

SPATIAL ANALYSIS OF BICYCLE COUNT DATA

FINAL PROJECT REPORT

By

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16. Abstract <p>Every year since 2010, volunteers from more than 50 communities have helped the Washington State Department of Transportation (WSDOT) collect bicycle count data.</p> <p>This project created the <i>AADB Estimation</i> website that communities can use to make maps of bicycle volumes across their street network count data. Someone using the website begins by uploading a spreadsheet of short-duration count data (i.e., manual counts for a period of less than 24 hours). The website analyzes the short-duration count data and seasonally adjusts the values on the basis of continuous count data that WSDOT collects at locations throughout the state and from other sources. The seasonally adjusted values are an estimation of Annual Average Daily Bicyclists (AADB). Next, the website spatially extrapolates AADB from the count locations to every segment in the street network. The spatial extrapolation is done by predicting the flow of bicycle travel between commercial destinations and residential locations that have been synthesized from U.S. Census bicycle commuting information.</p> <p>The <i>AADB Estimation</i> website can help communities conduct safety analyses and prioritize new bicycle infrastructure.</p>			
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Table of Contents

Acknowledgments.....	ix
Executive Summary	xi
CHAPTER 1 INTRODUCTION	1
1.1 Background.....	1
1.2 Project Objective and Outcomes.....	2
1.3 Report Organization.....	3
CHAPTER 2 USING THE NEW WEBSITE	5
2.1 User Interface.....	5
2.2 Input	6
2.3 Output	9
CHAPTER 3 SEASONAL FACTORING METHODOLOGY	13
3.1 Inflating to a Day Volume	13
3.2 Adjusting for Season.....	14
3.3 Combining Multiple Count Events	16
3.4 Summary of Seasonal Factors.....	16
CHAPTER 4 SPATIAL EXTRAPOLATION METHODOLOGY	17
4.1 Creating the Street Network, Origins, and Destinations.....	17
4.2 Calculating Expected Bicycle Flow	19
4.3 Fitting AADB to Expected Bicycle Flow	21
CHAPTER 5 CONCLUSIONS AND FUTURE WORK	23
5.1 Technology Transfer	23
5.2 Future Work.....	23
REFERENCES	27
APPENDIX A CREATION OF SEASONAL ADJUSTMENT FACTORS	29
APPENDIX B GUIDANCE FOR UPDATING OPEN STREET MAPS	33

List of Figures

Figure 2.1 Screenshot of the AADB Estimation website.	5
Figure 2.2 Changing the underlying base map.	6
Figure 2.3 The interface to upload an input.....	6
Figure 2.4 Example input csv file.	7
Figure 2.5 Selecting the count method.	8
Figure 2.6 Example of output displayed on the website.	9
Figure 2.7 Pop-up window displaying output.....	10
Figure 2.8 Output folder of GIS data.	10
Figure 2.9 Output GIS data in ArcGIS.	11
Figure 4.1 Expected bicycle flow through a network.	20
Figure 4.2 Fitting AADB to expected bicycle flow.....	21
Figure A.1 Creating seasonal adjustment factors.	299
Figure A.2 Washington state climate regions.	29
Figure A.3 Decision chart for travel pattern.	31
Figure B.1 Open Street Map showing the bicycle layer.	33
Figure B.2 Open Street Map editing interface.	34
Figure B.3 Street highlighted for editing.	34
Figure B.4 Bike Lane drop downs.	35
Figure B.5 OSM bicycle facilities.	35
Figure B.6 Line editing button.....	35
Figure B.7 Connecting a path to a street.....	36
Figure B.8 Path tag for the new line.	36

List of Tables

Table 3.1 Example hour-of-day factors	14
Table 3.2 Example month-and-day factors.....	15
Table 4.1 Assumed values for number of lanes and speed limit.	17
Table 4.2 Google Places used to create destination points.	19
Table 4.3 Example regression model for fitting AADT	21

List of Abbreviations

AADB: Annual average daily bicyclists
FHWA: Federal Highway Administration
GIS: Geographic information system
OSM: OpenStreetMap
PacTrans: Pacific Northwest Transportation Consortium
TEB: Total entering/exiting bicyclists
WSDOT: Washington State Department of Transportation

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Executive Summary

For nearly ten years, the Washington Department of Transportation (WSDOT) has supervised one of the most extensive state-run manual bicycle count programs in the country. Each fall, community volunteers gather in 38 cities to count at more than 350 locations statewide (WSDOT, 2017). WSDOT is also aggressively working to expand the number of permanent counters installed throughout the state (Trask, 2015).

This project was sponsored by WSDOT to improve the usability of manual count data and was part of a larger research activity focused on providing communities guidance concerning when and where to count bicyclists and pedestrians (Johnstone, et al. 2017). One result of this project was the creation of a website, called *AADB Estimation*, that communities can use to make maps of annual average daily bicyclists (AADB) across their street networks. Someone using the website begins by uploading a spreadsheet of observed short-duration count data. The website analyzes the data and seasonally adjusts the values by using continuous count data that WSDOT collects throughout the state and from other sources. The website can help communities conduct safety analyses and prioritize new bicycle infrastructure. This report describes how to use the *AADB Estimation* website and explains the underlying methodology.

Chapter 1 Introduction

1.1 Background

Cities and state departments of transportation (DOTs) need reliable bicycle volume data to conduct safety analysis and prioritize project proposals. Unfortunately, there is usually very little information about bicycle volumes because unlike traffic monitoring for automobiles, data collection for non-motorized travel is sparse and sporadic.

In the last few years, there has been a tremendous push across the country to collect better bicycle volume data. Cities and states are making huge strides in two areas: permanent counters and manual count programs. Permanent counters provide a means to collect “continuous” count data by monitoring with automatic equipment 24 hours a day, 7 days a week, and all year round. Large communities can sometimes afford to install two or three permanent counters at key locations, and very large communities, like Seattle, have upwards of ten permanent counters throughout the city.

Many communities have also begun collecting manual count data with the help of community volunteers who count bicyclists with clipboards and tally sheets for short durations (e.g., 2 hours). One manual count technique, called “screenline” counting, involves the volunteer sitting at a midblock location and counting the number of bicyclists traveling in both directions along a street or trail segment. Another approach is “intersection counting,” wherein the volunteer counts bicyclists entering or exiting an intersection (and perhaps even records the bicyclists turn movements). Either way, the intent of manual count programs is to collect “coverage” counts that capture information over a wide geographic area (Lowry et al, 2016b). However, because of temperature, weather, and other factors, coverage counts do not represent

“typical” volumes and therefore have limited use for safety analysis and prioritizing project proposals.

Coverage counts can be correlated with the observed fluctuation in continuous data, through a process called seasonal factoring (or temporal adjustment or short-duration inflating). A mathematical formula combines the short-duration count with a specific adjustment factor that matches the particular month, day, hour, and climate region of the short-duration count (Nordback et al, 2013). The result is an estimate of annual average daily bicyclists (AADB) for screenline locations or total entering/exiting bicyclists (TEB) for intersection locations. AADB is the total number of bicyclists traveling in both directions. TEB is the total number of bicyclists entering (or exiting) an intersection.

