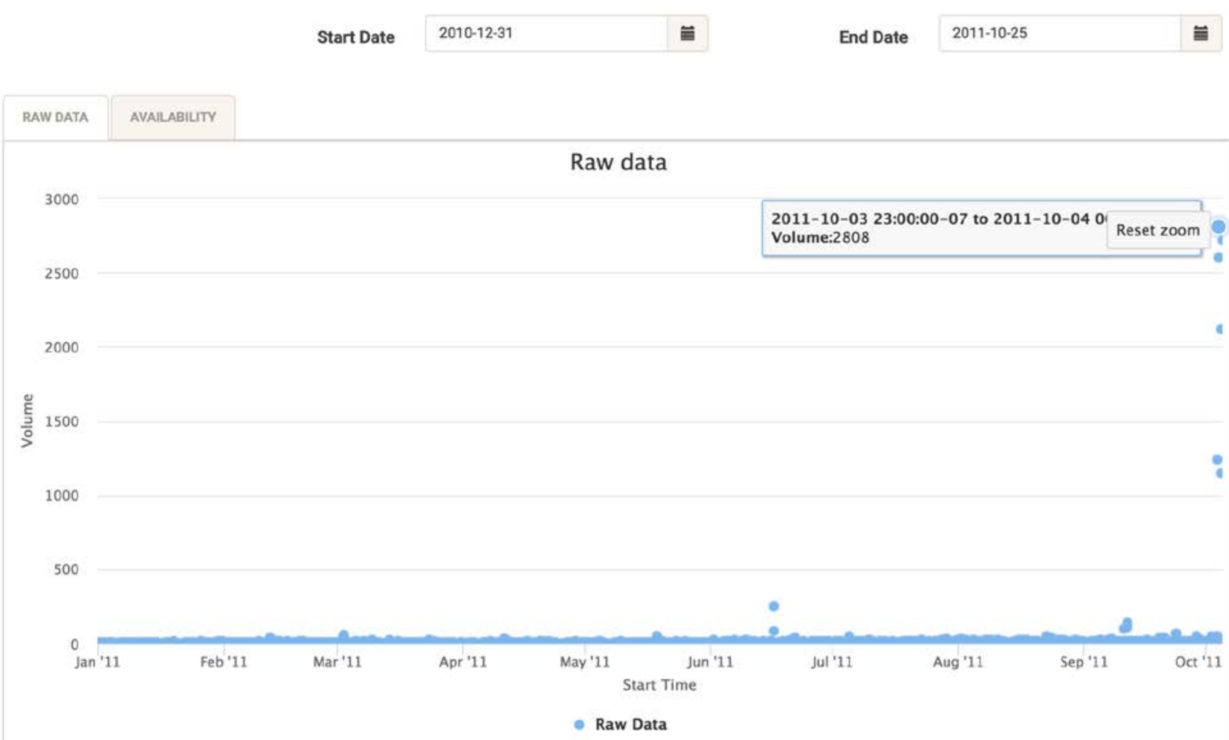
Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
1/14/2008	1/14/2008	215	40-55	unusually high count		OKAY	GOOD
2/5/2008	2/7/2008	532; 221; 361	100-231	unusually high count	special event?	OKAY	GOOD
12/31/2008	12/31/2008	269	108	unusually high count	New Year's Eve	OKAY	GOOD

The 2008 data looks to have some spikes, but there is no reason to believe that this is not real data. The spikes are within a reasonable range of the average daily count and do not appear to be a malfunction of the detector.

Daily Counts in Excel, Kulshan Creek Trail (18th St West Side)



Hourly Counts on Bike-Ped Portal, Kulshan Creek Trail (18th St West Side)

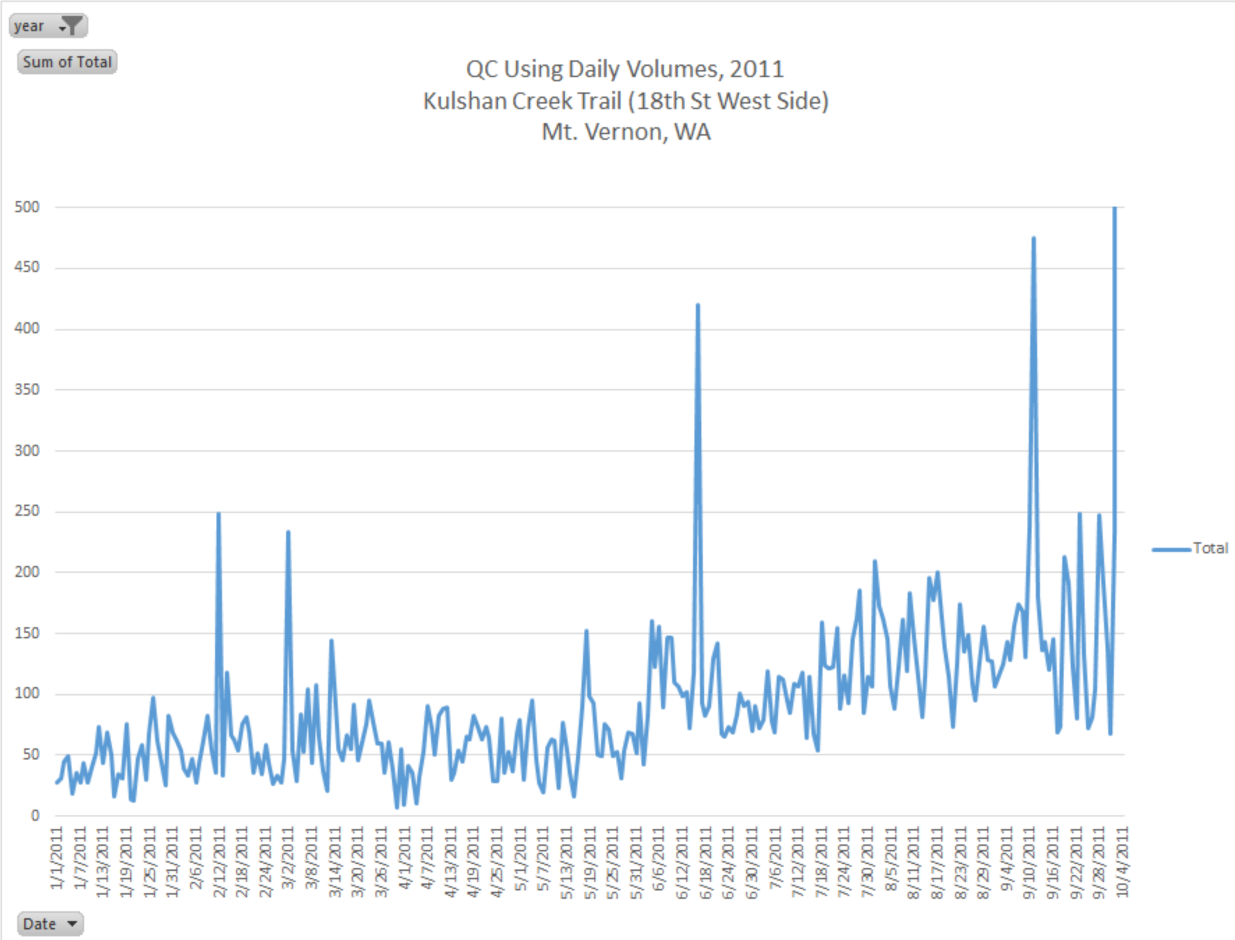


Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
10/3/2011	10/3/2011	6,831	1,200+	unusually high count	malfunction	DON'T USE	BAD
10/4/2011	10/4/2011	65,029	2,500+	unusually high count	malfunction	DON'T USE	BAD

In 2011, the data clearly shows high spikes just before the end of the data set, which is highly suspect. There may have been a malfunction in the detector and therefore this data was not used in our analysis.

Next, the research team zoomed in on this same data to a maximum of 500 on the vertical axis to look for any additional issues.

Daily Counts in Excel, Kulshan Creek Trail (18th St West Side)

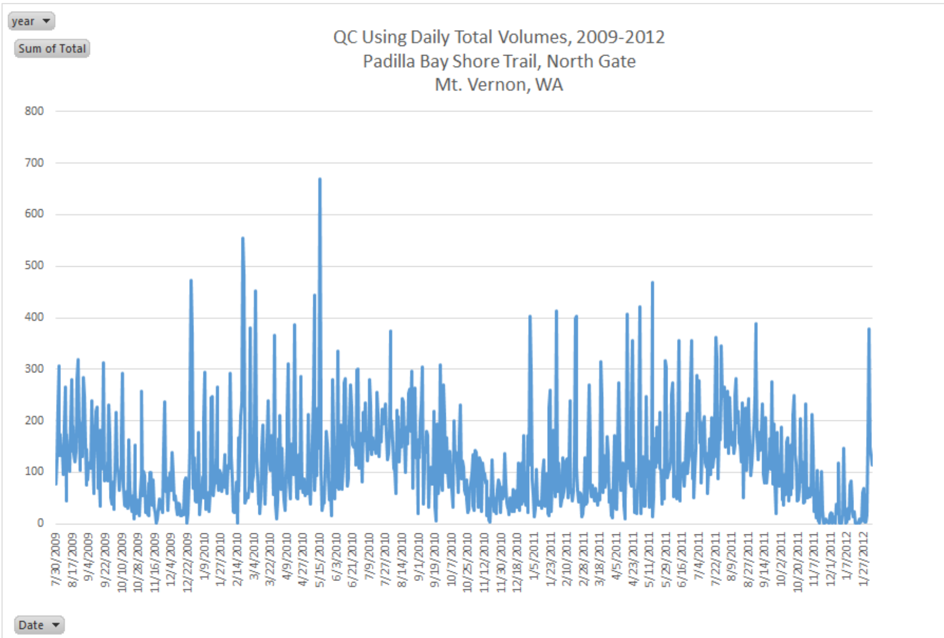


Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
6/16/2011	6/16/2011	420	253	unusually high count	special event?	OKAY	UNSURE
9/11/2011	9/11/2011	475	144	unusually high count	Sunday	OKAY	GOOD

While these spikes are unusually high counts for this data set, they are reasonable for a higher volume weekend or special event and are likely to be real data.

PADILLA BAY SHORE TRAIL, NORTH GATE

The Padilla Bay Shore Trail is a 2.25 mile multi-use path in Skagit County. It is located on top of a dike that is adjacent to the Padilla Bay and Skagit River Estuary.[10]



Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
12/25/2009	12/25/2009	250	50-75	unusually high count	special event?	OKAY	GOOD
12/26/2009	12/26/2009	472	109	unusually high count	special event?	OKAY	GOOD
12/27/2009	12/27/2009	373	55-73	unusually high count	special event?	OKAY	GOOD
2/20/2010	2/20/2010	555	108	unusually high count	Saturday	OKAY	GOOD
2/21/2010	2/21/2010	485	107	unusually high count	Sunday	OKAY	GOOD
3/6/2010	3/6/2010	453	30-80	unusually high count	Saturday	OKAY	GOOD
5/9/2010	5/9/2010	445	30-95	unusually high count	Sunday	OKAY	GOOD
5/15/2010	5/15/2010	670	50-348	unusually high count	Saturday	OKAY	GOOD

Spikes in this data set indicated higher activity on weekends, which is likely for a multi-use trail that is predominantly for recreational use. It is possible that a special event occurred around Christmas that would account for higher counts from 12/25-12/27.

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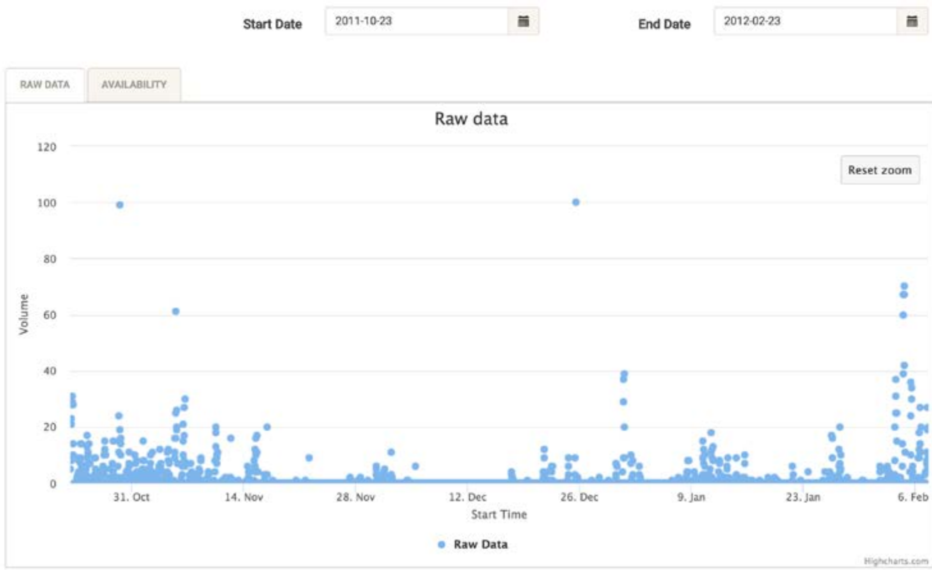
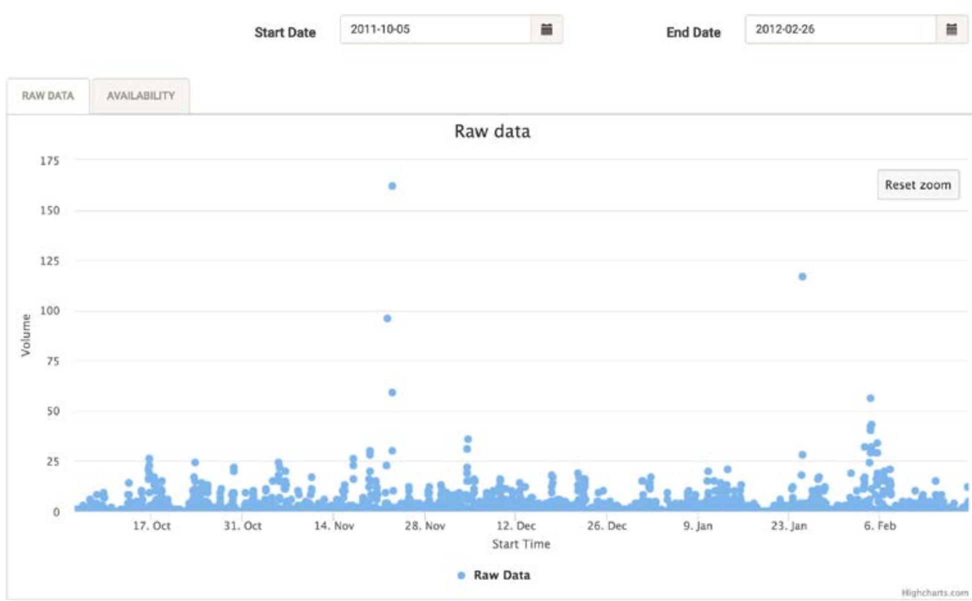
[10] Padilla Bay Shore Trail. Retrieved from http://www.skagitcounty.net/Departments/ParksAndRecreation/parks/padilla.htm

Repeating zeroes from 12/05/2011-12/17/2011 look like a potential trail closure, although the same trail at the South Gate doesn't show these zeroes over this same time period. However, it is not uncommon for there to be lower counts and zeroes during the winter months.