1.2 Project Objective and Outcomes

For nearly ten years, the Washington Department of Transportation (WSDOT) has supervised one of the most extensive state-run manual bicycle count programs in the country. Each fall, community volunteers gather in 38 cities to count at more than 350 locations statewide (WSDOT, 2017). Furthermore, WSDOT is aggressively working to expand the number of permanent counters installed throughout the state (Trask, 2015).

This project was sponsored by WSDOT to improve the usability of manual count data and was part of a larger research activity focused on providing communities guidance concerning when and where to count bicyclists and pedestrians (Johnstone, et al. 2017).

One result of this project was the creation of a website, called *AADB Estimation*, that communities can use to make maps of AADB across their street networks. Someone using the website begins by uploading a spreadsheet of observed short-duration count data. The website analyzes the data and seasonally adjusts the values by using continuous count data that WSDOT

collects throughout the state and from other sources. The website can help communities conduct safety analyses and prioritize new bicycle infrastructure.

1.3 Report Organization

This report describes the *AADB Estimation* website. Chapter 2 provides directions for using the website, including how to download and use the results. Chapter 3 describes the methodology used to adjust short-duration count data to estimate AADB for the count locations. Chapter 4 describes the methodology used to spatially extrapolate AADB across the street network. Chapter 5 provides concluding remarks and suggestions for future work. Appendix A describes the process for creating seasonal adjustment factors, and Appendix B provides guidance for updating the street network used by the website.

Chapter 2 Using the New Website

This chapter describes how to use the *AADB Estimation* website, with a description of the input and output. Throughout this report, “user” refers to someone using the website.

2.1 User Interface

The website opens to a full map extent of Washington state, as shown in figure 2.1. At any time, the user can change the underlying base map to imagery, topography, or other renderings (OpenStreetMap is the default) by clicking the icon with four squares shown in figure 2.2. There are additional mapping tools for zooming and searching for a place name. The print icon provides a means to create pdf files for printing the current map extent.

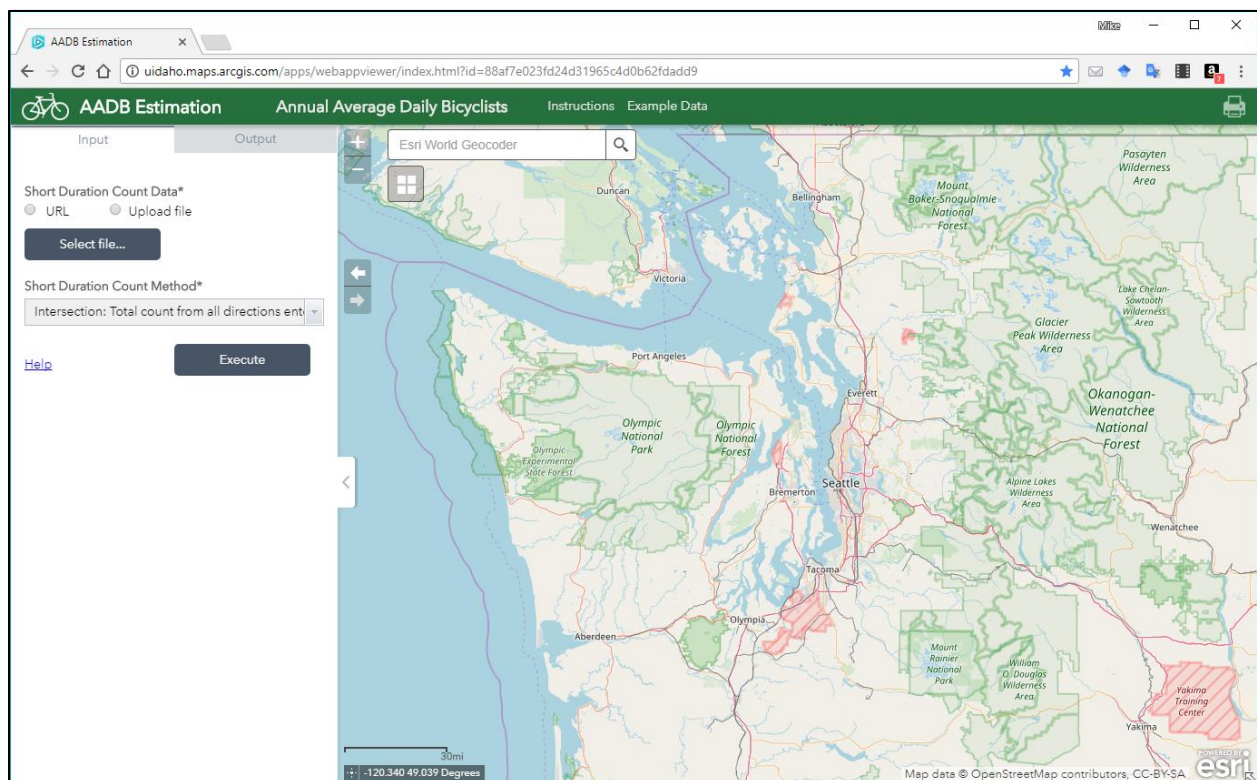


Figure 2.1 Screenshot of the AADB Estimation website.

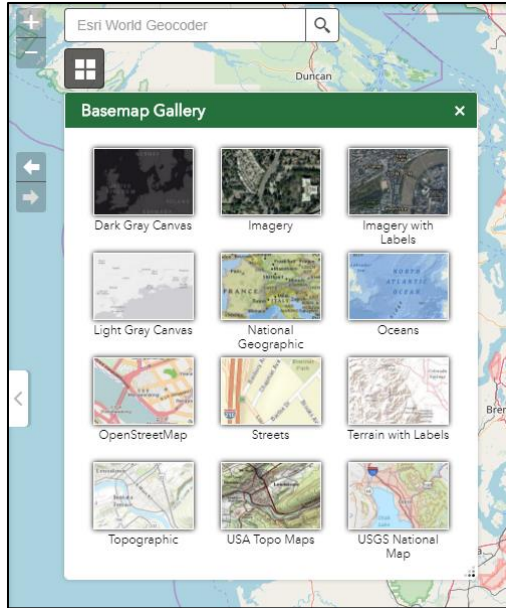


Figure 2.2 Changing the underlying basemap.

2.2 Input

A user begins analysis by clicking the Upload file radial button and then Select file (see fig. 2.3). The user browses to a csv file that contains short-duration count data in the precise format of the example file shown in figure 2.4.

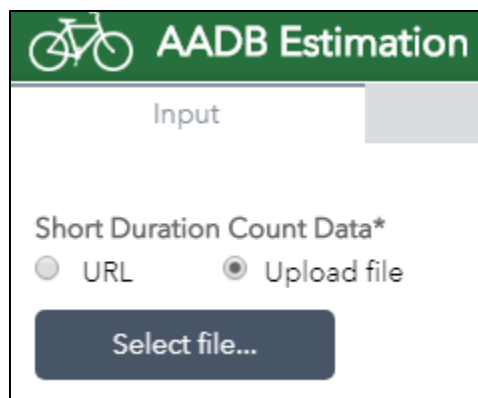


Figure 2.3 The interface to upload an input

	A	B	C	D	E	F	G	H	I	J	K
1	LocationID	Description	Assumed Type of Travel	Latitude	Longitude	Year	Month	Day	Start Hour	Duration	Count
2	1	Blaine and Sixth	Commute	46.7302	-116.9856	2014	10	9	7	2	33
3	2	Jackson St and Sixth St.	Commute	46.730091	-117.002733	2014	10	9	7	2	73
4	3	Hayes St. and Third St.	Commute	46.732427	-116.988507	2014	10	9	7	2	39
5	4	N. Almon St and W. A St	Commute	46.734574	-117.004091	2014	10	9	16	2	37
6	5	N. Main St and E. D St	Commute	46.73745	-117.001435	2014	10	9	16	2	17
7	1	Blaine and Sixth	Commute	46.7302	-116.9856	2014	10	9	16	2	21
8	2	Jackson St and Sixth St.	Commute	46.730091	-117.002733	2014	10	9	16	2	128
9	8	Line St. and Sixth St.	Commute	46.729739	-117.012043	2014	10	9	16	2	177
10	9	Line St. and State HWY 8	Commute	46.733368	-117.012038	2014	10	9	16	2	35
11	10	Peterson Dr. and State HWY 8	Commute	46.732888	-117.016285	2014	10	9	16	2	83
12	11	Main St. and Third St.	Commute	46.732373	-117.001388	2014	10	9	16	2	83
13	12	US 95 and Styner/Laudner	Commute	46.721966	-117.001404	2014	10	9	16	2	45
14											
15											

Figure 2.4 Example input csv file.

The input csv must have the following fields spelled and capitalized as follows:

- LocationID = numeric or text identifying the count location
- Description = text describing the count location
- Assumed Type of Travel = Commute, Recreation, or Mixed
- Latitude = numeric value
- Longitude = numeric value
- Year = integer value
- Month = integer value
- Day = integer value
- Start Hour = integer value 0 to 24
- Duration = integer value 0 to 24
- Count = nonnegative integer value

Each row represents a count event that occurred for at least one hour and at most 24 hours. If a count event spans more than 24 hours, then each day should be included as a separate row. It is possible that multiple count events have occurred at the same location within the same day or perhaps sporadically throughout the year; in this case, each event should be provided with a separate row.

Once the csv file has been uploaded, the user must declare how the data are structured. There are two options: screenline or intersection (fig. 2.5). Screenline counts are a tally of the total number of bicyclists in both directions. Such counts usually are done at mid-segment locations. The other option is a total count of all movements through the intersection. Note that other count techniques are used in practice. For example, intersection counts might count (1) “entering” bicyclists from each leg of the intersection, or (2) “existing” bicyclists as they leave toward each leg, or (3) turn movements through the intersection (12 movements for a four-leg intersection). For many years WSDOT’s manual count program has collected “exiting” intersection counts. It is possible to convert exiting, entering, and turn movement counts into a total intersection count by summing the leg-entering or leg-exiting counts. Likewise, turn movement counts can be converted to screenline counts for each leg of the intersection (entering and exiting counts cannot be converted to screenline). Screenline data are preferred for various reasons (Lowry, et al., 2016b).

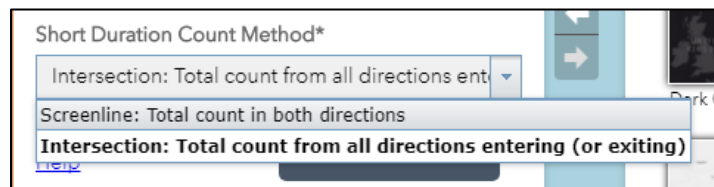


Figure 2.5 Selecting the count method.

The back-end algorithm of the website uses the count method specified by the user to determine how the analysis will occur and what output will be produced. The algorithm will estimate AADB for the count locations if the user declared the count method as Screenline and will estimate TEB for the count locations if the user declared the count method as Intersection. AADB is estimated for the links of the network regardless of the count method.

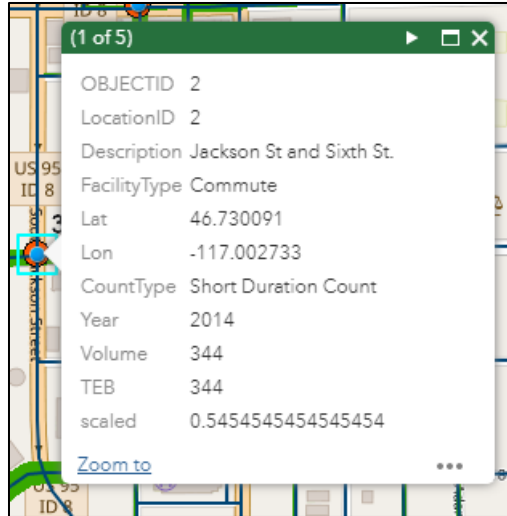


Figure 2.7 Pop-up window displaying output.

The user can download the files for viewing and editing in a geographic information system (GIS). The download includes an ArcGIS® map and database. The output zip file must be un-zipped (extracted) and then can be opened in ArcGIS. Figure 2.8 shows the folder structure. Three layers are included in the map file (.mxd): the point layer, polyline layer, and another polyline layer displaying the bicycle facilities for the network that were obtained from OpenStreetMap. Within ArcGIS the user can open the map and inspect the attribute tables that are associated with the underlying point and polyline files (see fig. 2.9).

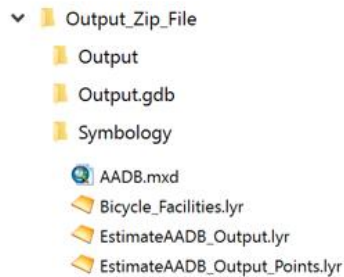


Figure 2.8 Output folder of GIS data.