North Gate Hourly Counts, October 2011-February 2012



South Gate Hourly Counts, October 2011-February 2012

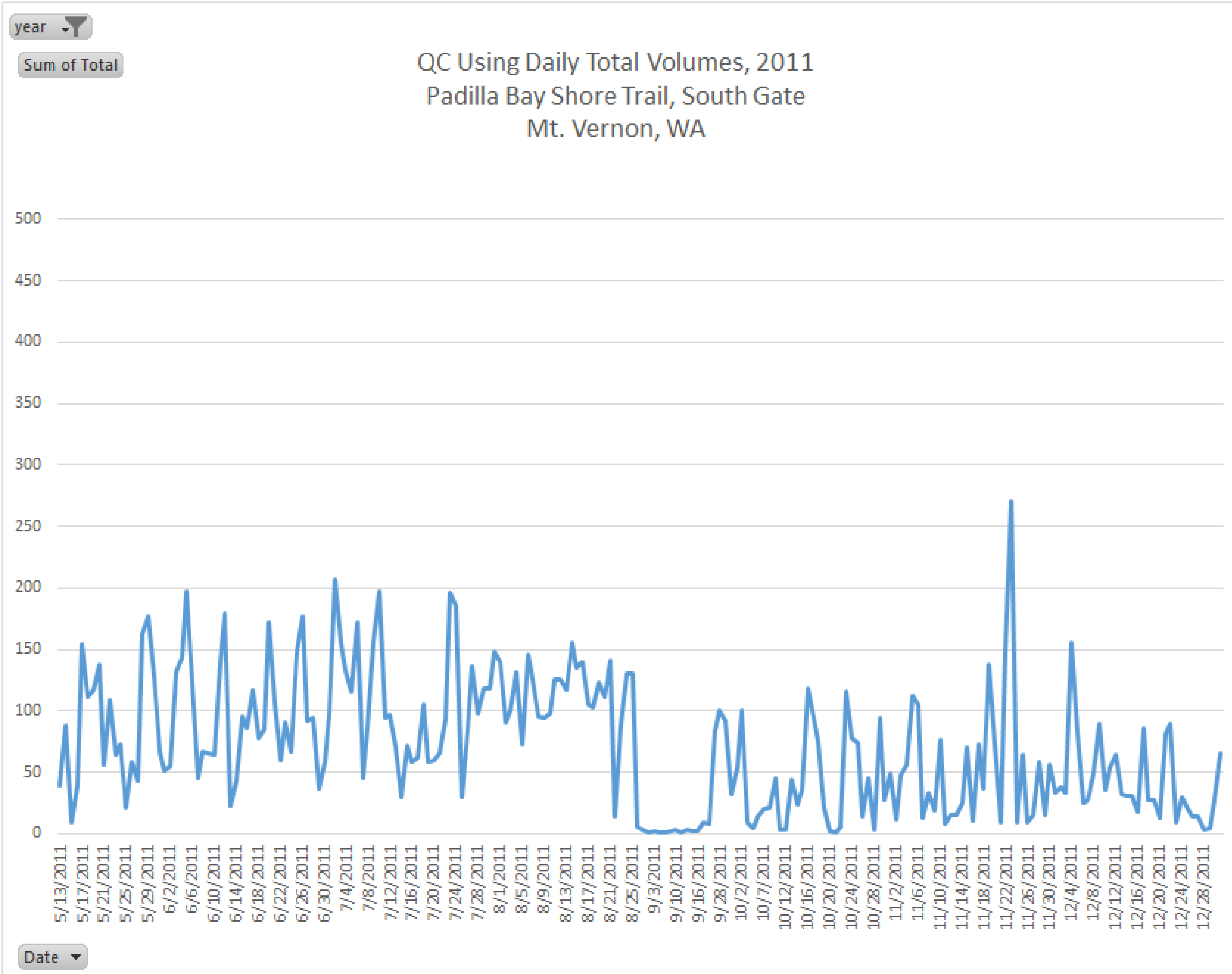


North Gate Consecutive Zeroes from Bike-Ped Portal Upload Screen

segment_name	RunStart	RunEnd	RunLength
Padilla Bay Shore Trail (North Gate)	2011-12-05 14:00:00-08	2011-12-17 10:00:00-08	285
	2011-11-22 06:00:00-08	2011-11-27 05:00:00-08	120
	2012-01-02 16:00:00-08	2012-01-06 14:00:00-08	95
	2011-11-17 15:00:00-08	2011-11-20 12:00:00-08	70
	2012-01-30 13:00:00-08	2012-02-01 12:00:00-08	48

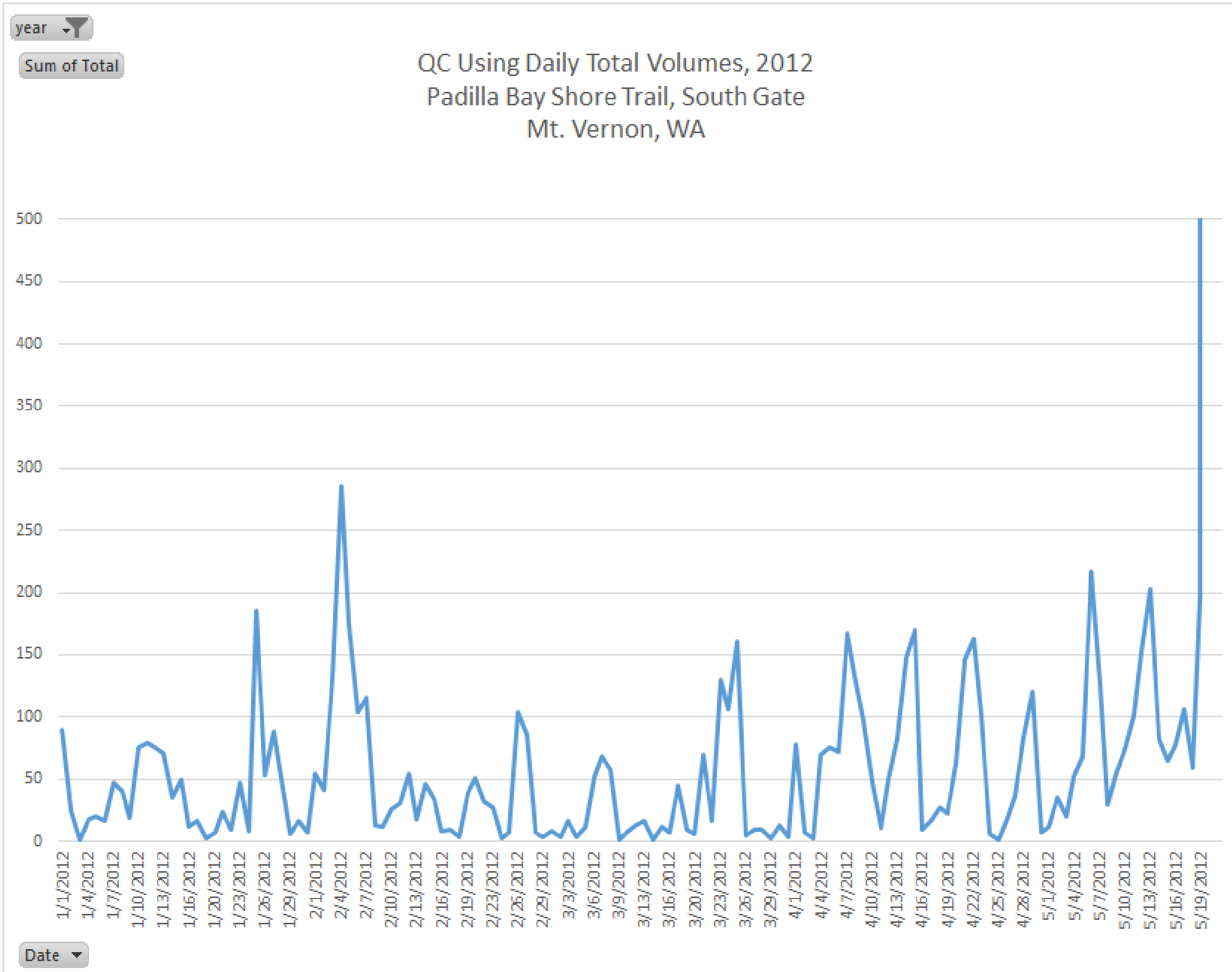
Bike-Ped Portal's automated checks include looking for runs of consecutive zeroes. For this site, the run of 285 hours of consecutive zeroes was removed.

<u>**PADILLA BAY SHORE TRAIL, SOUTH GATE**</u>



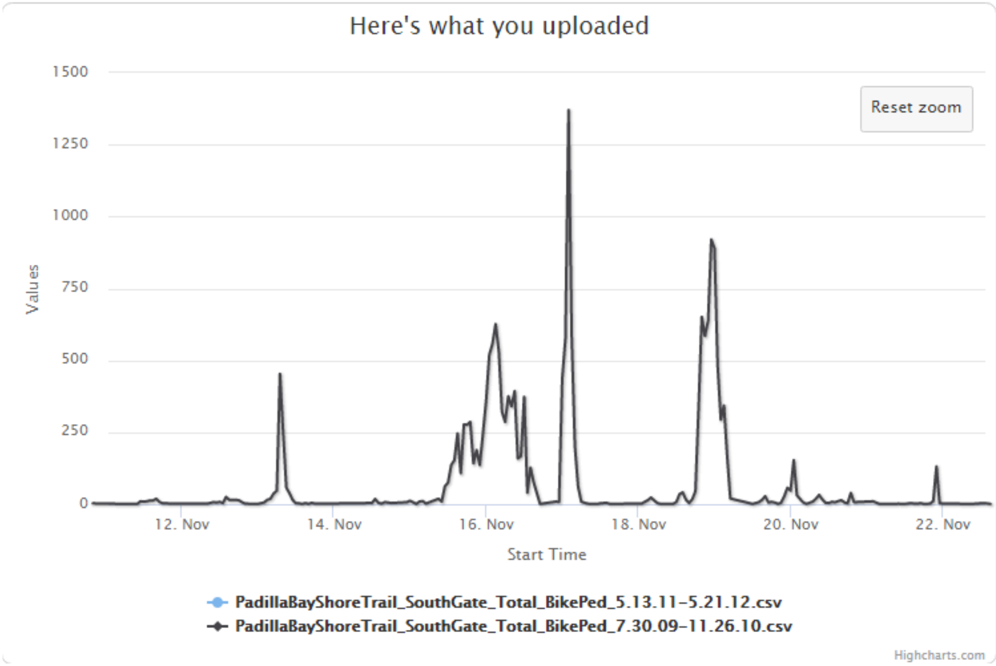
Start	End	Daily Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
8/26/2011	9/26/2011	1-9	unusually low counts	construction/closure?	OKAY	UNSURE

Unusually low counts in late August through September of 2011 appear as a dip in the graph. It is likely that there was construction on the trail or a closure for some reason that resulted in low counts.



Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
5/20/2012	5/20/2012	41,953	1000+	unusually high count	end of data	DON'T USE	BAD
5/21/2012	5/21/2012	28,125	1000+	unusually high count	end of data	DON'T USE	BAD

In May 2012, the data spikes to 41k and then 28k the next day just prior to the end of the data set. This is likely to be a detector malfunction.

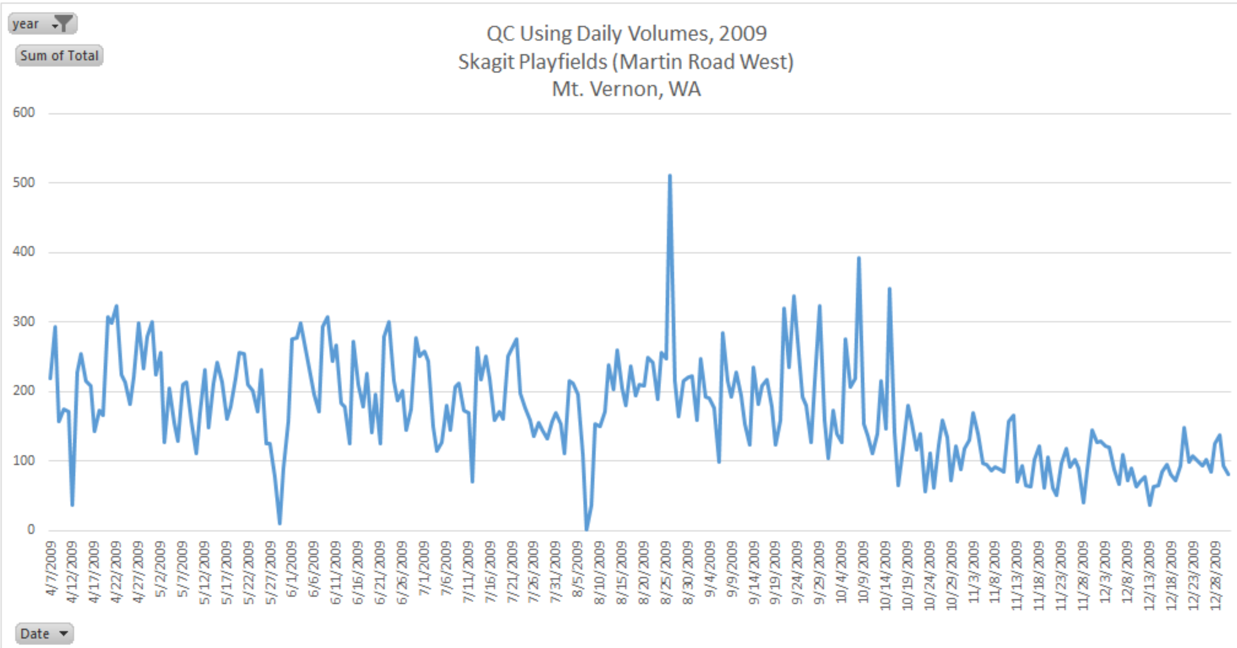


Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
11/15/2009	11/15/2009	2393	286	unusually high counts at night, 286 at 7pm	Sunday	DON'T USE	UNSURE
11/16/2009	11/16/2009	5270	626	unusually high counts at night, 626 at 3am	Monday	DON'T USE	UNSURE
11/17/2009	11/17/2009	3248	1370	unusually high count at night, spike at 2am (1370)	Tuesday	DON'T USE	UNSURE
11/18/2009	11/18/2009	3354	920	unusually high counts at night, 920 at 23:00	Wed	DON'T USE	UNSURE
11/19/2009	11/19/2009	2360	890	unusually high counts at night, 890 at midnight	Thurs	DON'T USE	UNSURE

In mid-November 2009, the research team found five days where unusually high counts (e.g., hourly counts ranging from 286-1370) occurred at night. There is not enough evidence to conclude the cause of these high counts, but a reasonable guess is that they could be attributed to wildlife.

SKAGIT PLAYFIELDS (MARTIN ROAD WEST)

The Skagit Playfields are located next to the Skagit Community College. The fields may be reserved from March to October and the picnic shelter may be reserved from May to September for use.[11] A multi-use, unpaved trail runs along the perimeter of the fields.



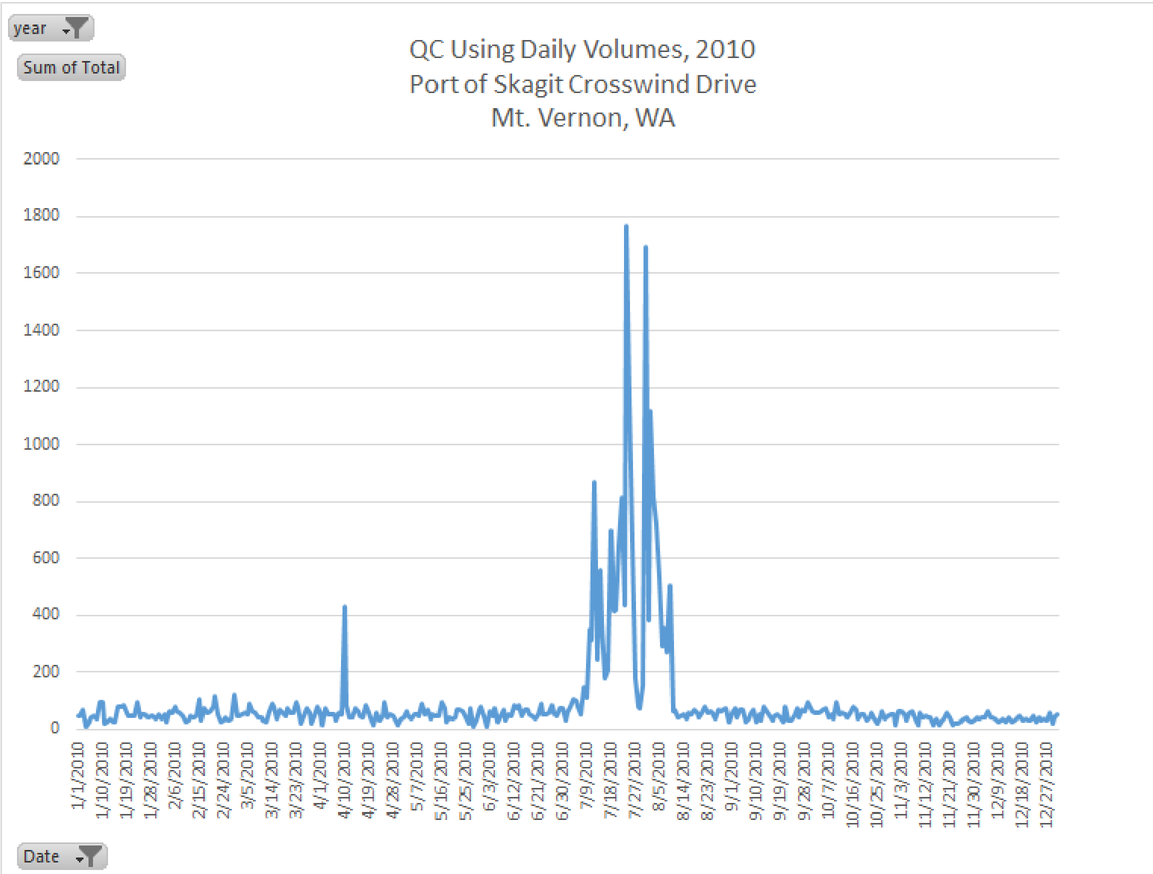
Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
4/12/2009	4/12/2009	37	0-2	unusually low counts, typical 100-300		OKAY	UNSURE
5/29/2009	5/29/2009	10	0-2	unusually low counts, typical 100-300		OKAY	UNSURE
8/7/2009	8/7/2009	2		unusually low counts, typical 100-300		OKAY	UNSURE
8/8/2009	8/8/2009	37		unusually low counts, typical 100-300		OKAY	UNSURE

Very low dips in April, May, and August when counts are regularly between 100-300 per day. While we are unsure of what may have caused these unusually low counts, it is likely to be real data.

[11] Retrieved from http://www.skagitcounty.net/Departments/ParksAndRecreation/parks/playfields.htm

PORT OF SKAGIT CROSSWIND DRIVE

Located next to the airport, the Port of Skagit trail system spans 10 miles and is composed of wide, gravel trails.[12] These trails are popular for walking, running, and biking.



Start	End	Daily Count	Hourly Count	PSU Observations	Potential Cause	OKAY/ DON'T USE	GOOD/ BAD/ UNSURE
7/8/2010	8/9/2010	74-1691		unusual data and spikes	start of shuttle file	DON'T USE	UNSURE

This data was flagged as suspect because it differs largely from the usual pattern that tends to be with 50-100 people per day. The large spikes and dips in the counts are suspect, especially since the suspect data ranges over the period of one month. Additionally, some of the larger hourly counts occur overnight, which would be unlikely.

[12] Retrieved from http://www.beactiveskagit.org/uploads/Port%20Trail%20System.pdf

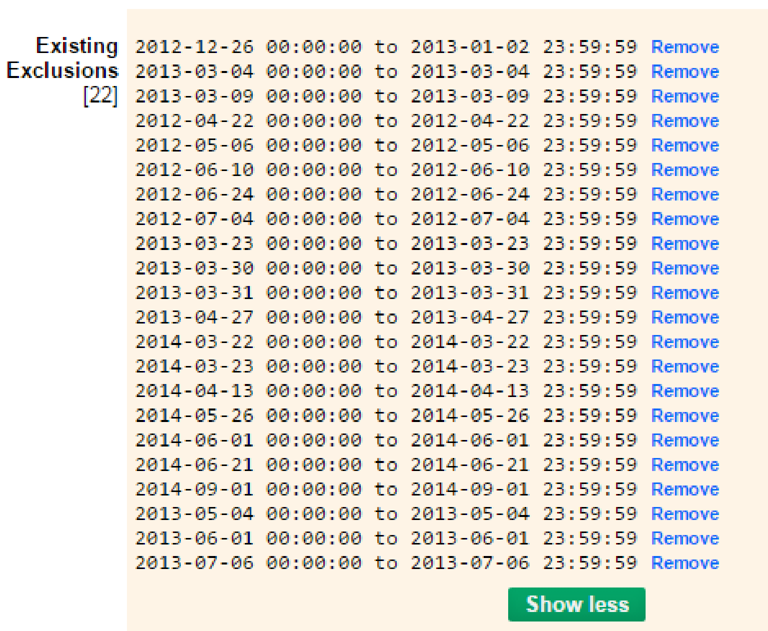
APPENDIX G

Quality Control Reports for Portland, OR

Sites Provided by Metro in Portland, OR QC Report

The Metro data was collected using TRAFx Infrared Trail Counters by three different jurisdictions: Metro, Tualatin Hills Park & Recreation District (THPRD), and Explore Washington Park. These detectors count pedestrians, bicyclists, and any warm body that enters the detection zone. The raw data was provided through TRAFx DataNet, which is binned into hourly data. This data was adjusted for Daylight Savings Time and uploaded to Bike-Ped Portal.

The data was quality checked for unusual patterns, spikes, unusually low counts, and zeroes using graphs of the volume over time found on Bike-Ped Portal. Unusually low counts and zeroes where there appeared to be temporary closures to the facility (e.g., holidays, snow events) were not removed. On DataNet, users were able to indicate data exclusions by day (but not by hour), which the research team considered excluding from the analysis. If the research team used these exclusions when they appeared to be excluded due to equipment malfunction, vandalism, or insect or other wildlife activity, but not when they appeared due to special events that genuinely increased pedestrian or bicycle activity.

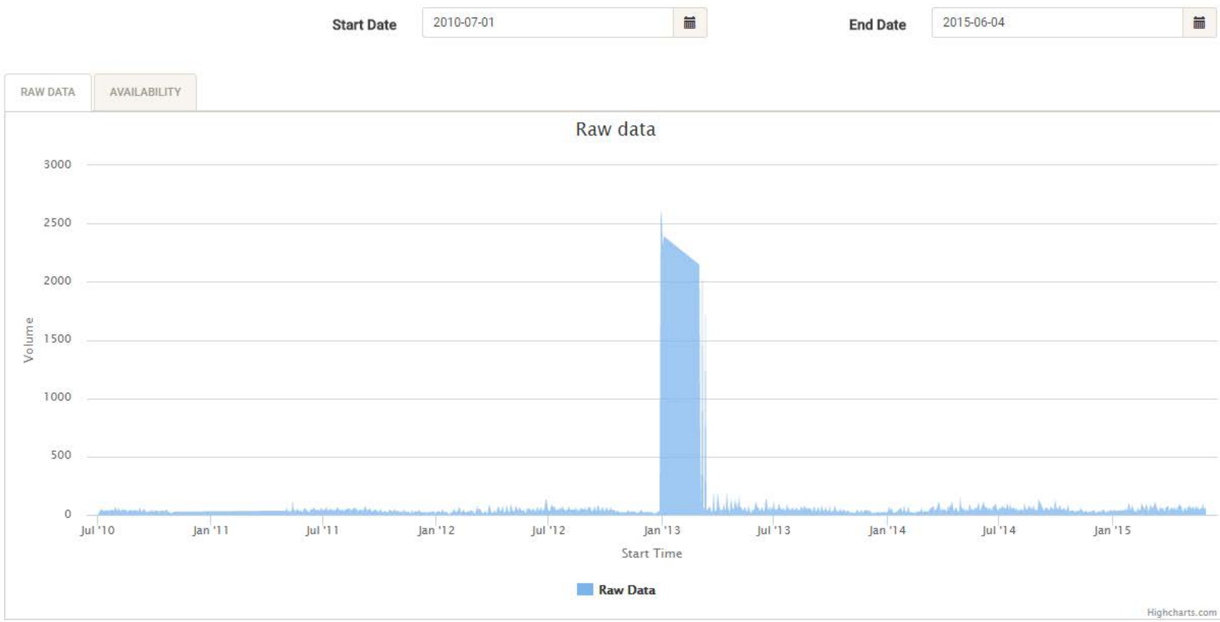


Example of data exclusions for Fanno Creek at Hall found on TRAFx DataNet

Below are examples of common issues we came across when completing QC for these data sets.

FANNO CREEK AT HALL (SITE ID: 15)

This data is from a paved bike/pedestrian path that is part of the Fanno Creek Trail. The count was taken close to Hall Blvd where the path curves to briefly run parallel to the road before crossing. This facility is close to a retail area.



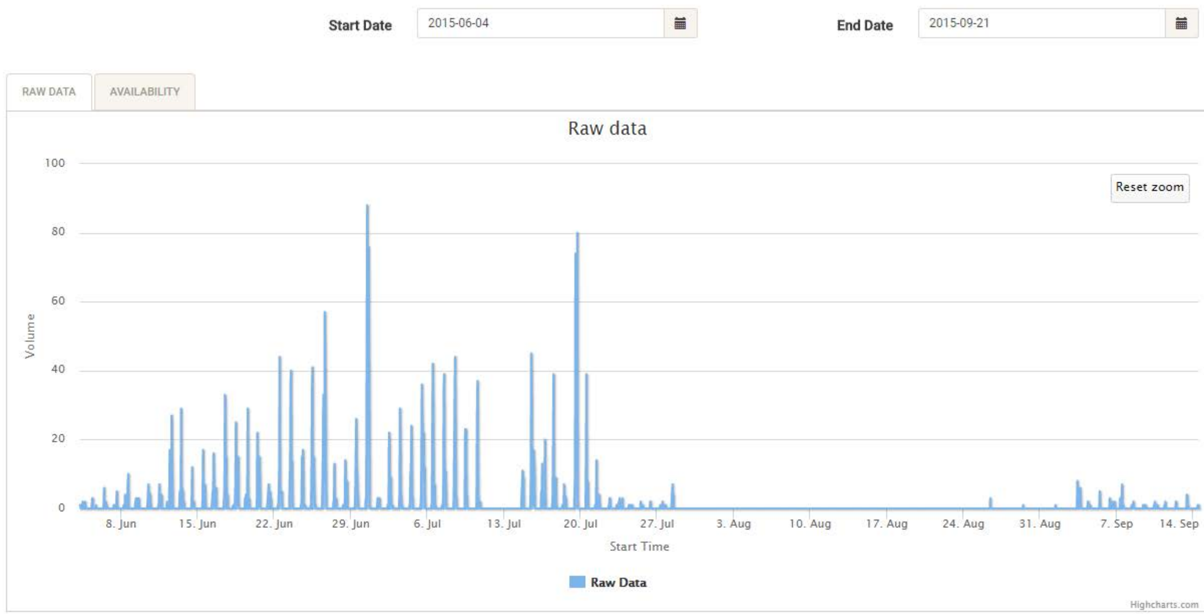
Above is a graph of all available raw data for Fanno Creek at Hall found on Bike-Ped Portal from July 1, 2010 to June 4, 2015. It shows a series of spikes and a data gap following the spikes.

Below is a zoomed-in view of this same data from December 2012 to March 2013. Spikes occur before a data gap from January 3rd to March 3rd. Normally, this data ranges from 100-200 daily counts. This is likely an issue with the detector’s battery.

Start	End	Daily Count	Hourly Count	PSU observations	Exclusion on DataNet	Cause?	OKAY /DON'T USE	GOOD/ BAD/ UNSURE
12/26/2012	3/9/2012	spikes 1000-2600		series of spikes and a data gap from Jan 2, 2013- Mar 1, 2013		probably battery	DON'T USE	UNSURE
12/26/2012	1/2/2013	1808		spike	Y		DON'T USE	UNSURE
3/4/2013	3/4/2013	4056		spike	Y	Monday	DON'T USE	UNSURE
3/9/2013	3/9/2013	3312		spike	Y	Saturday	DON'T USE	UNSURE
3/23/2013	3/23/2013	615		seasonal variation	Y	Saturday	OKAY	UNSURE

BURLINGTON CREEK (SITE ID: 3)

This is site a pedestrian trail along a heavily forested, gravel road. The road is closed to motor vehicles and is located off of McNamee Rd.

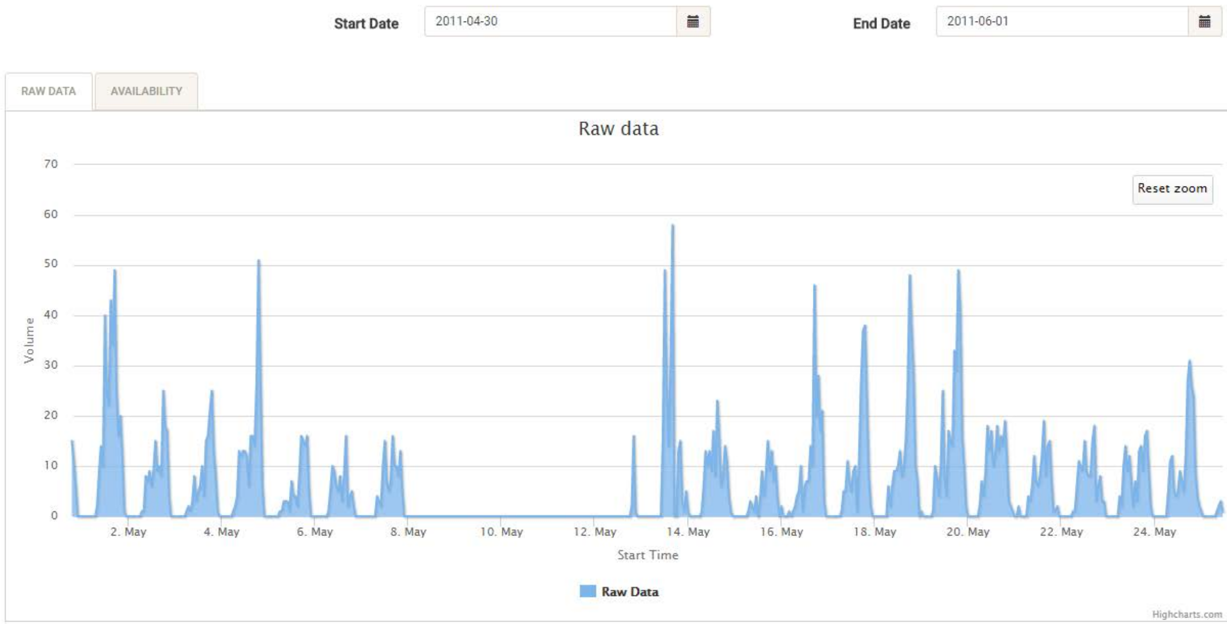


Start	End	Daily Count	Hourly Count	PSU observations	Exclusion on DataNet	Cause?	OKAY /DON'T USE	GOOD/ BAD/ UNSURE
7/11/2015	7/13/2015	0	0	zeroed out	N	Possible reasons: construction closure, vandalism or equipment move.	DON'T USE	UNSURE
7/29/2015	9/15/2015	mostly 0	0	zeroed out	N	Possible reasons: construction closure, vandalism or equipment move.	DON'T USE	UNSURE

The data is suspect because repeated zeroes are present in mid-July 2015 for two days and then again in late July through mid-September.

HAZELDALE PARK (SITE ID: 26)

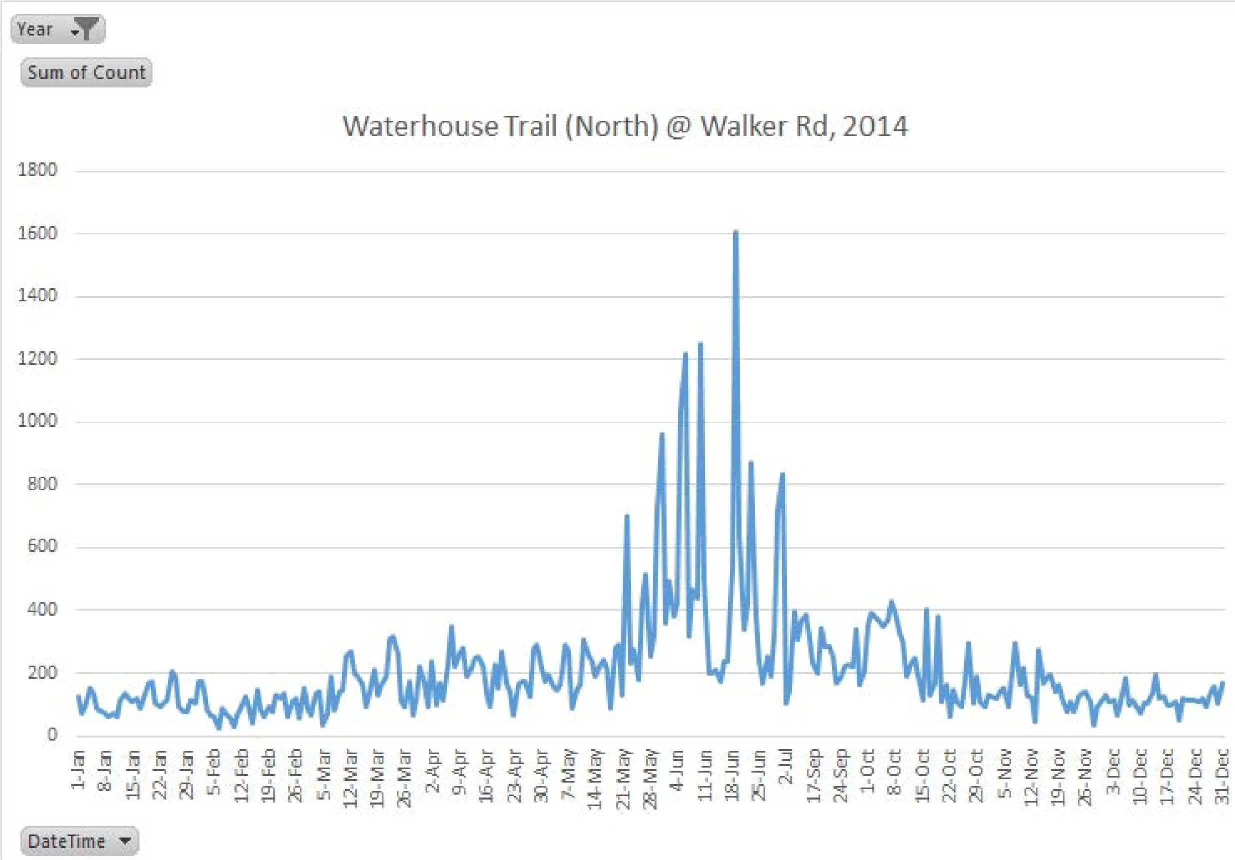
This site is a paved path that connects a residential area to Hazeldale Park. The count is conducted underneath trees and includes pedestrians and bicyclists. There are also sports facilities nearby.



Start	End	Daily Count	Hourly Count	PSU observations	Exclusion on DataNet	Cause?	OKAY /DON'T USE	GOOD/ BAD/ UNSURE
5/8/2011	5/12/2011	0-12		zeroed out	N		DON'T USE	UNSURE

This is an example of another site where zeroes are present for multiple days, this time in May. This could be a potential closure, although there was no evidence to confirm this.