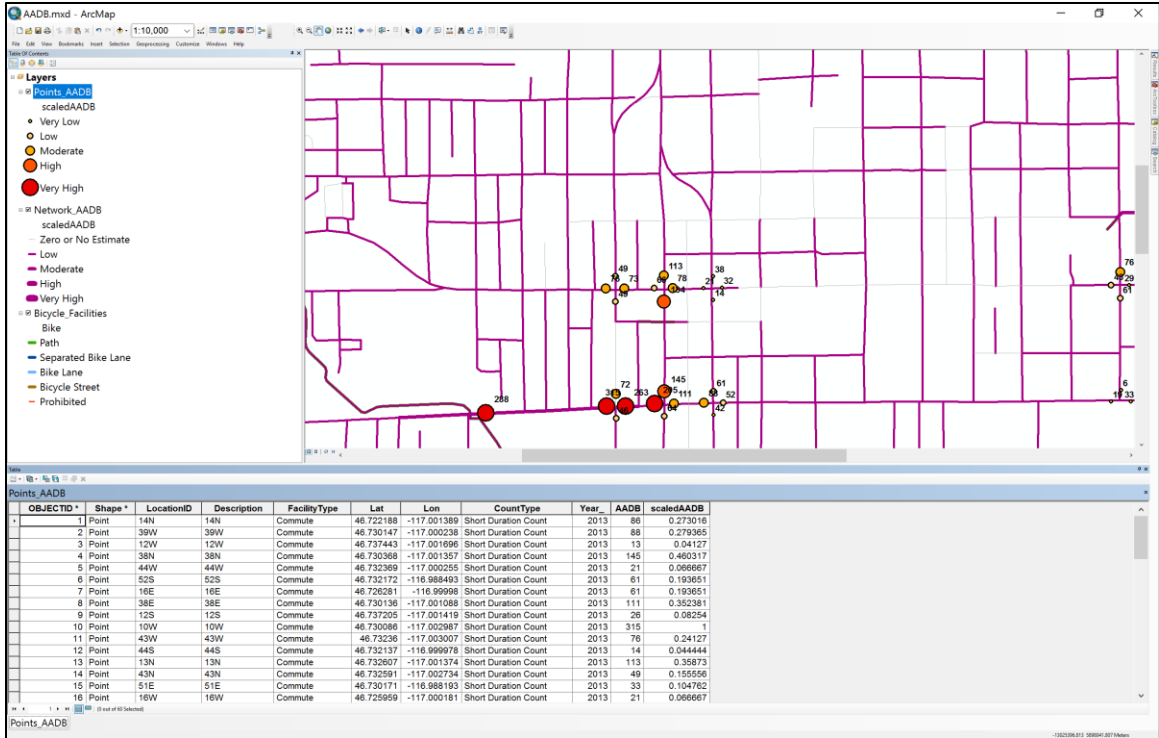


Figure 2.9 Output GIS data in ArcGIS.

Chapter 3 Seasonal Factoring Methodology

This chapter describes how the website seasonally adjusts short-duration counts to obtain AADB and TEB values. The website follows a computer algorithm with steps that roughly follow the subsections of this chapter. Thousands of factors are stored in a database for the *AADB Estimation* website. The factors were calculated from permanent continuous count data for certain years. Appendix A describes how the factors are created.

3.1 Inflating to a Day Volume

First, the short-duration count in each row of the input csv file is inflated to an estimated day volume, D , using hour-of-day factors. The equation is

$$D = \frac{\sum_h C_h}{\sum_h F_{r,y,p,s,w,h}} \quad (3.1)$$

where $\sum_h C_h$ is a row of count data for a consecutive time period and $F_{r,y,p,s,w,h}$ is the hour-of-day factor for climate region r (Washington has four climate regions), year y , travel pattern p (commute, recreation, mixed), season s (fall, winter, spring, or summer), day of the week w (Monday, Tuesday, etc.), and hour of day h . Since the csv file provides an aggregated total across a count period, the website's algorithm need only identify and summate the corresponding hour-of-day factors.

For illustration, table 3.1 shows the hour-of-day factors for fall, climate region 2, and commute travel. If a 2-hour count event on a Thursday from 7:00am to 9:00am observed 56 bicyclists, then the estimated day volume would be $56/(0.09 + 0.13) = 254.5$ bicyclists. If factors are not available for that particular climate region, travel pattern, and year because of a lack of permanent continuous count data, then a generic factor is used for the corresponding travel pattern, season, day, and hour-of-day, $F_{p,s,w,h}$. Appendix A describes how factors are created.

Table 3.1 Example hour-of-day factors

Hour ^a	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
0	0.00	0.00	0.00	0.00	0.00	0.01	0.01
1	0.00	0.00	0.00	0.00	0.00	0.01	0.01
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.01	0.01	0.01	0.00
6	0.04	0.04	0.04	0.04	0.04	0.02	0.01
7	0.09	0.10	0.09	0.09	0.08	0.02	0.02
8	0.13	0.13	0.13	0.13	0.12	0.04	0.04
9	0.07	0.07	0.07	0.07	0.07	0.06	0.06
10	0.03	0.03	0.03	0.03	0.04	0.06	0.07
11	0.03	0.02	0.03	0.03	0.03	0.08	0.08
12	0.03	0.03	0.03	0.03	0.04	0.09	0.09
13	0.03	0.03	0.03	0.03	0.04	0.10	0.10
14	0.04	0.03	0.04	0.03	0.04	0.09	0.10
15	0.05	0.04	0.05	0.05	0.06	0.10	0.10
16	0.09	0.09	0.09	0.09	0.10	0.09	0.09
17	0.16	0.16	0.15	0.15	0.14	0.07	0.07
18	0.10	0.11	0.10	0.10	0.09	0.05	0.05
19	0.04	0.04	0.04	0.04	0.04	0.04	0.03
20	0.02	0.02	0.02	0.02	0.02	0.02	0.02
21	0.01	0.01	0.01	0.01	0.01	0.02	0.02
22	0.01	0.01	0.01	0.01	0.01	0.02	0.01
23	0.00	0.00	0.00	0.01	0.01	0.01	0.01

^a These factors are for climate region 2, 2016, commute travel, fall.

Note: The values represent the fraction of travel during that hour of day. Each column sums to 100 percent.

3.2 Adjusting for Season

Next, the estimated day volume is factored to estimate AADB in one of two possible methods. Method 1: If continuous count data for that climate region, travel pattern, and year are available from a permanent counter within 50 miles, then a day-of-year factor is used, as follows:

$$AADB = D * F_{r,y,p,d} \quad (3.2)$$

where $F_{r,y,p,d}$ is the day-of-year factor for climate region r , year y , travel pattern p , and day-of-year d . The advantage of day-of-year factors was documented by Hankey et al (2014). However,

if a day-of-year factor is not available from a nearby permanent counter, then Method 2 is to use a month and day-of-week factor, as follows:

$$AADB = D * F_{r,y,p,m,w} \quad (3.3)$$

where $F_{r,y,p,m,w}$ is the month and day-of-week factor for climate region r , year y , travel pattern p , month m , and day of week w .

For illustration, table 3.2 shows the month and day-of-week factors for climate region 2, commute travel, fall season. Continuing the previous example, if the Thursday count event occurred in October, then the estimated AADB would be $254.5 * 0.79 = 201$ bicyclists.

If factors are not available for that particular climate region, travel pattern, and year because of a lack of permanent continuous count data, then a generic factor is used for the corresponding travel pattern, month, and day of week, $F_{p,m,w}$.