WATERHOUSE TRAIL (NORTH) @ WALKER RD



Start	End	Daily Count	Hourly Count	PSU observations	Exclusion on DataNet	Cause?	DON'T USE	GOOD/ BAD/ UNSURE
5/22/2014	5/22/2014	702		Thursday, unusually high counts	Y		OKAY	UNSURE
5/27/2014	5/27/2014	515		Tuesday, unusually high counts	Y		OKAY	UNSURE
5/30/2014	5/31/2014	720; 963		Fri-Sat, unusually high counts	Y		OKAY	UNSURE
6/2/2014	6/2/2014	492		Monday, unusually high counts	Y		OKAY	UNSURE
6/5/2014	6/6/2014	1035; 1217		Thurs-Fri, unusually high counts	Y		OKAY	UNSURE
6/10/2014	6/11/2014	1252; 495		Tues-Wed, unusually high counts	Y		OKAY	UNSURE

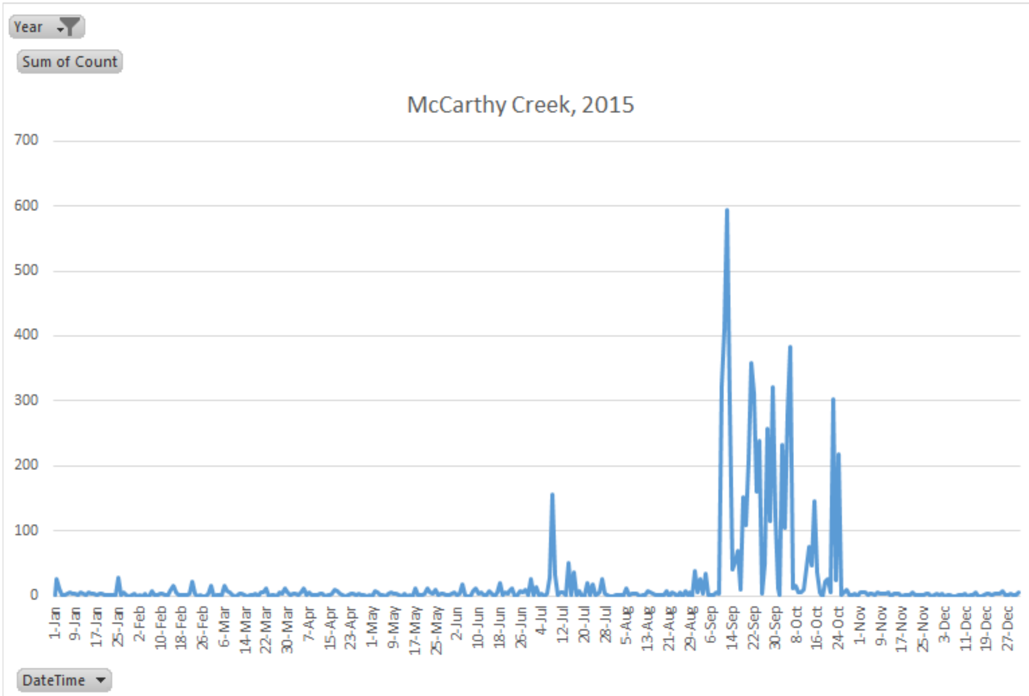
6/18/2014	6/20/2014	536; 1605; 637	309	Spike; unusually high counts followed by gap, Wed-Fri	Y		OKAY	UNSURE
6/23/2014	6/23/2014	874		Monday, unusually high counts	Y		OKAY	UNSURE
6/30/2014	6/30/2014	717		Monday, unusually high counts	Y		OKAY	UNSURE
7/1/2014	7/1/2014	836		Tuesday, unusually high counts	Y		OKAY	UNSURE
7/3/2014	9/11/2014	DATA GAP	data gap	data gap	N		DON'T USE	N/A

Waterhouse Trail connects to the Rock Creek Regional Trail. It is a greenway surround by residential areas in a suburban setting. The hourly counts look okay around the morning peak (see examples for 5/22 and 5/27 below) and are reasonable counts for summer months. However, these counts were flagged as suspect originally because these patterns are very different from other years in the data set, occur before a data gap, and the spikes were excluded by the data provider (THPRD). Upon consulting the data provider the team was unable to secure documentation or reasons for why the data was originally excluded on DataNet, and therefore kept the data for our analysis because it was not unreasonable.

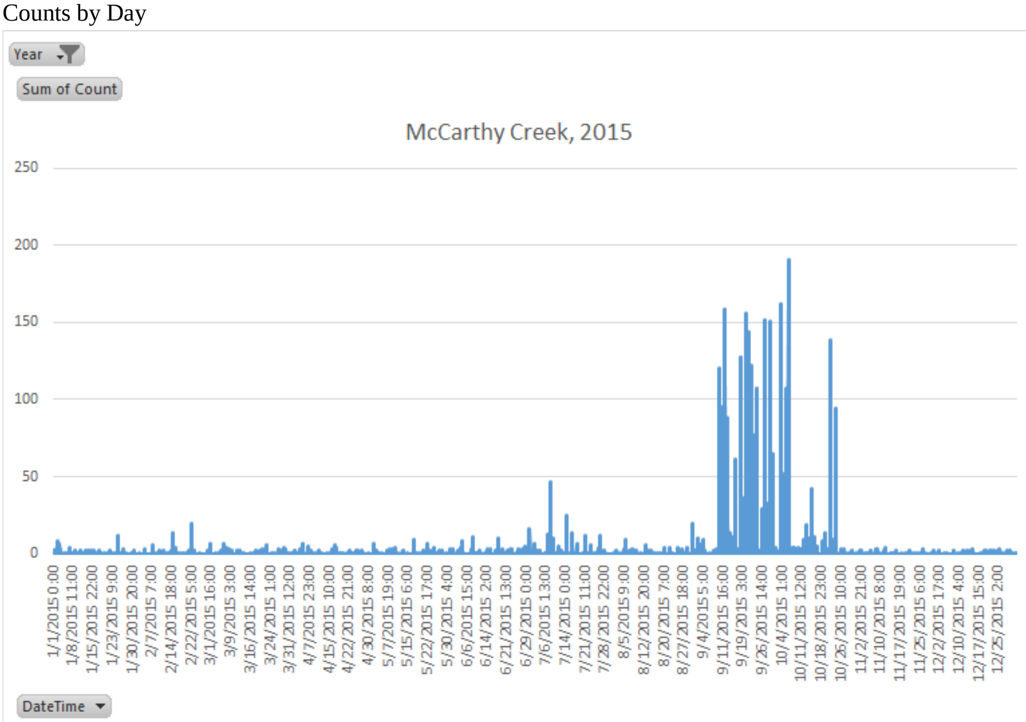
Date Time	Count
5/22/2014 0:00	0
5/22/2014 1:00	0
5/22/2014 2:00	0
5/22/2014 3:00	0
5/22/2014 4:00	0
5/22/2014 5:00	0
5/22/2014 6:00	25
5/22/2014 7:00	94
5/22/2014 8:00	81
5/22/2014 9:00	111
5/22/2014 10:00	66
5/22/2014 11:00	85
5/22/2014 12:00	43
5/22/2014 13:00	29
5/22/2014 14:00	22
5/22/2014 15:00	30
5/22/2014 16:00	24
5/22/2014 17:00	15
5/22/2014 18:00	29
5/22/2014 19:00	35
5/22/2014 20:00	6
5/22/2014 21:00	2
5/22/2014 22:00	0
5/22/2014 23:00	5

Date Time	Count
5/27/2014 0:00	1
5/27/2014 1:00	1
5/27/2014 2:00	0
5/27/2014 3:00	1
5/27/2014 4:00	1
5/27/2014 5:00	9
5/27/2014 6:00	12
5/27/2014 7:00	10
5/27/2014 8:00	27
5/27/2014 9:00	125
5/27/2014 10:00	80
5/27/2014 11:00	45
5/27/2014 12:00	51
5/27/2014 13:00	20
5/27/2014 14:00	19
5/27/2014 15:00	22
5/27/2014 16:00	17
5/27/2014 17:00	13
5/27/2014 18:00	24
5/27/2014 19:00	28
5/27/2014 20:00	7
5/27/2014 21:00	2
5/27/2014 22:00	0
5/27/2014 23:00	0

MCCARTHY CREEK



Counts by Day



Counts by Hour

Start	End	Daily Count	Hourly Count	PSU observations	Exclusion on DataNet	Cause?	DON'T USE	GOOD/ BAD/ UNSURE
9/10/2015	10/24/2015	150-600	100-200	Spikes; unusually high counts	N	Could be school related use.	USE	UNSURE

This site has such low counts regularly that seeing any activity seems irregular. Sudden activity in September could be attributed to a school pattern. The weather is still nice in the fall, but activity then drops off again when the weather gets colder and rainier. The research team decided to use this site for the analysis, but leave it out of the factoring because it has such an odd pattern.

Miscellaneous Sites in Portland, OR QC Report

The Portland data was collected using a variety of counting technologies including inductive loops, pneumatic tubes, and infrared from Portland Bureau of Transportation (PBOT), Metro, the regional metropolitan planning agency for Portland, the Oregon Department of Transportation (ODOT), and TriMet.

The data was quality checked for unusual patterns, spikes, zeroes, and unusually low counts using graphs of the volume over time in Bike-Ped Portal, Eco-Visio, and PORTAL, a data archive for the Portland-Vancouver metro region. Unusually low counts and zeroes where there appeared to be temporary closures to the facility (e.g., holidays, snow events) were not removed. The research team excluded data that appeared to be due to equipment malfunction, but not when they appeared due to special events that genuinely increased pedestrian or bicycle activity.

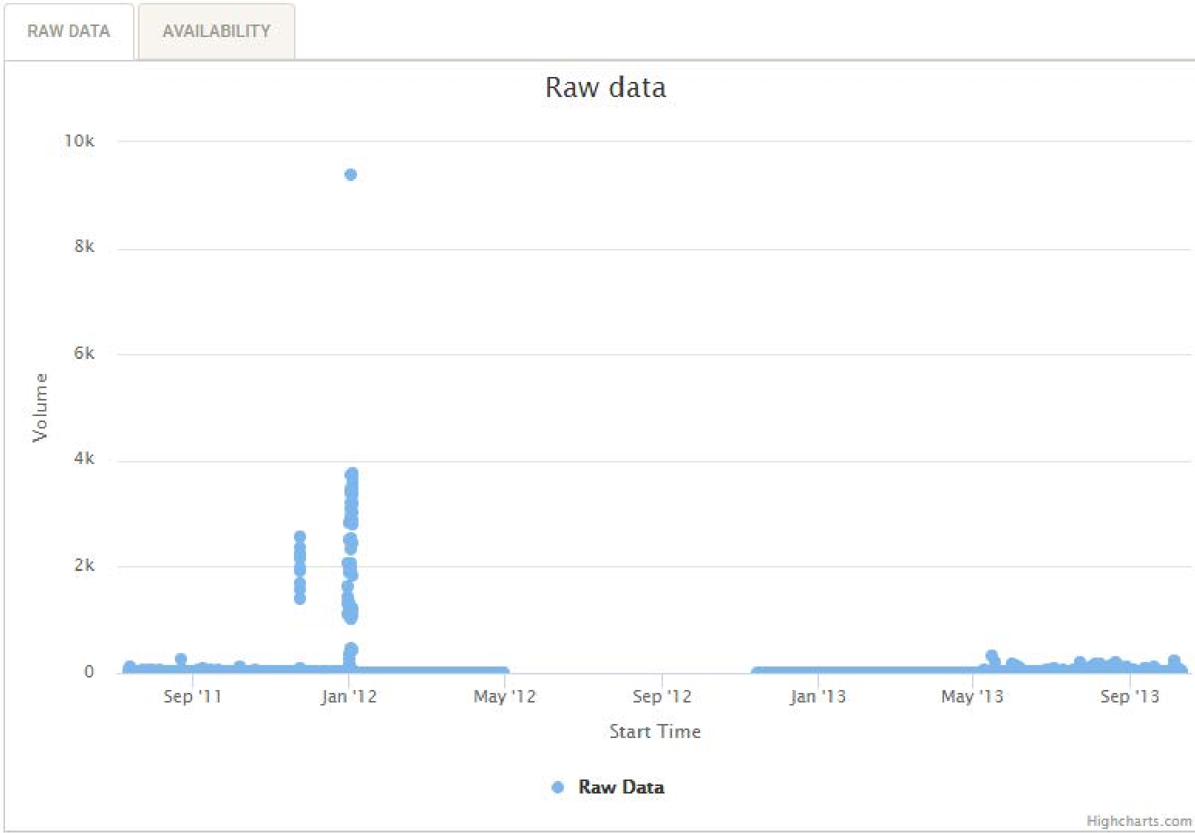
If counts spiked for just one or a few hours and the counts were below 1,000 per hour, we considered this an actual event, even if we could not find the event listed on the internet. However if such a spike was followed by a data gap, we felt this was indicative of a counter malfunction and excluded such spikes. If the high volumes (>200 per hour) continued into late and night and went on for days, we considered this a malfunction of some sort.

I-205 MULTI-USE PATH ON YAMHILL ST.

Data provided by ODOT for this site was available from June 2014 to May 2016. There are four data gaps in February and March of 2015 and 2016. January 4, 2016 has unusually low counts due to a snow event.

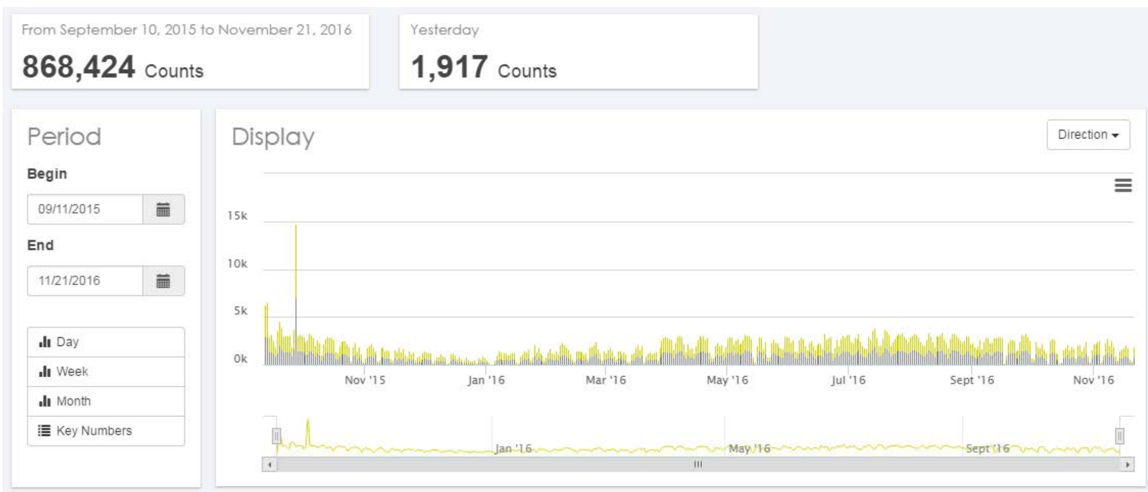
TONQUIN TRAIL

This trail is located in Wilsonville and is managed by Metro. The data is collected using an Eco-MULTI, which had various installation problems. A long string of zeroes occurs after a spike and before a data gap. Following this data gap, another long string of zeroes is observed. These observations occur for both the pedestrian and bicycle data.



RAW DATA
AVAILABILITY
Raw data
Volume
10k
8k
6k
4k
2k
0
Sep '11
Jan '12
May '12
Sep '12
Jan '13
May '13
Sep '13
Start Time
Raw Data
Highcharts.com

TILIKUM CROSSING



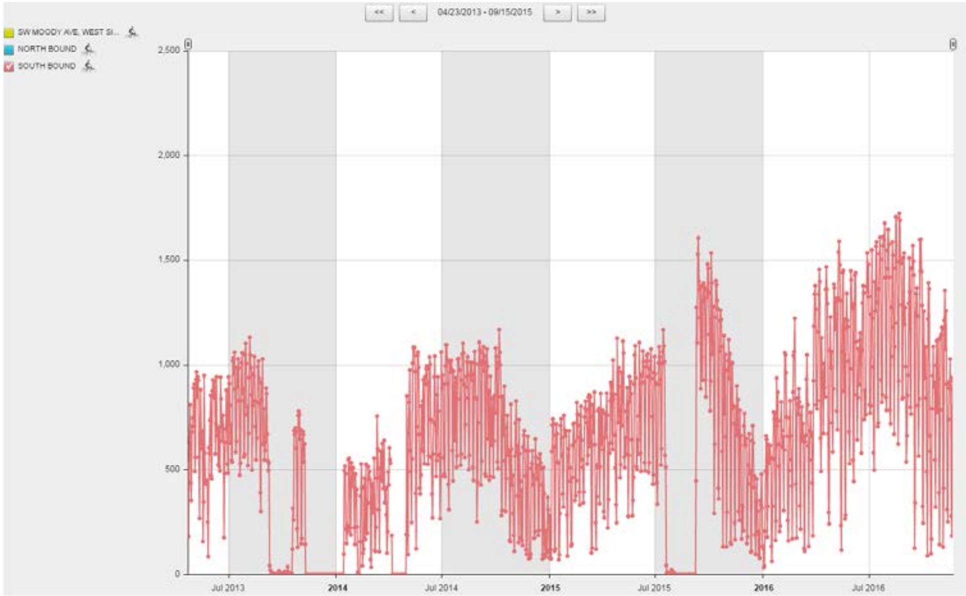
A spike in the data of 14,723 on September 27, 2015 occurs because the route for PBOT's Sunday Parkways, an open streets event, included the bridge. This was kept for the analysis since it could be verified.

A spike in the data of 14,723 on September 27, 2015 occurs because the route for PBOT's Sunday Parkways, an open streets event, included the bridge. This was kept for the analysis since it could be verified.

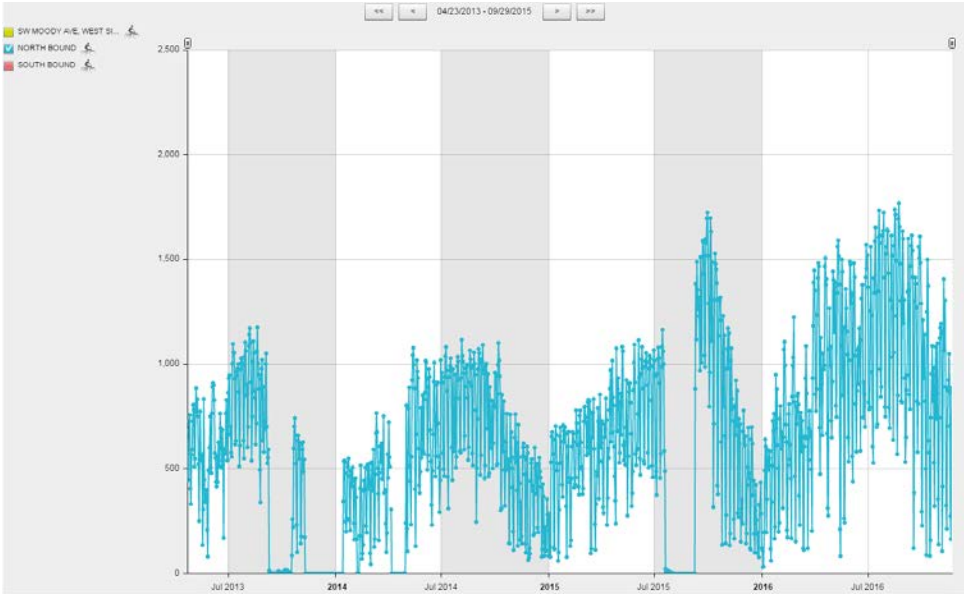
SW MOODY AVE.

Because of technical issues in loading the graphs of raw data on Bike-Ped Portal, graphs in Eco-Visio were used instead. Unusually low counts from September 9-October 17, 2013 were kept. Repeated zeroes over a period of days were removed. Unusually low counts found before repeated zeroes for both southbound and northbound bikes from July 20-September 8, 2015, which were removed. There were no issues observed with spikes.

Southbound



Northbound



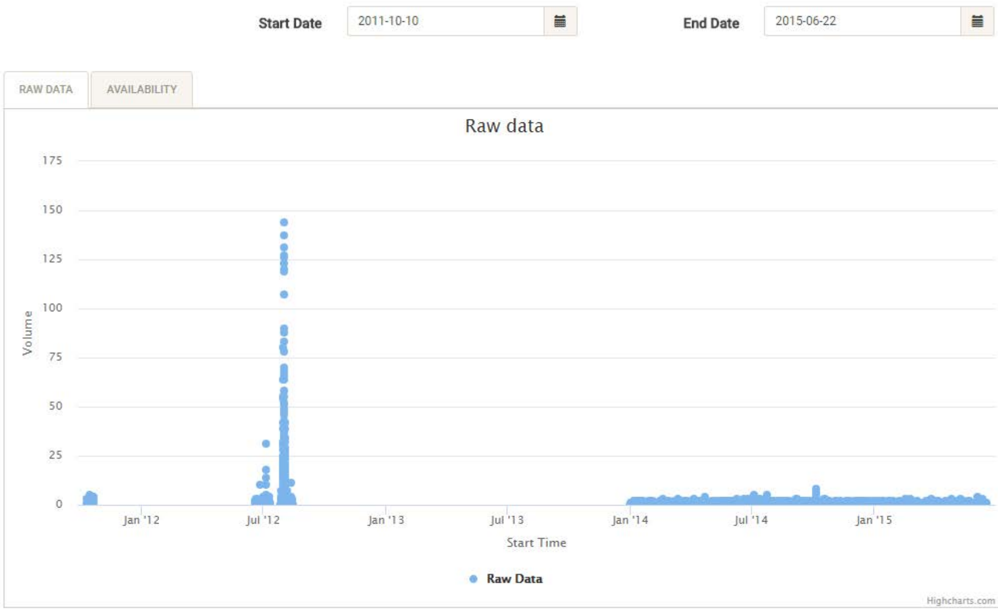
BROADWAY BRIDGE

Repeated zeroes were the only issues observed in this data, aside from data gaps.

South Sidewalk (Eastbound)

This is the typical flow that most cyclists going eastbound will follow on the Broadway Bridge. Higher volumes are expected for this flow. The only observable issue was repeated zeroes between March 27-April 2, 2015.

<u>Southside Sidewalk (Westbound)</u>

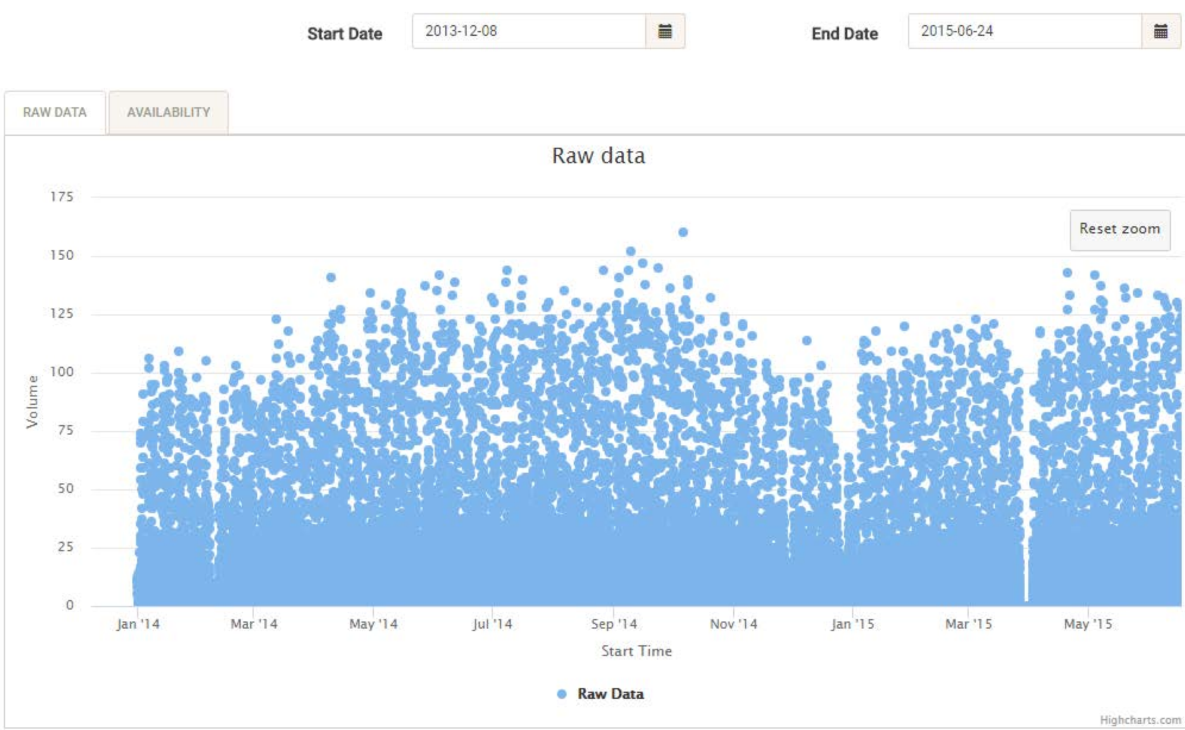


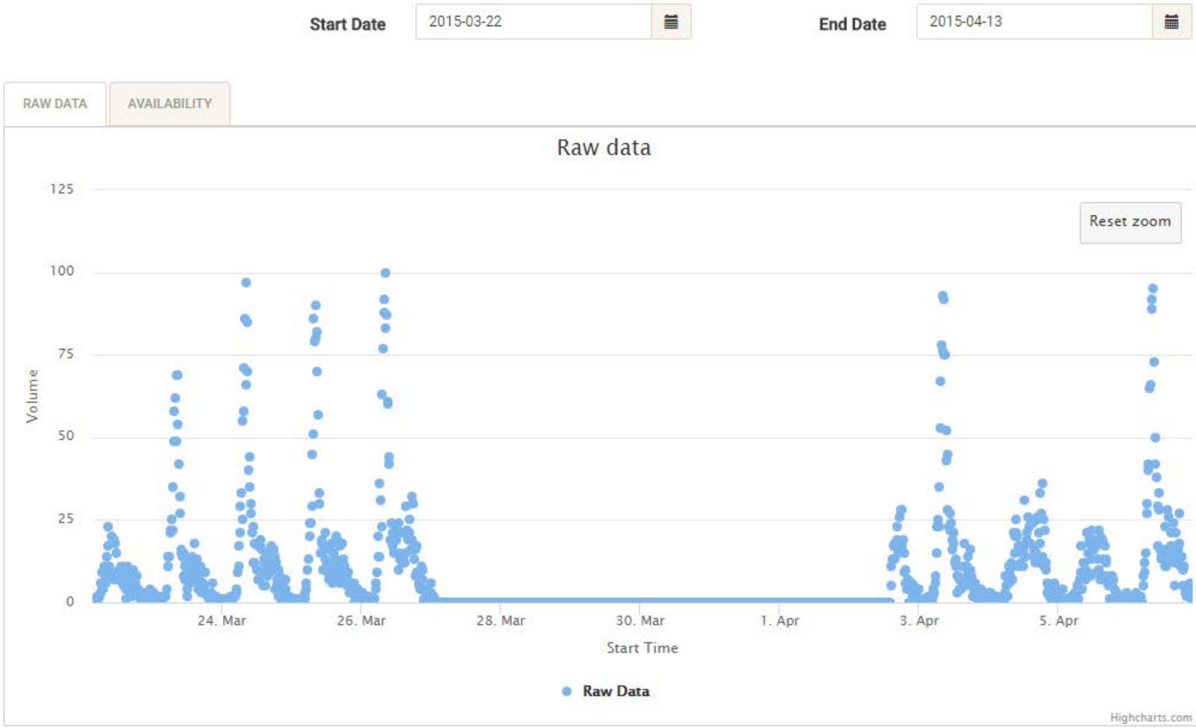
There are expected to be lower volumes on the south sidewalk riding westbound because it is contraflow to the higher volumes going eastbound on the same side. Most cyclists going westbound chose to be on the north sidewalk.

The counts during this time appear to be abnormally more than the typical patterns observed. It is possible that this may be due to construction occurring on the bridge that closed the north sidewalk, thus requiring cyclists going eastbound and westbound to share.

North Sidewalk (Westbound)

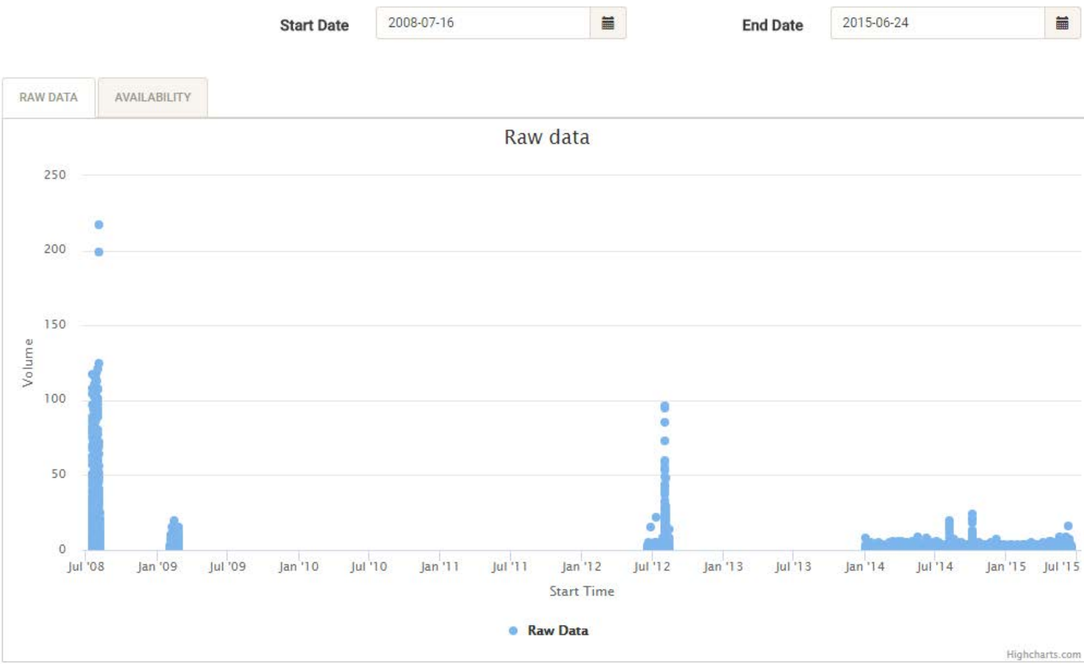
Higher volumes are expected for westbound cyclists on the north sidewalk as this is the typical observed flow.

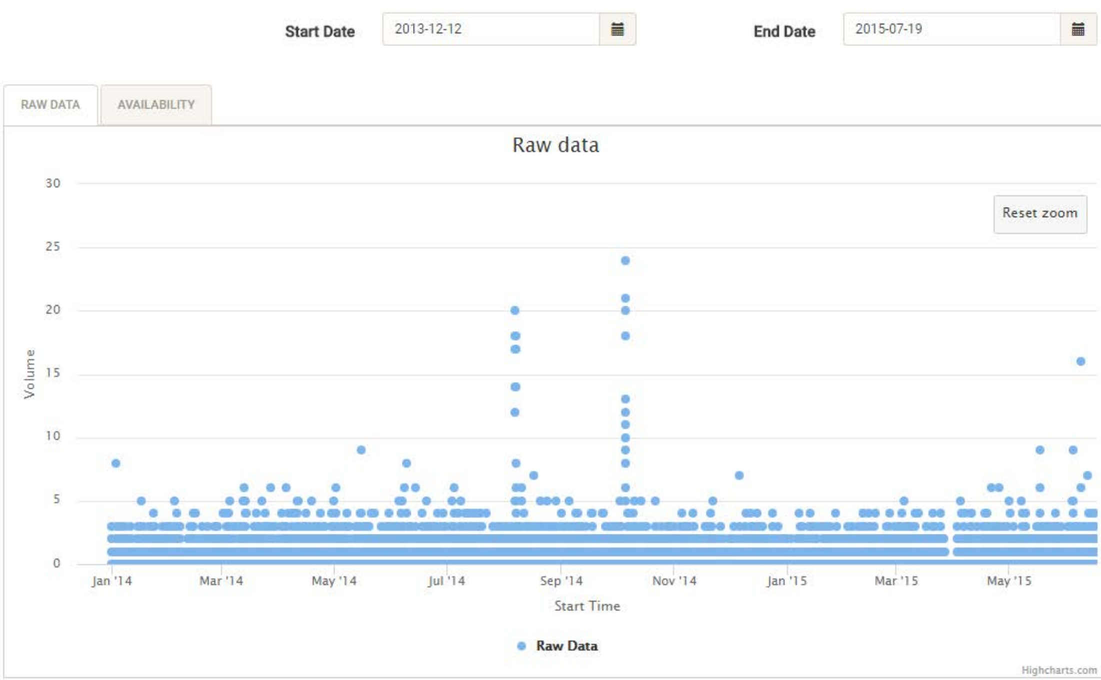



Start Date
2015-03-22
End Date
2015-04-13
RAW DATA
AVAILABILITY
Raw data
Reset zoom
125
100
75
50
25
0
Volume
24. Mar
26. Mar
28. Mar
30. Mar
1. Apr
3. Apr
5. Apr
Start Time
Raw Data
Highcharts.com

North Sidewalk (Eastbound)

Lower volumes are expected for eastbound cyclists on the north sidewalk as this is not the typical observed flow.





RIVERWALK (LOWER DECK OF THE STEEL BRIDGE)

Repeated zeroes from a few days to a month were observed for the same time periods for both the eastbound and westbound counts over four periods.

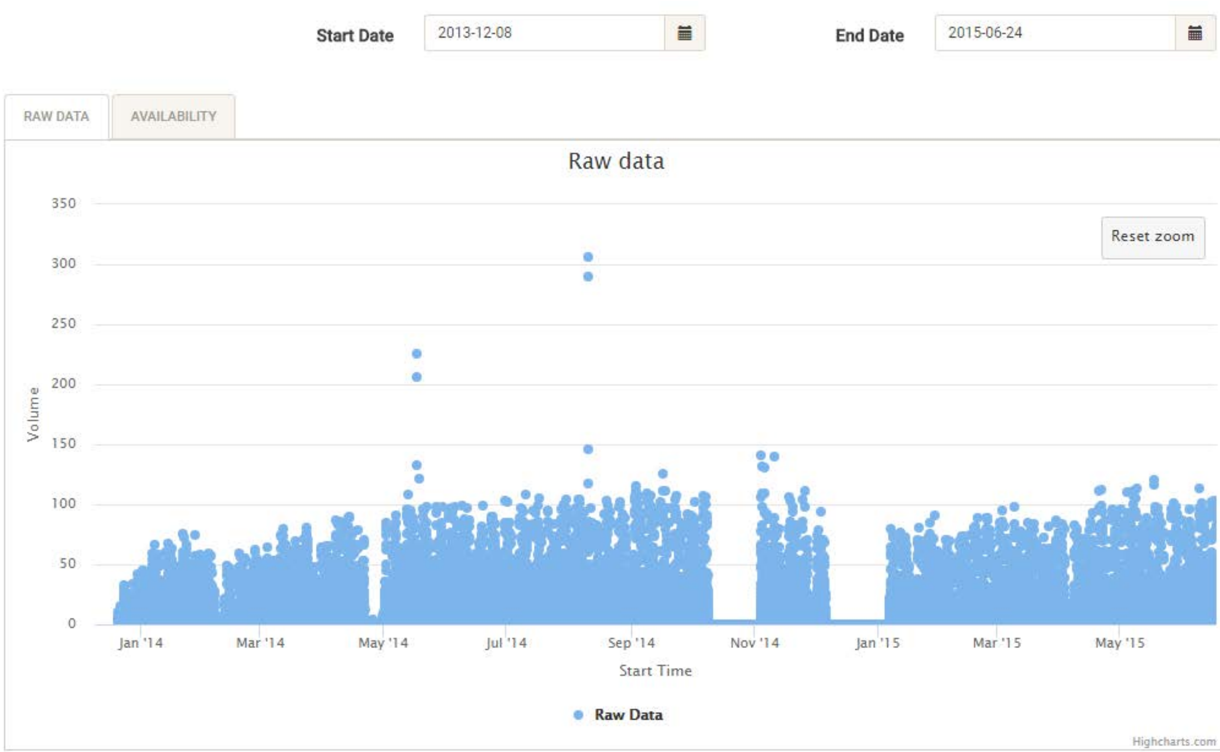
Eastbound


Start Date
2008-09-15
End Date
2015-06-24
RAW DATA
AVAILABILITY
Raw data
500
400
300
200
100
0
Volume
2009
2010
2011
2012
2013
2014
2015
Start Time
Raw Data
Highcharts.com