Table 3.2 Example month-and-day factors

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January	1.12	0.95	0.99	1.25	1.32	2.92	2.91
February	1.16	0.94	1.03	1.19	1.30	1.96	1.87
March	0.75	0.79	0.81	0.67	0.75	1.61	5.22
April	0.78	0.92	0.84	0.81	1.03	1.50	1.49
May	0.72	0.70	0.66	0.58	0.60	1.18	1.27
June	0.70	0.64	0.65	0.61	0.74	1.16	1.36
July	0.67	0.59	0.58	0.62	0.76	1.30	1.53
August	0.71	0.60	0.64	0.64	0.88	1.49	1.29
September	0.81	0.72	0.67	0.78	0.87	1.42	2.18
October	0.87	0.74	0.91	0.79	0.94	2.61	1.95
November	1.14	1.11	1.02	1.24	1.46	3.80	3.54
December	1.52	1.39	1.41	1.91	1.71	5.02	5.85

^a These factors are for climate region 2, 2016, commute travel, fall.

Note: The values represent the adjustment needed to obtain an annual average. Values of less than 1.0 mean the observed value occurred when volumes were relatively high, so the observed count needed to be reduced to match the annual average. Values of greater than 1.0 mean the observed value occurred when volumes were relatively low, so the observed count needed to be increased to match the annual average.

3.3 Combining Multiple Count Events

It is likely that multiple count events will occur for the same count location. In this case, the individual count events (each row in the csv file) are inflated and adjusted by using equations 3.1 and 3.2 or 3.3, and then averaged across all count events. For example, if counts were observed during a morning period (7:00am to 9:00am) and an evening period (4:00pm to 6:00pm) in the fall and in the spring, then four *AADB* values would be calculated and then averaged.

3.4 Summary of Seasonal Factors

Factoring to obtain *AADB* involves thousands of factors stored in the database of the *AADB Estimation* website. The factors are stored as csv files with columns and rows that resemble tables 3.1 and 3.2. Each file is accessed according to climate region, year, travel pattern, and, in some cases, season. Within each file the factor values are obtained by looking them up according to column and row. The following is a comprehensive list of the factor notation presented earlier.

$F_{r,y,p,s,w,h}$	= specific hour-of-day factor
$F_{p,s,w,h}$	= generic hour-of-day factor
$F_{r,y,p,d}$	= specific day-of-year factor
$F_{r,y,p,m,w}$	= specific month and day-of-week factor
$F_{p,m,w}$	= generic month and day-of-week factor
r	= climate region (4 regions in Washington state)
y	= year (2015 or 2016)
p	= travel pattern (commute, recreation, mixed)
s	= season (Fall, Winter, Spring, Summer)
m	= month (1 to 12)
w	= day of week (1 to 7),
d	= day of year (1 to 365 or 364)
h	= hour of day (1 to 24).

Chapter 4 Spatial Extrapolation Methodology

This chapter describes how point data for AADB or TEB are spatially extrapolated to every street in the network. The algorithm follows steps that roughly match the order and description presented in the subsections of this chapter.

4.1 Creating the Street Network, Origins, and Destinations

The first step of the algorithm is to create a street network, origin points, and destination points for the study area. The study area is defined by adding a 2-mile rectangular buffer around the spatial extent of the count locations (i.e., the minimum bounding envelope). If a street network, origin points, and destination points for that area already exist in the database, then the existing features are used. Otherwise, new GIS features are created (See Future Work in the Conclusion for plans to improve this aspect of the website).

The street network is created by downloading all streets and paved pathways from OpenStreetMap (OSM) for the study area. The OSM tags for bicycle facilities and paths are recoded as Path, Separated Bike Lane, Bike Lane, or Bicycle Street. The OSM tags for identifying the kind of road are recoded to match the functional classification system defined by the Federal Highway Administration (FHWA) (FHWA, 2016). If OSM data are available for number of lanes and speed limit, then those data are utilized; otherwise these values are assumed on the basis of functional class (see table 4.1).

Table 4.1 Assumed values for number of lanes and speed limit.

Functional Class	Lanes (number)	Speed Limit (mph)
Freeway	4	65
Principal Arterial	5	35
Minor Arterial	3	35
Collector	2	30
Local	2	25
Access Road	1	20
Unpaved	1	20

The OSM network is modified to have routable topology (i.e., breaks at intersections, etc., so that a routing algorithm can find routes across the network). Next, an “augmented street network” is created to have (1) parallel unidirectional links (i.e., a directed graph), (2) a field for slope (i.e., grade) across each link, and (3) new links that represent the turn movements at intersections.

The origin points are created by downloading the bicycle commute share for each Census block group in the study area for the year in which the count event occurred (US Census Bureau, 2017). The percentage of the adults who bicycle in a day, A , is calculated by using the high-end model reported by Krizek et al. (2006).

$$A = 0.5\% * 3(C) \tag{4.1}$$

where C is the bicycle commute share as a percentage for the block group. The number of daily bicyclists in a block group, $N_{bicyclists}$, is calculated as follows:

$$N_{bicyclists} = A * Population_{adult} + 2(A) * Population_{non-adult} \tag{4.2}$$

The “origins points” are randomly located GIS points for every bicyclist within the spatial bounds of the block group.

The destination points are created by downloading points-of-interest from Google Places for the study area (Google, 2017). The Google places are assigned a “multiplier” value representing the magnitude of trip attraction potential (origin points have a multiplier equal to 1.0). Table 4.2 shows the Google places that are included and the corresponding multiplier.

Table 4.2 Google Places used to create destination points.

Google Place	Multiplier	Google Place	Multiplier
accounting	1	lawyer	1
art_gallery	1	library	5
atm	1	local_government_office	1
bakery	1	meal_takeaway	1
bank	1	mosque	1
bar	1	movie_rental	5
beauty_salon	1	movie_theater	5
bicycle_store	10	museum	5
book_store	5	night_club	1
bowling_alley	1	park	5
bus_station	5	pet_store	1
cafe	5	pharmacy	1
church	1	post_office	1
city_hall	1	restaurant	1
clothing_store	5	school	10
convenience_store	5	shoe_store	1
courthouse	1	shopping_mall	5
department_store	5	stadium	5
electronics_store	1	store	1
florist	1	subway_station	5
gym	5	synagogue	1
hair_care	1	train_station	5
home_goods_store	1	transit_station	5
hospital	1	university	10
jewelry_store	1	zoo	1

4.2 Calculating Expected Bicycle Flow

“Expected bicycle flow” from origins to destinations is calculated by finding the route between every origin and every destination that has the lowest total “traffic stress.” The flow between two points is magnified by the multipliers of the points. Traffic stress along street segments depends on functional classification, slope, number of lanes, and speed limit. Traffic stress at intersections depends on turn movement penalties, as well as the cross-street’s functional classification, number of lanes, and speed limit. Traffic stress is reduced by the

presence of bicycle accommodations (see Chapter 3 of Wang et al., 2016, for details about how traffic stress is calculated).