Start Date
2013-12-06
End Date
2015-06-24
RAW DATA
AVAILABILITY
Raw data
Reset zoom
250
200
150
100
50
0
Volume
Jan '14
Mar '14
May '14
Jul '14
Sep '14
Nov '14
Jan '15
Mar '15
May '15
Start Time
Raw Data
Highcharts.com

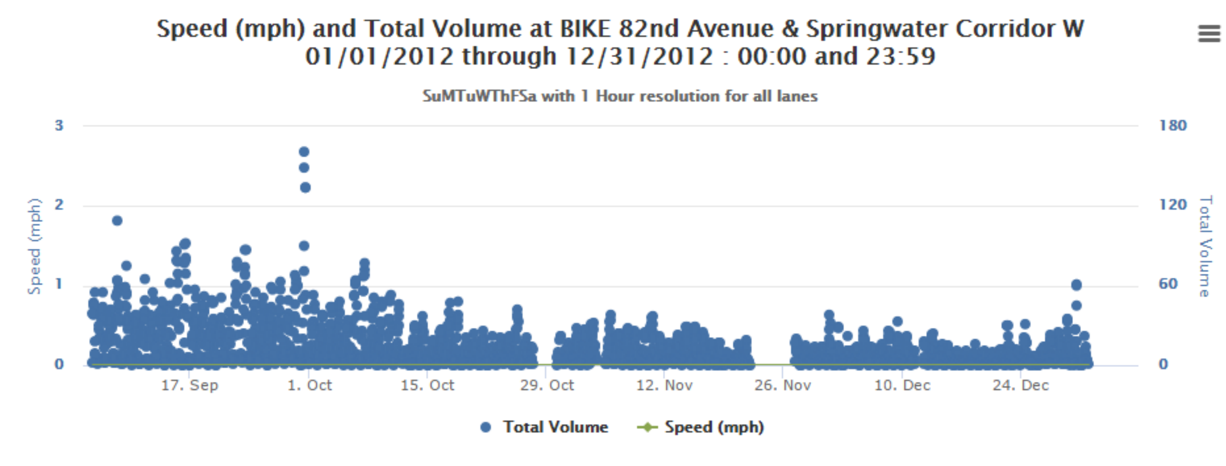
Westbound

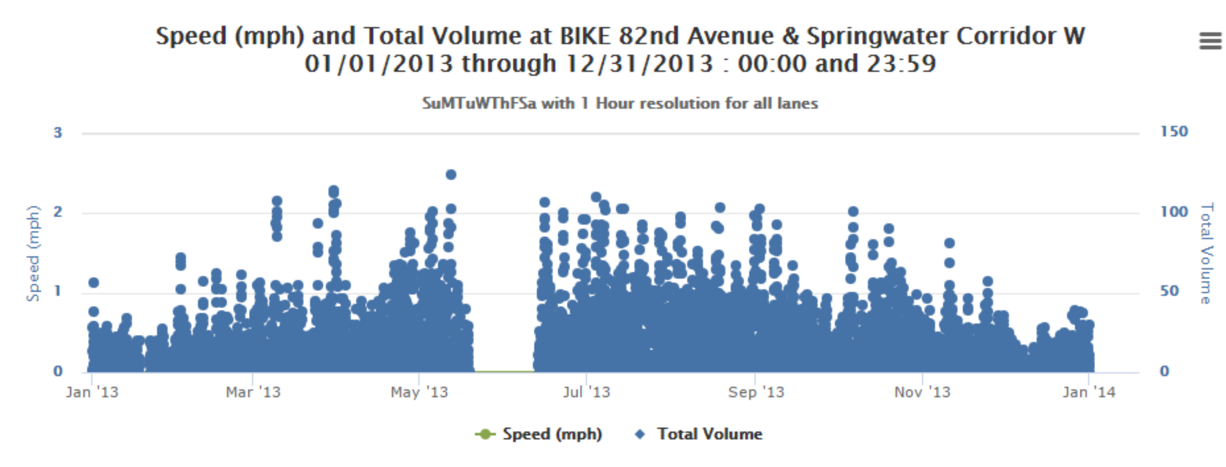

Start Date
2008-09-15
End Date
2015-06-22
RAW DATA
AVAILABILITY
Raw data
Volume
350
300
250
200
150
100
50
0
Jan '09
Jul '09
Jan '10
Jul '10
Jan '11
Jul '11
Jan '12
Jul '12
Jan '13
Jul '13
Jan '14
Jul '14
Jan '15
Jul '15
Start Time
Raw Data
Highcharts.com

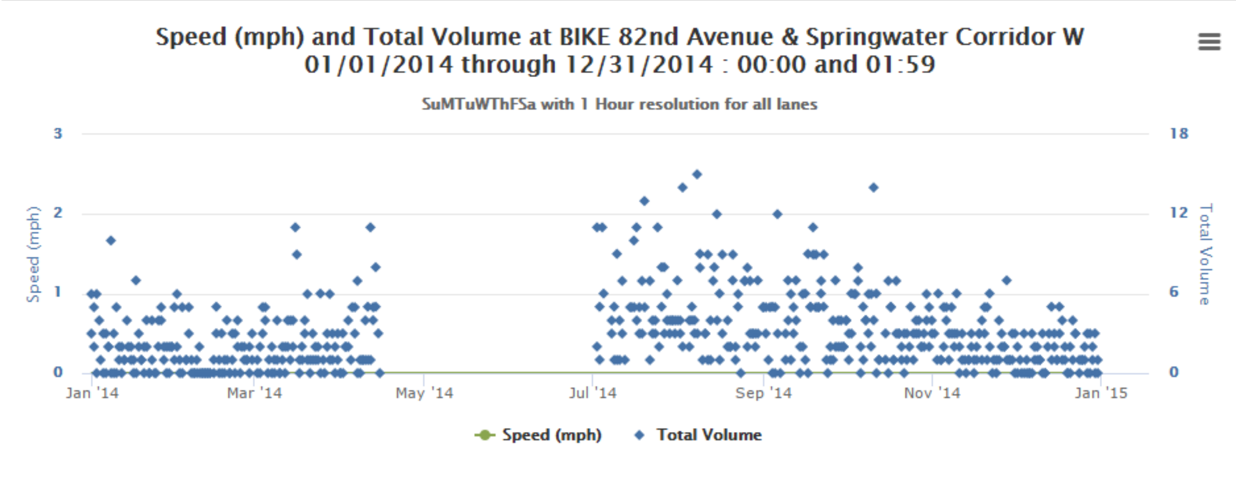

Start Date
2013-12-08
End Date
2015-06-24
RAW DATA
AVAILABILITY
Raw data
Reset zoom
Volume
350
300
250
200
150
100
50
0
Jan '14
Mar '14
May '14
Jul '14
Sep '14
Nov '14
Jan '15
Mar '15
May '15
Start Time
Raw Data
Highcharts.com

SPRINGWATER TRAIL AT 82ND

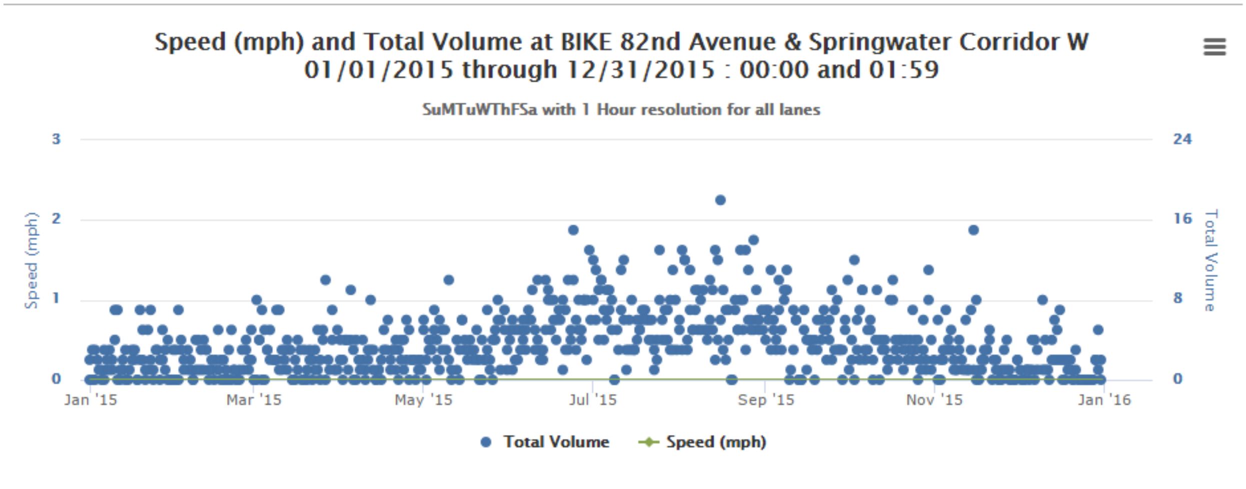
West Side, 1/1/2012 - Present



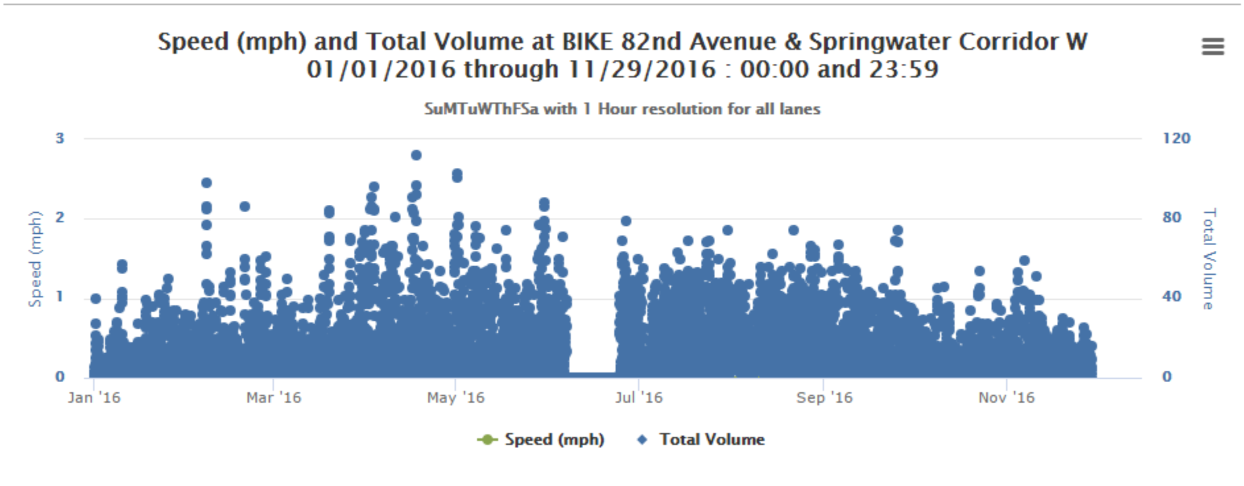




Speed (mph) and Total Volume at BIKE 82nd Avenue & Springwater Corridor W
01/01/2014 through 12/31/2014 : 00:00 and 01:59
SuMTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
18
12
6
0
Jan '14
Mar '14
May '14
Jul '14
Sep '14
Nov '14
Jan '15
Speed (mph)
Total Volume

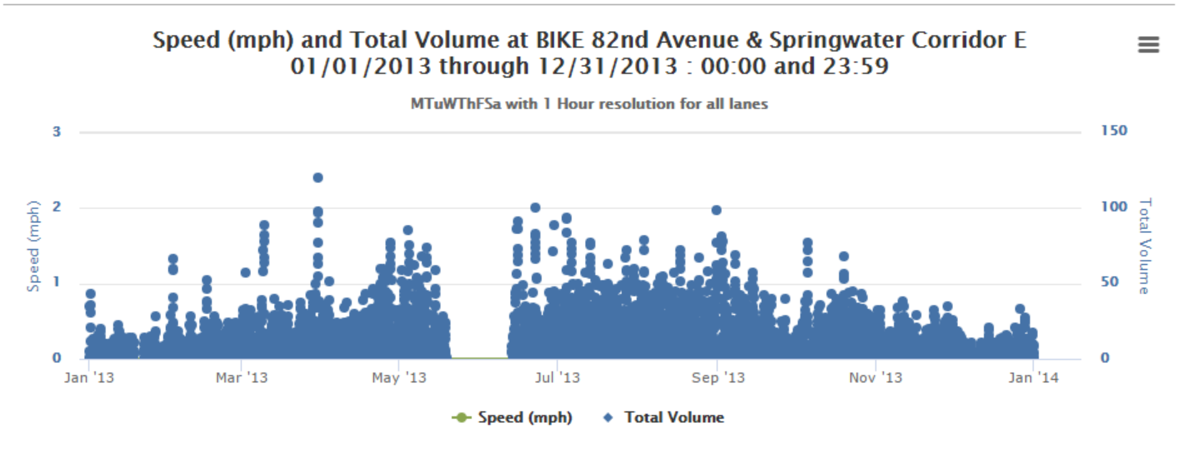


Speed (mph) and Total Volume at BIKE 82nd Avenue & Springwater Corridor W
01/01/2015 through 12/31/2015 : 00:00 and 01:59
SuMTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
24
16
8
0
Jan '15
Mar '15
May '15
Jul '15
Sep '15
Nov '15
Jan '16
Total Volume
Speed (mph)

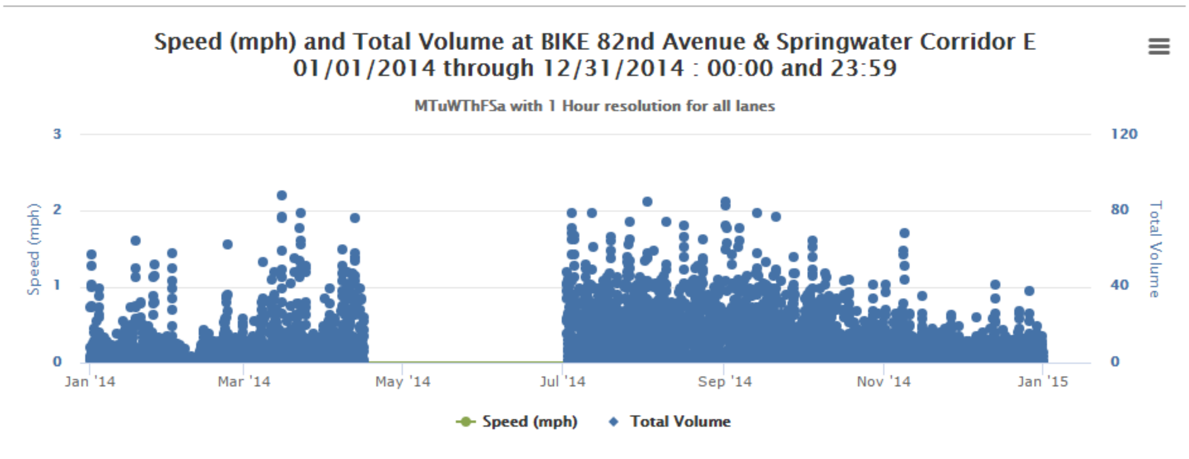


Speed (mph) and Total Volume at BIKE 82nd Avenue & Springwater Corridor W
01/01/2016 through 11/29/2016 : 00:00 and 23:59
SuMTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
120
80
40
0
Jan '16
Mar '16
May '16
Jul '16
Sep '16
Nov '16
Speed (mph)
Total Volume

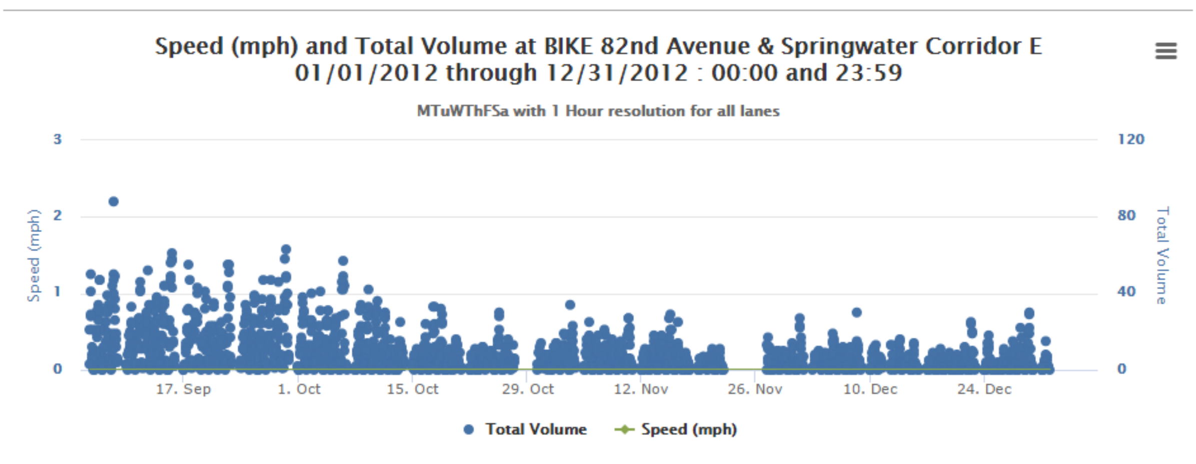
East Side



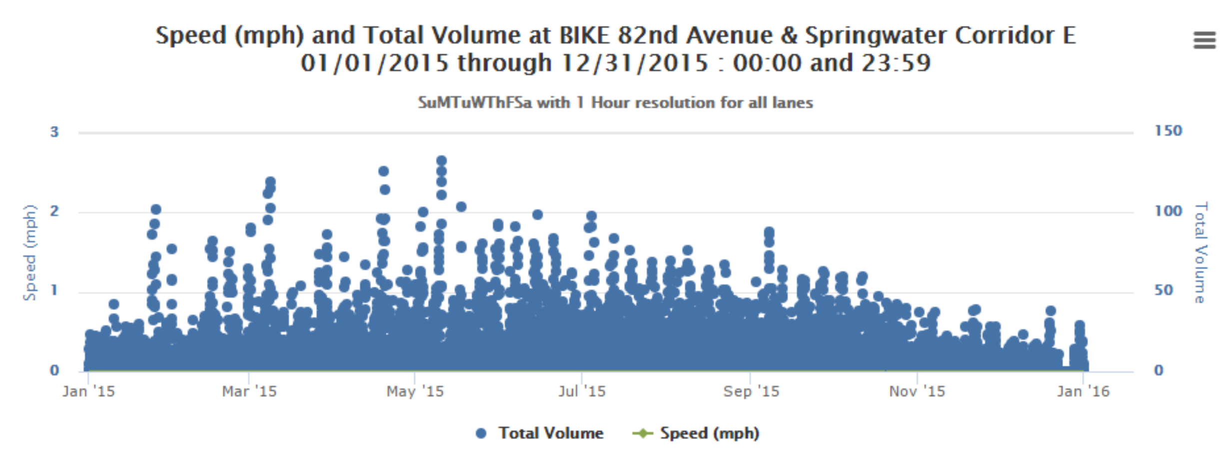
Speed (mph) and Total Volume at BIKE 82nd Avenue & Springwater Corridor E
01/01/2013 through 12/31/2013 : 00:00 and 23:59
MTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
150
100
50
0
Jan '13
Mar '13
May '13
Jul '13
Sep '13
Nov '13
Jan '14
Speed (mph)
Total Volume