Expected bicycle flow is the accumulation of thousands of potential trips that have been routed between every origin and every destination. Figure 4.1 shows an example of expected bicycle flow through a network. The thicker lines represent more flow. Lowry et al. (2016a) provided the equations for calculating flow, also called “edge centrality,” for every link in a network (note that the *AADB Estimation* website does not involve stress constraints). A unique flow is calculated for every combination of origins and destinations, such that there is q_{od} for the flow from origins to destinations, q_{oo} for the flow from origins to origins, q_{do} for the flow from destinations to origins, etc.

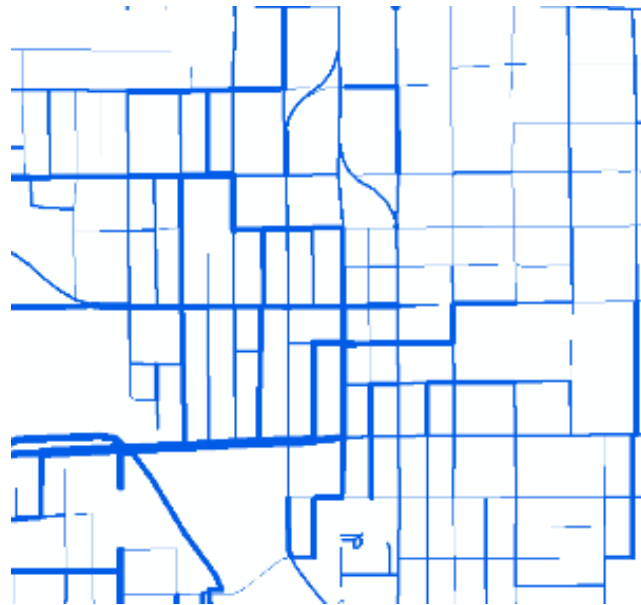


Figure 4.1 Expected bicycle flow through a network.

4.3 Fitting AADB to Expected Bicycle Flow

Finally, the website’s algorithm fits a regression model of the AADB points against the expected bicycle flow of the streets at the count locations and then applies the model to every link in the network. Figure 4.2 illustrates how this process provides a means to spatially extrapolate the count data across the network.

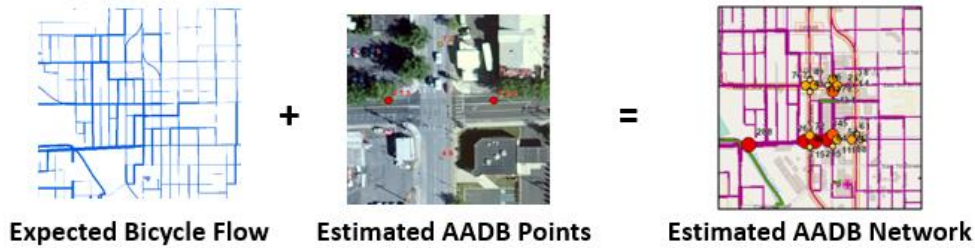


Figure 4.2 Fitting AADB to expected bicycle flow.

The algorithm fits the regression model by exhaustively trying every combination of subset combination of the flow values and the square of the flow values. Candidate models are compared for adjusted R^2 to determine the best fit. For example, the regression model for one community is shown in table 4.3. Linear regression is used, so it is possible that a model will not have a constant and could possibly have negative coefficients, which could result in negative values upon application. Negative values are forced to zero.

Table 4.3 Example regression model for fitting AADT

Item	Value
constant	16
q_{oo}	0.0045
q_{od}	0.0094
q_{od}^2	0.0003
Adj. R-squared	0.597
n observations	23

Chapter 5 Conclusions and Future Work

5.1 Technology Transfer

This project created the *AADB Estimation* website, which communities can use to make maps of bicycle volumes from their street network count data. Communities can use the website to conduct safety analyses and prioritize new bicycle infrastructure. The website is maintained by Dr. Michael Lowry at the University of Idaho. The website was created through grants from the Washington State Department of Transportation and US Department of Transportation specifically to help communities in Washington state. However, the website can be used by anyone and for anywhere in the United States. Results outside of Washington take longer to compute and are less reliable.

5.2 Future Work

This section lists a few ways in which the *AADB Estimation* website could be improved.

- Provide a means for the user to upload permanent counter data. This would allow users outside of Washington to have more accurate AADB estimates. This would also have the benefit of establishing a database that would continue to grow. The seasonal adjustment could combine the user-supplied factors with existing factors, perhaps in 70/30 ratio to give more credence to the user-supplied data.
- Provide a user option to extract new OSM data, regardless of whether data exist in the database. This would allow the user to fix errors in the OSM data.
- Update the algorithm for calculating seasonal adjustment factors (Appendix A) with the new “modified AASHTO” method. The current AASHTO method that is used for the website requires a full day of continuous data, while the modified method is applicable for every hour of available count data (FHWA, 2016, page 1-7).

- Provide a more advanced version of the tool that allows users to supply their own network to conduct analysis for past conditions and future proposed scenarios (presently the tool bases the analysis on current OSM data). Scenario analysis would require calculating a flow under two conditions. Consequently, the modeling technique would need to be altered. The current modeling technique finds the best polynomial model, which might involve multiple regressor variables. This process provides a “tight” fit to the data but might also produce “over-fit” to noise. This not a problem if the model is not being transferred to a different scenario. Therefore, a more restrictive method of model fitting (using fewer flow variables) should be explored. A related issue is multicollinearity, which was apparent in the regression meta-data during testing.
- Explore the usefulness of other regression techniques, such as negative binomial regression. Such techniques would assure non-negative integer output.
- Create a relational database for the adjustment factors, rather than the current use of a “flat file database,” which is likely slow. A more sophisticated database would also provide a more efficient means for scaling across the country.
- Investigate combining factors through some kind of distance-weighting. The counter locations would still need to be in the same climate region and within a certain cutoff distance. For example, suppose the cutoff distance was 300 miles and there were three continuous counters in the region that were 5 miles, 26 miles, and 220 miles away. Then the factors would be combined as follows:

$$F = \frac{(300-5)}{300} F_1 + \frac{(300-26)}{300} F_2 + \frac{(300-220)}{300} F_3 \quad (5.1)$$

- Develop a way to calculate slope without using a digital elevation model (DEM).
Presently the tool uses a DEM for the state of Washington that is stored in the database. Consequently, analysis for any study area outside of Washington does not incorporate slope into the routing algorithm. The Google elevation API might be useful.
- Develop a way to create origins for outside of the United States that does not involve US Census data. Perhaps they could be based on the density of residential street intersections.

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Appendix A Creation of Seasonal Adjustment Factors

The *AADB Estimation* website includes a massive database of adjustment factors that have been created from permanent continuous counting equipment. The process for creating seasonal adjustment factors is based on the hourly, daily, and monthly variations observed in the continuous counts (see figure A.1).



Figure A.1 Creating seasonal adjustment factors.

The current method uses only complete days of data. The first step is to catalog every counter on the basis of climate region r , year of data y , and travel pattern p . Redundant factors for r , y , and p are averaged. Four climate regions are defined for Washington (fig. A.2).

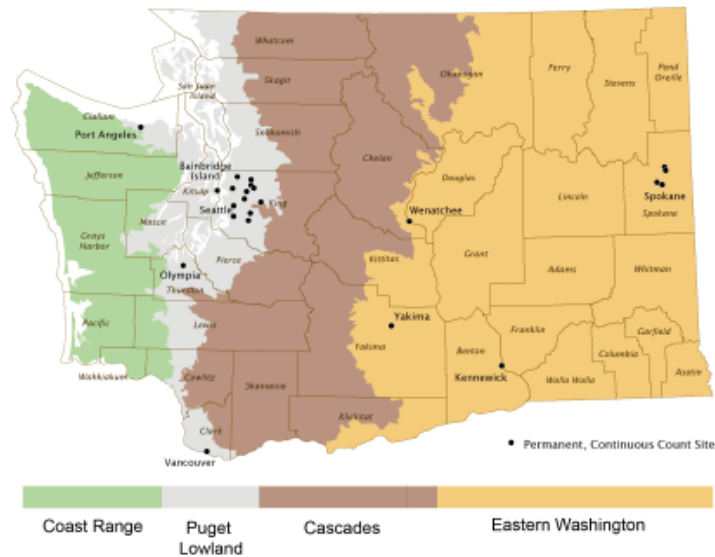


Figure A.2 Washington state climate regions.

Travel pattern (commute, recreation, or mixed) is determined by first calculating the morning ratio as

$$\text{morning ratio} = \frac{\frac{1}{n_1} \sum_{h=7}^8 v_h}{\frac{1}{n_2} \sum_{h=11}^{12} v_h} \quad (\text{A.1})$$

where

v_h = bicycle volume for hour h

n_1 = the number of hours of data for 7:00am and 8:00am for the year

n_2 = the number of hours of data for 11:00am and 12:00noon for the year

Next, the weekend ratio is calculated as

$$\text{weekend ratio} = \frac{\frac{1}{n_3} \sum_{w=6}^7 (\sum_h^{24} v_h)}{\frac{1}{n_4} \sum_{w=1}^5 (\sum_h^{24} v_h)} \quad (\text{A.2})$$

where

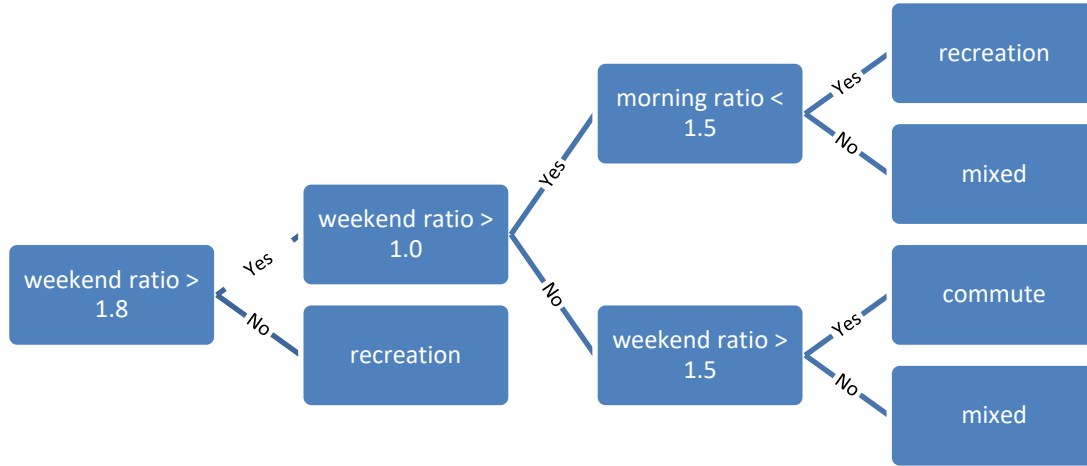
v_h = bicycle volume for hour h

n_3 = the number of weekend days of data for the year

n_4 = the number of weekdays of data for the year.

Travel pattern is then determined according to the decision chart shown in figure A.3

Figure A.3 Decision chart for travel pattern.



The second step is to calculate AADB from the continuous data. Theoretically, AADB is the total annual volume in both directions divided by 365 (364 for leap years). However, it is very common for permanent counters to fail for a few hours or a few days throughout the year. Consequently, the American Association of State Highway and Transportation Officials (AASHTO) developed the following equation in case data are missing for a few days in a year (See the third suggestion under section 5.2 Future Work) (FHWA, 2016):

$$AADB = \frac{1}{7} \sum_w \left\{ \frac{1}{12} \sum_m \left[\frac{1}{n} \sum_k \left(\sum_h^{24} v_{w,m,k,h} \right) \right] \right\} \quad (A.3)$$

where

v = bicycle volume for hour h for the k^{th} occurrence of day-of-week w within month m

n = the number of days of that day of the week during that month

The hour-of-day factors are calculated by season: Fall (September, October, and November), Winter (December, January, and February), Spring (March, April, and May), and Summer (June, July, and August). The calculation for region r , year y , travel pattern p , and season s is calculated as follows:

$$F_{r,y,p,s,w,h} = \frac{1}{3} \sum_{m=s}^S \left[\frac{1}{n} \sum_k^n (\sum_h^{24} v_{w,m,k,h}) \right] * AADB \quad (A.4)$$

where s is the starting month number for the season and S is the ending month number.

The day-of-year factor is

$$F_{r,y,p,d} = \frac{AADB}{\sum_h^{24} v_{hd}} \quad (A.5)$$

where v_{hd} is the hourly volumes for day d within the year.

The month and day-of-week factors are

$$F_{r,y,p,m,w} = \frac{AADB}{\frac{1}{n} \sum_k^n (\sum_h^{24} v_{w,m,k,h})} \quad (A.6)$$

where s is the starting month number for the season and S is the ending month number.

References

Federal Highway Administration (2016) *Traffic Monitoring Guide*. Washington, DC, U.S. DOT

Appendix B Guidance for Updating Open Street Maps

The *AADB Estimation* website extracts the street and trail network from OpenStreetMap (OSM). OSM is a community-generated mapping service, like Wikipedia. Currently, the *AADB Estimation* website extracts and caches an OSM network every three months. A future improvement to the website will allow the user to initiate a new extraction. This will allow the user to make updates to OSM and assure that those updates are included in the AADB analysis.

The user should begin by navigating in a browser to the desired location in OSM. Select the Cycle Map layer shown in figure B.1 (note that OSM began in England and often uses British English). Making edits in OSM requires registering for an account. Registration is free. After login, the user can begin editing by choosing the first option in the Edit drop down (see figure B.1). The browser will switch to an editing interface shown in figure B.2.