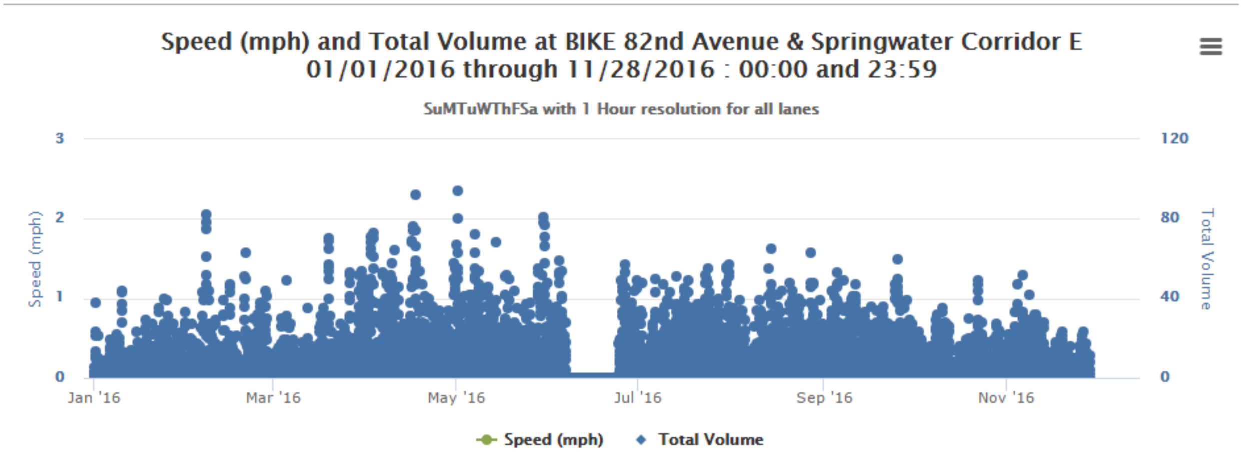


Speed (mph) and Total Volume at BIKE 82nd Avenue & Springwater Corridor E
01/01/2014 through 12/31/2014 : 00:00 and 23:59
MTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
120
80
40
0
Jan '14
Mar '14
May '14
Jul '14
Sep '14
Nov '14
Jan '15
Speed (mph)
Total Volume

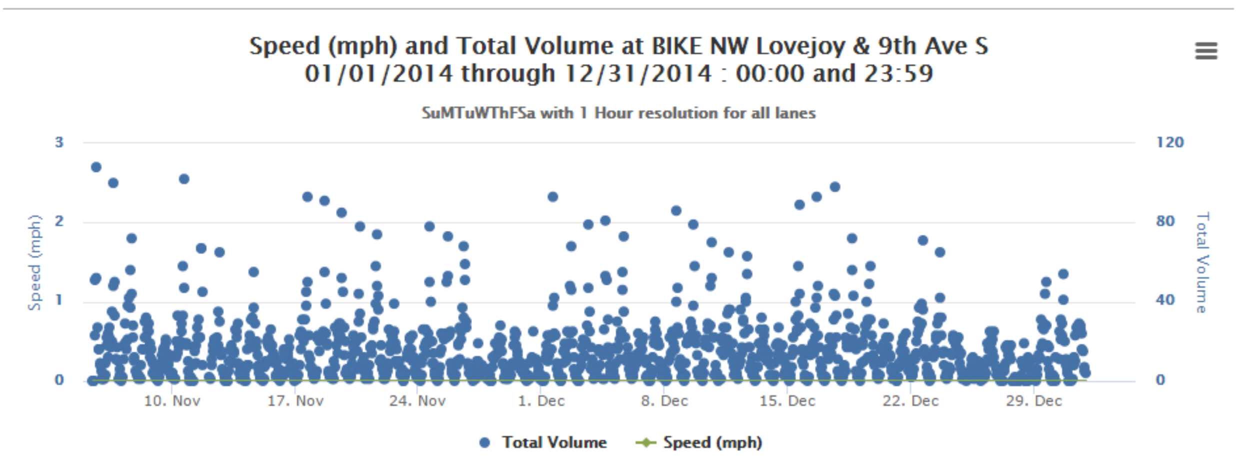


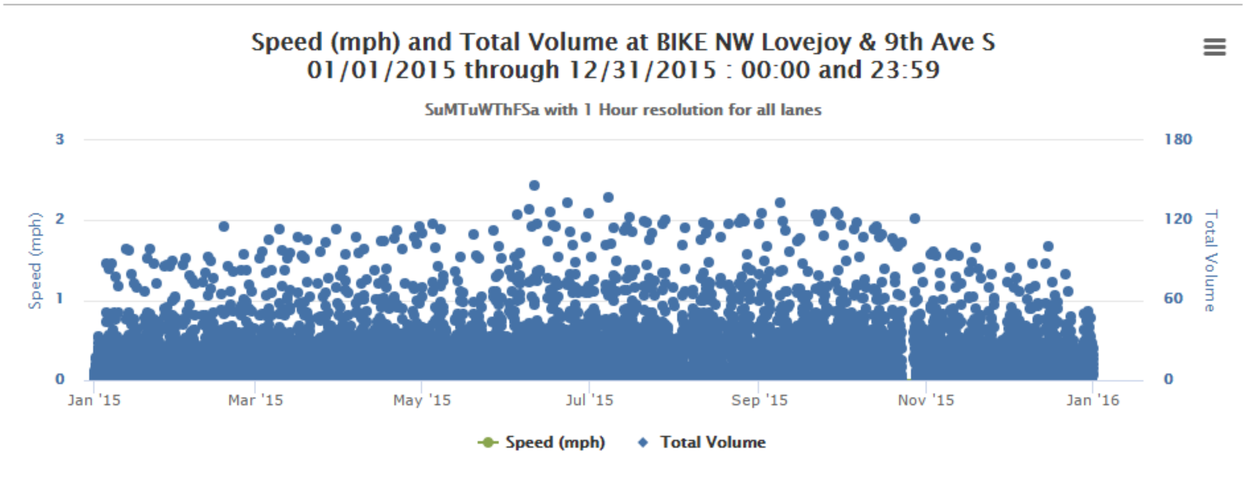
Speed (mph) and Total Volume at BIKE 82nd Avenue & Springwater Corridor E
01/01/2012 through 12/31/2012 : 00:00 and 23:59
MTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
120
80
40
0
17. Sep
1. Oct
15. Oct
29. Oct
12. Nov
26. Nov
10. Dec
24. Dec
Total Volume
Speed (mph)



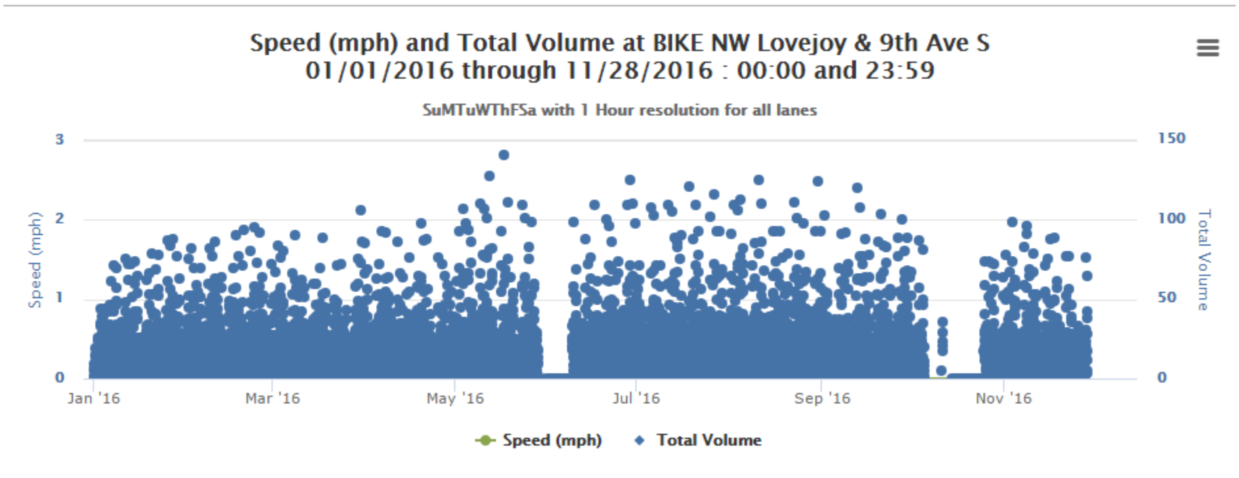


NW 9TH AVE (N OF NW LOVEJOY ST)





Speed (mph) and Total Volume at BIKE NW Lovejoy & 9th Ave S
01/01/2015 through 12/31/2015 : 00:00 and 23:59
SuMTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
180
120
60
0
Jan '15
Mar '15
May '15
Jul '15
Sep '15
Nov '15
Jan '16
Speed (mph)
Total Volume

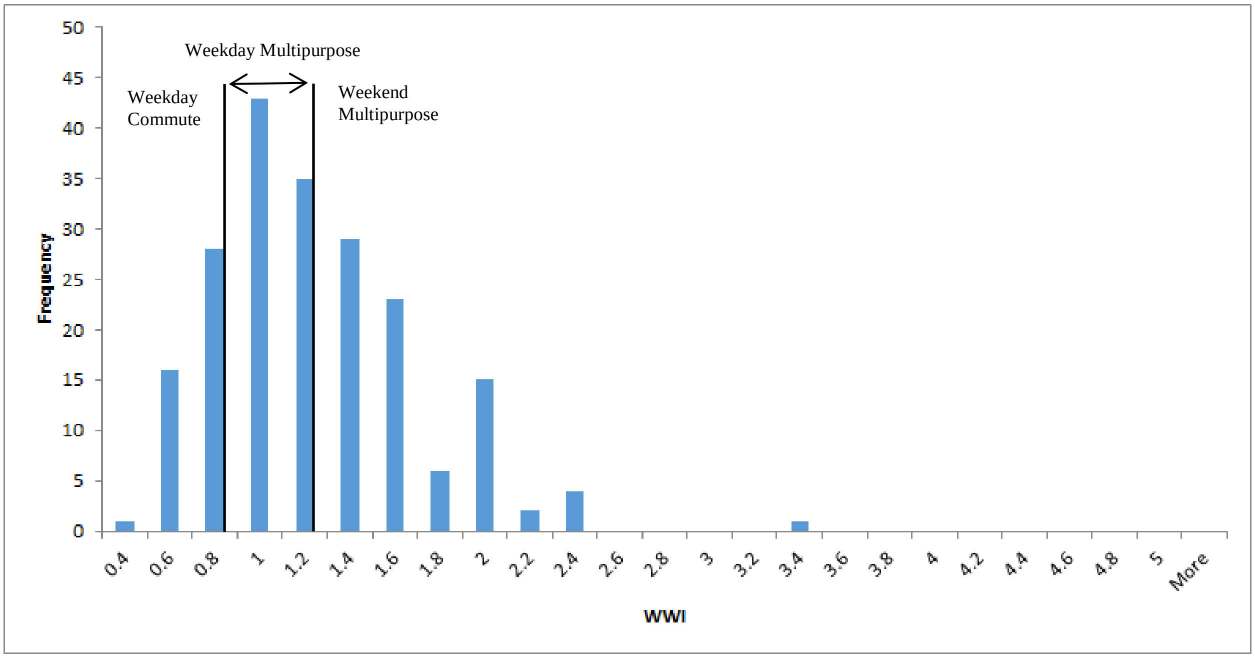


Speed (mph) and Total Volume at BIKE NW Lovejoy & 9th Ave S
01/01/2016 through 11/28/2016 : 00:00 and 23:59
SuMTuWThFSa with 1 Hour resolution for all lanes
Speed (mph)
Total Volume
3
2
1
0
150
100
50
0
Jan '16
Mar '16
May '16
Jul '16
Sep '16
Nov '16
Speed (mph)
Total Volume

APPENDIX I

Weekday/Weekend Index (WWI) Analysis

Summary of WWI

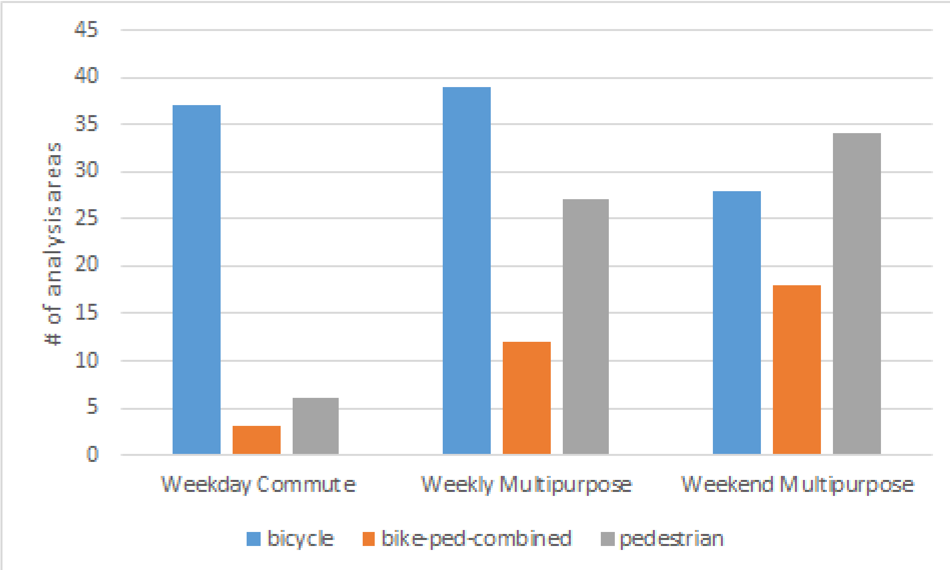


$WWI = V_{we} / V_{wd}$

where:
V_{we} = average weekend daily traffic
V_{wd} = average weekday daily traffic
(Miranda-Moreno 2013)

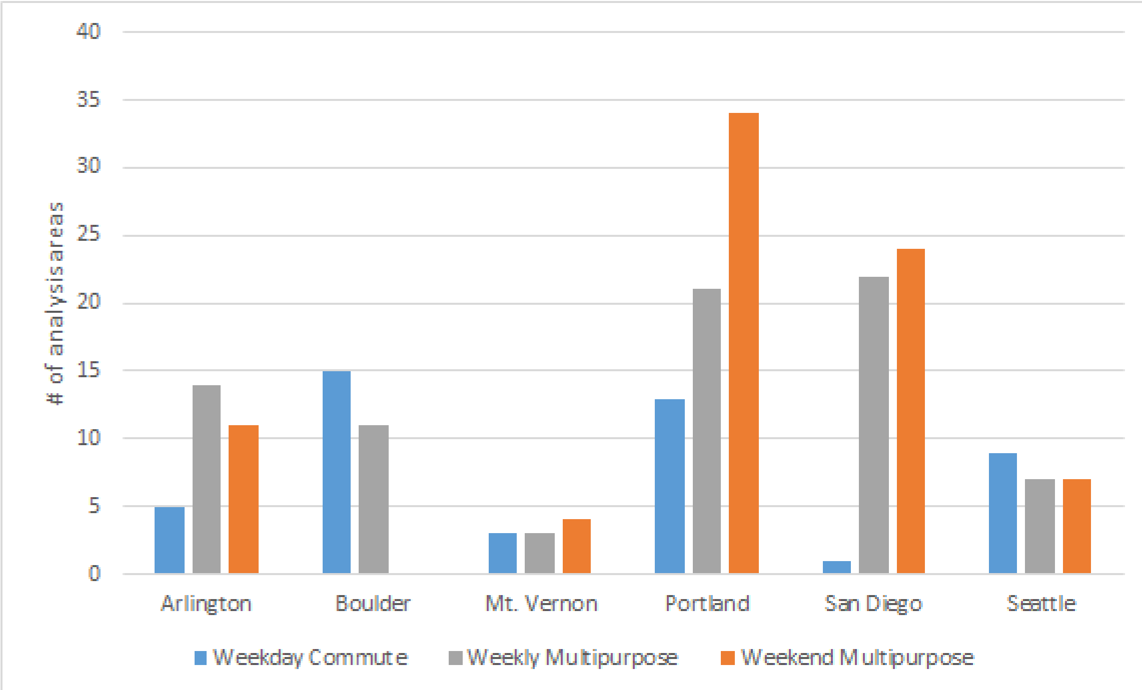
BAA Cutoffs
Weekday Commute: Average WWI <=0.8
Weekly Multipurpose: 0.8<(Average WWI)<=1.2
Weekend Multipurpose: Average WWI >1.2