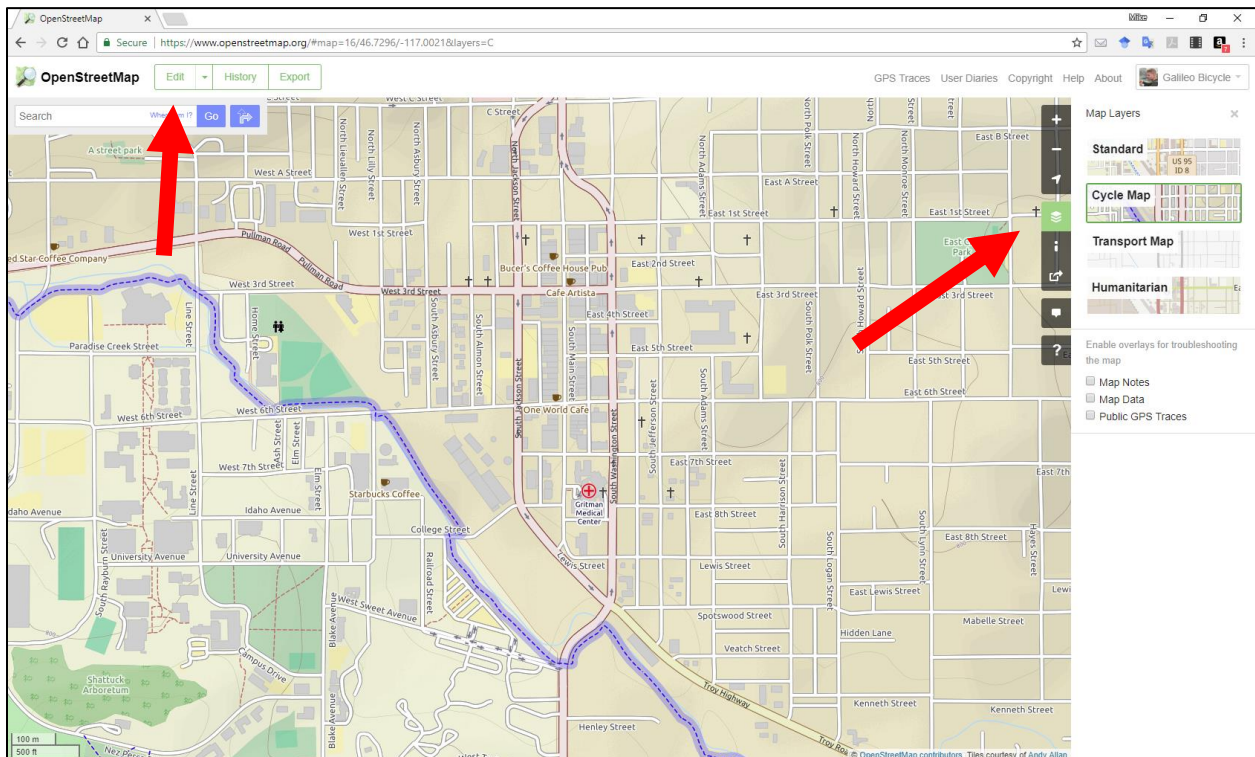


Figure B.1 OpenStreetMap showing the bicycle layer.



Figure B.4 Bike lane drop downs.



Figure B.5 OSM bicycle facilities.

To add off-street paths, begin by selecting the line create button shown in figure B.6. Click along the desired path. Be sure to include all connections to other paths and streets, such as at the beginning and end (figure B.7). Double click to finish the new line and select the Path option (figure B.8). This assures correct topology.

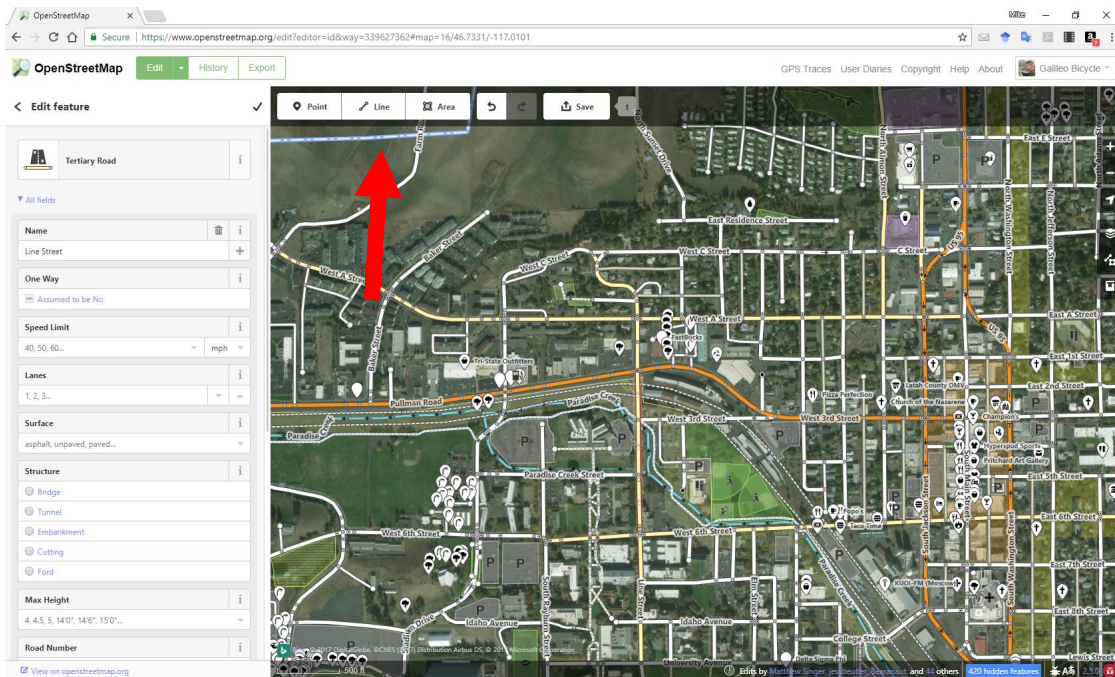


Figure B.6 Line editing button.



Figure B.7 Connecting a path to a street.

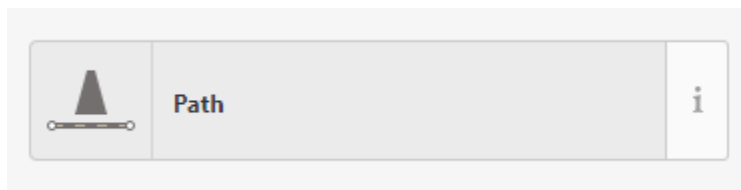


Figure B.8 Path tag for the new line.

To finish the editing session, users must save and upload the edits. The edits are saved immediately but will not show on the Cycle Map layer for a few days.