WWI by mode



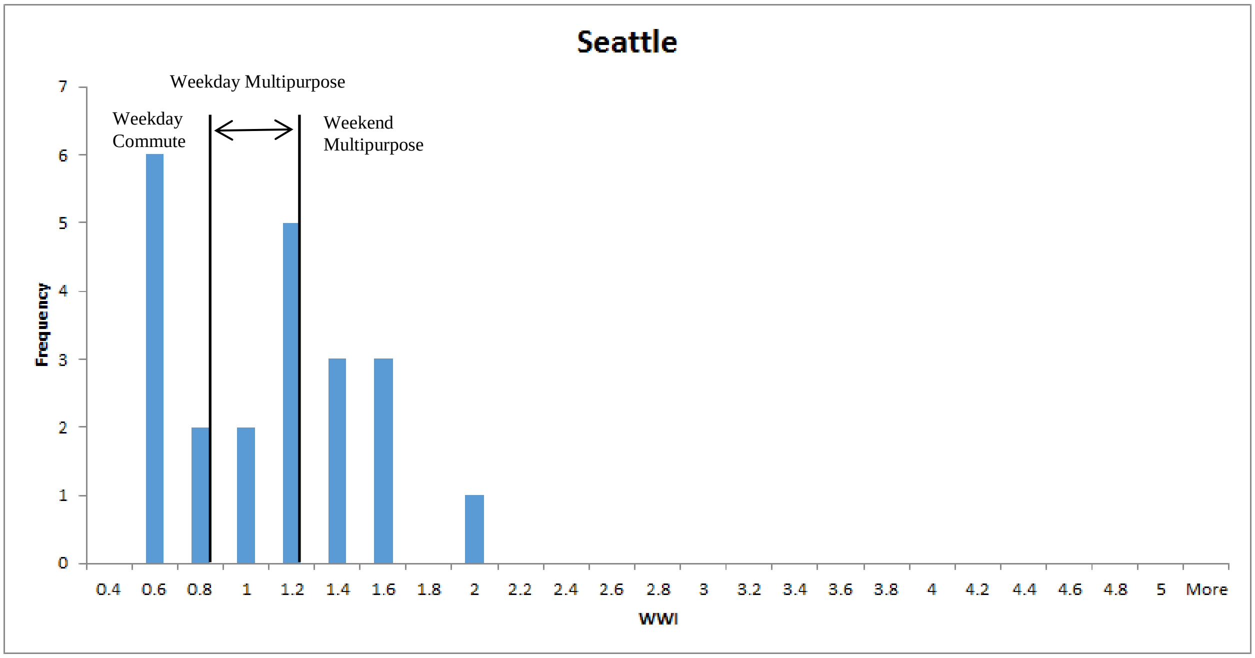
Group	Bicycle	Bike-ped-combined	Pedestrian	Total
Weekday Commute	37	3	6	46
Weekend Multipurpose	28	18	34	80
Weekly Multipurpose	39	12	27	78
Total	104	33	67	204

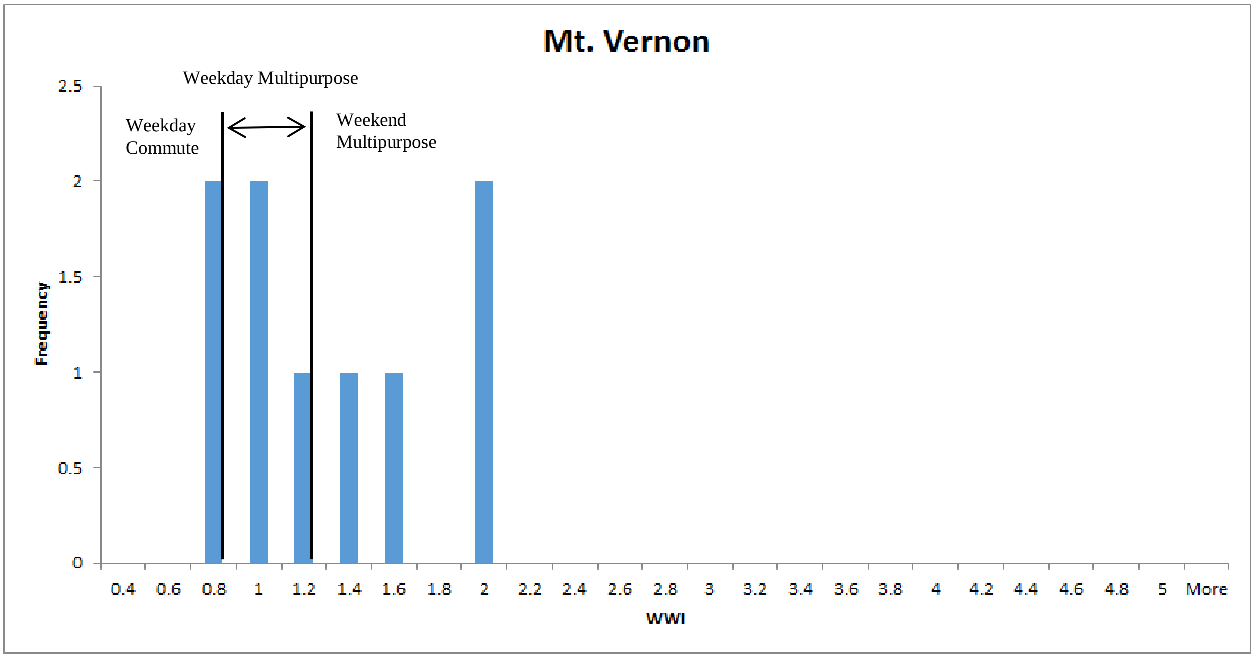
WWI by City

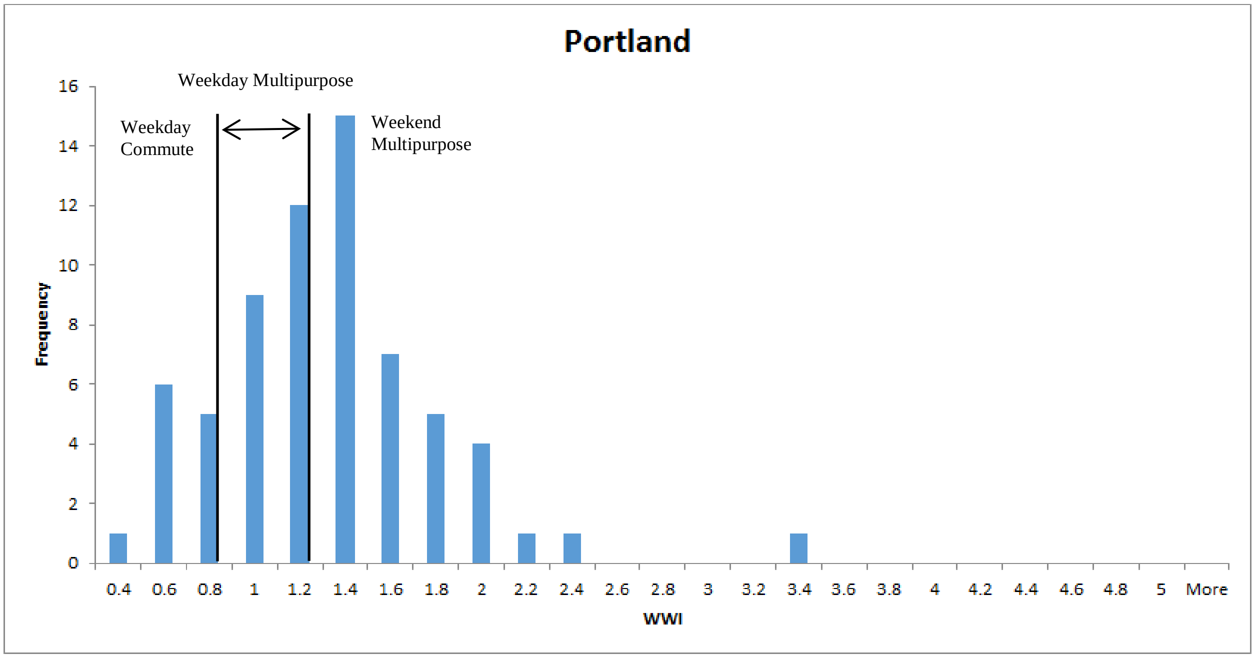


City	Weekday Commute	Weekend Multipurpose	Weekly Multipurpose	Total
Arlington	5	11	14	30
Boulder	15		11	26
Mt. Vernon	3	4	3	10
Portland	13	34	21	68
San Diego	1	24	22	47
Seattle	9	7	7	23

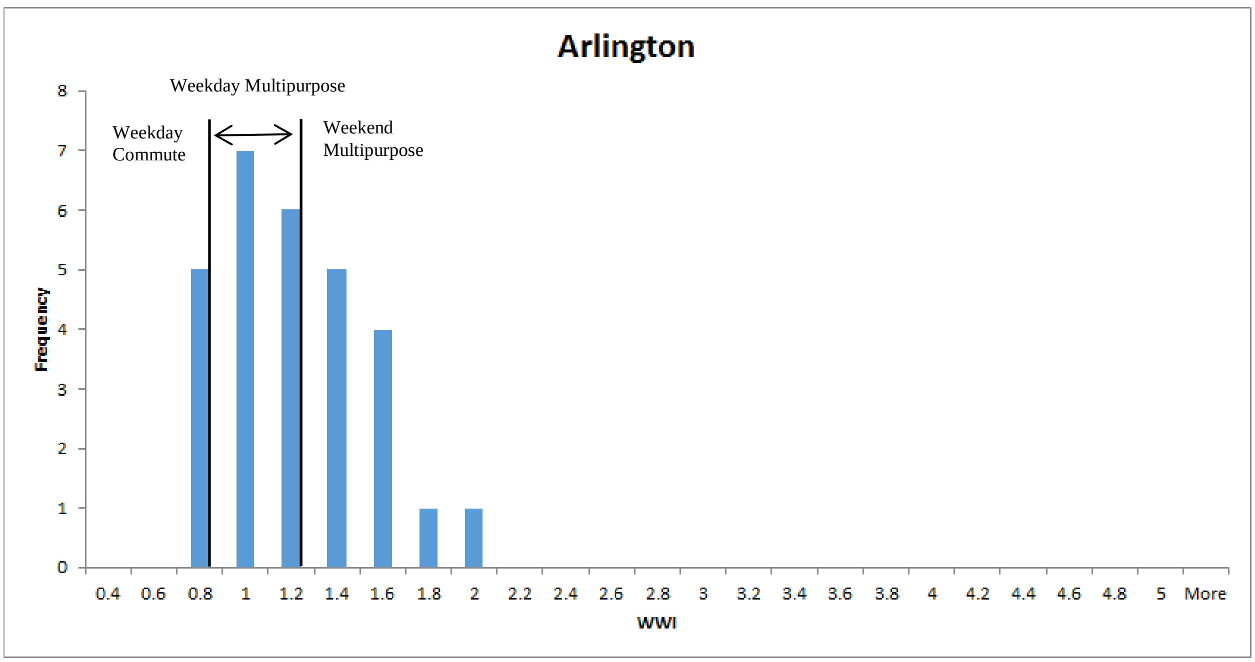
WWI Histograms by City



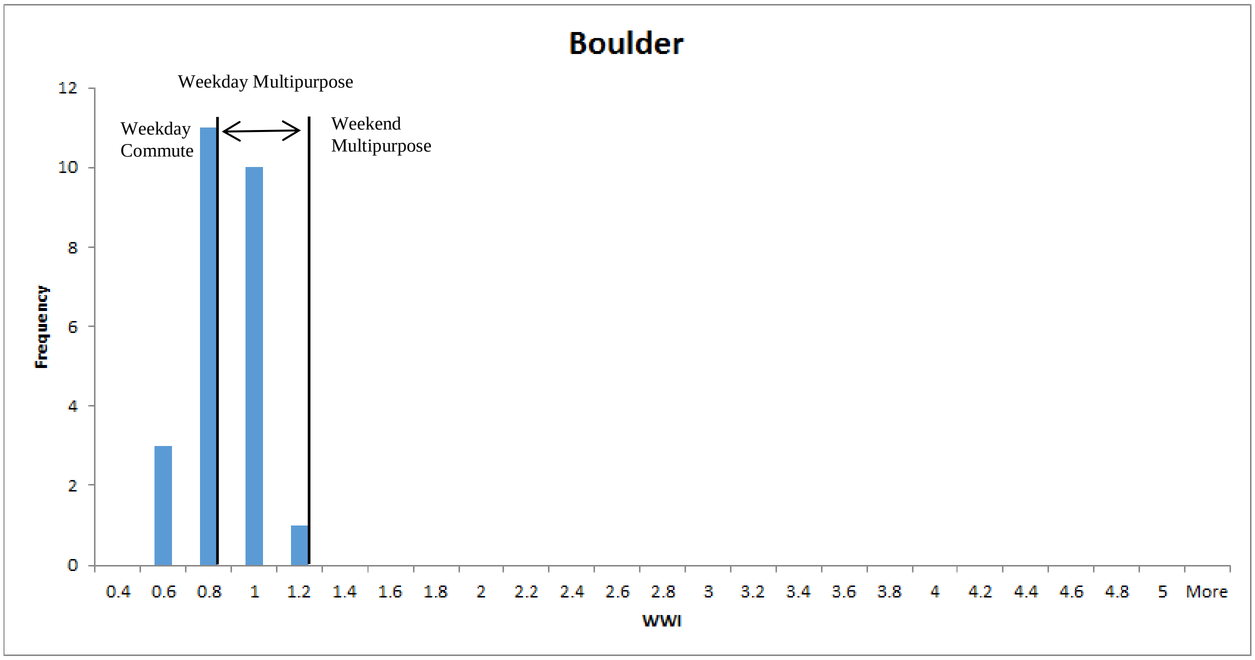


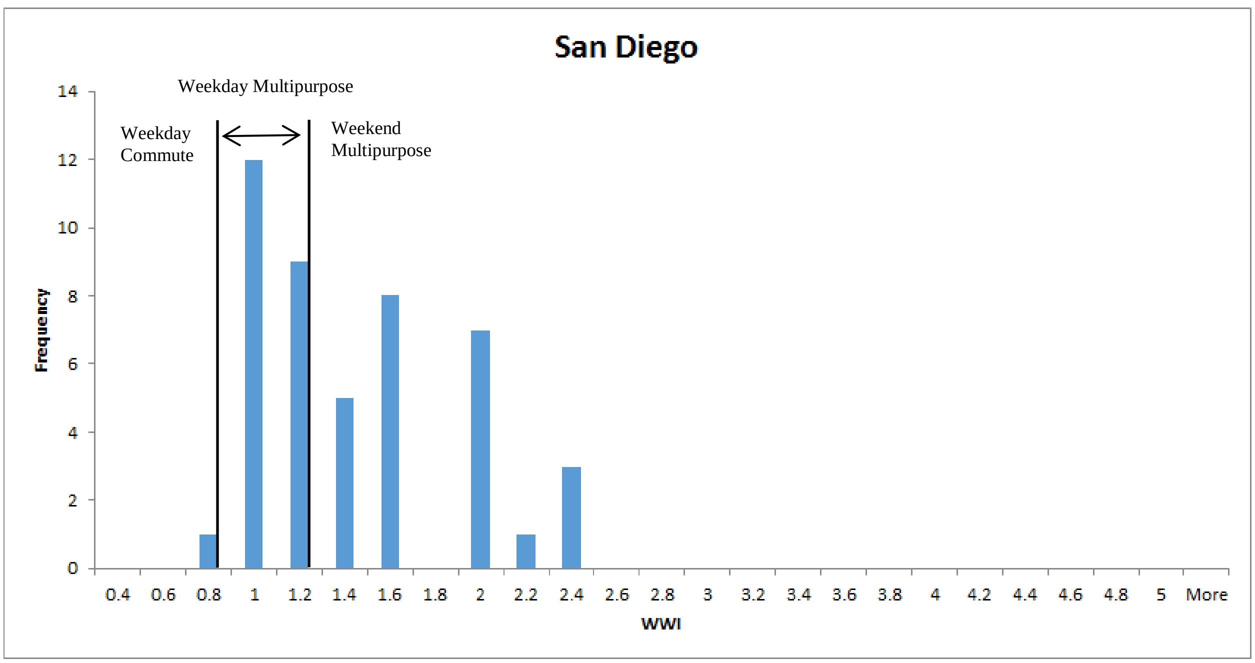


Portland
Weekday Multipurpose
Weekday Commute
Weekend Multipurpose
Frequency
16
14
12
10
8
6
4
2
0
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
More
WWI



Arlington
Weekday Multipurpose
Weekday Commute
Weekend Multipurpose
Frequency
8
7
6
5
4
3
2
1
0
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
More
WWI


Boulder
Weekday Multipurpose
Weekday Commute
Weekend Multipurpose
Frequency
12
10
8
6
4
2
0
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 More
WWI


San Diego
Weekday Multipurpose
Weekday Commute
Weekend Multipurpose
Frequency
14
12
10
8
6
4
2
0
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 More
WWI

APPENDIX J

Collecting Network-wide Bicycle and Pedestrian Data: A Guidebook for When and Where to Count / Dylan Johnstone, Krista Nordback, Michael Lowry. Transportation Research and Education Center (TREC). Portland State University. September 2017.

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http://www.wsdot.wa.gov/research/reports/fullreports/875-1.pdf