Estimating Pedestrian and Bicycle Miles Traveled (PMT/BMT) in Washington State

Krista Nordback, P.E., Ph.D., PSU

Mike Sellinger, MURP, Alta Planning & Design

Taylor Phillips, PSU

Portland State UNIVERSITY

TREC

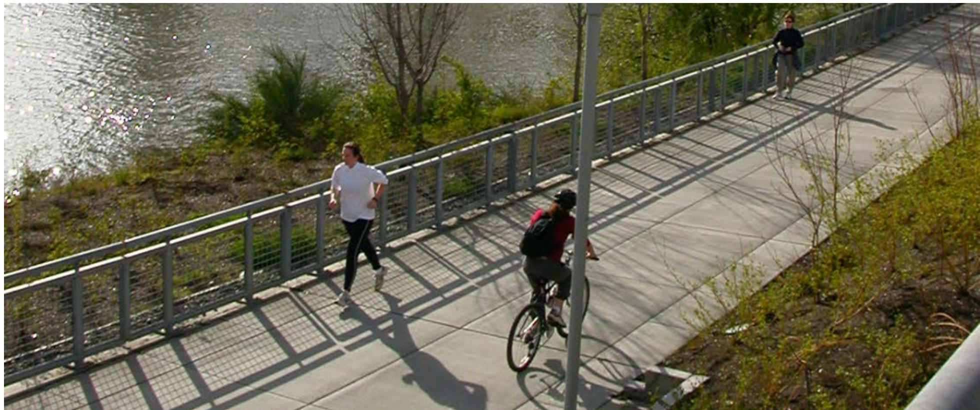
Overview

- Purpose
- Review
- Data
- Methods
- Results
- Conclusions & Recommendations

PURPOSE

Why measure walking & biking?

- Funding & policy decisions
- To show change over time
- Facility design
- Planning (short-term, long-term, regional…)
- Economic impact
- Public health
- Safety

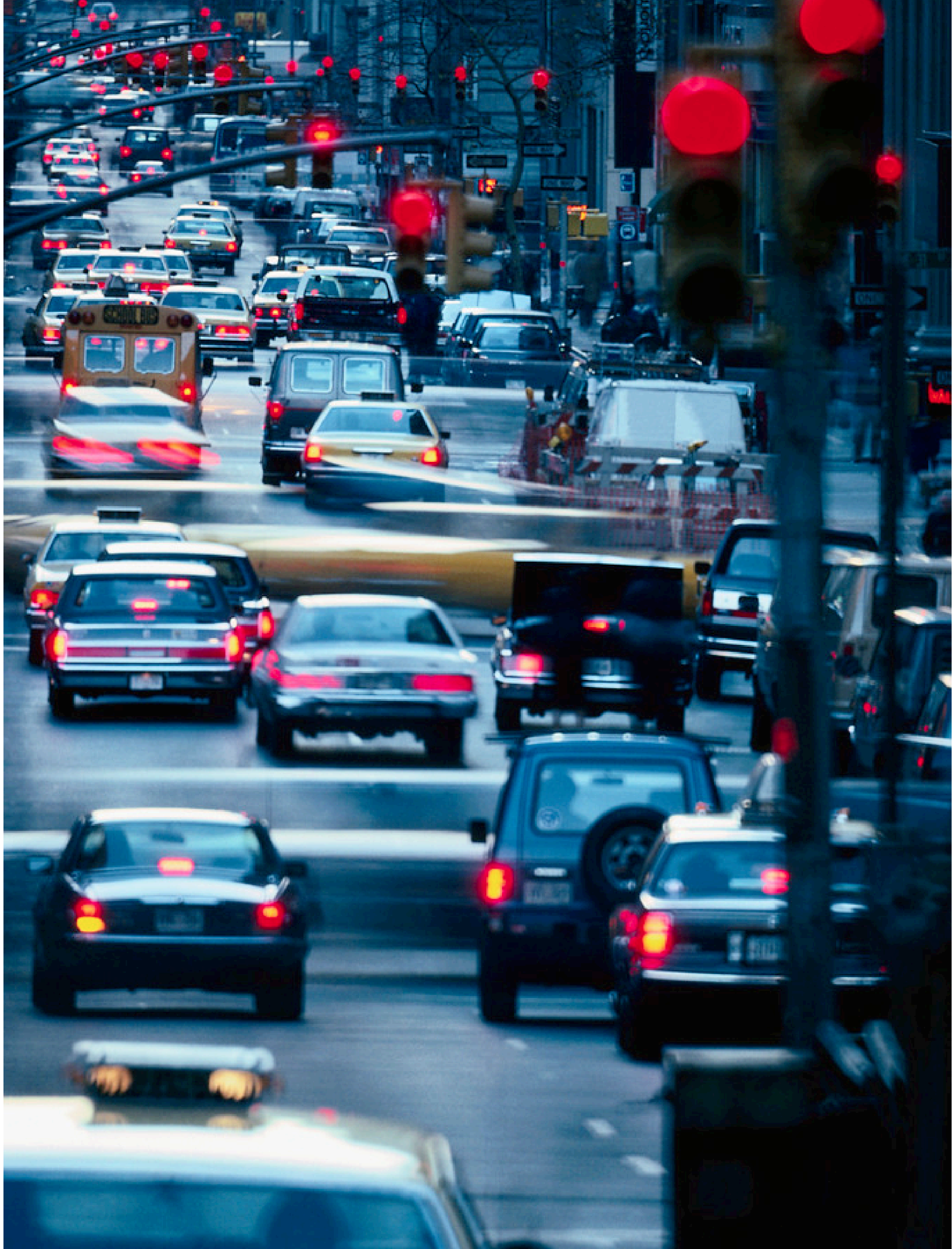


BMT and PMT

- Bicycle Miles Traveled (BMT)
- Pedestrian Miles Traveled (PMT)

REVIEW

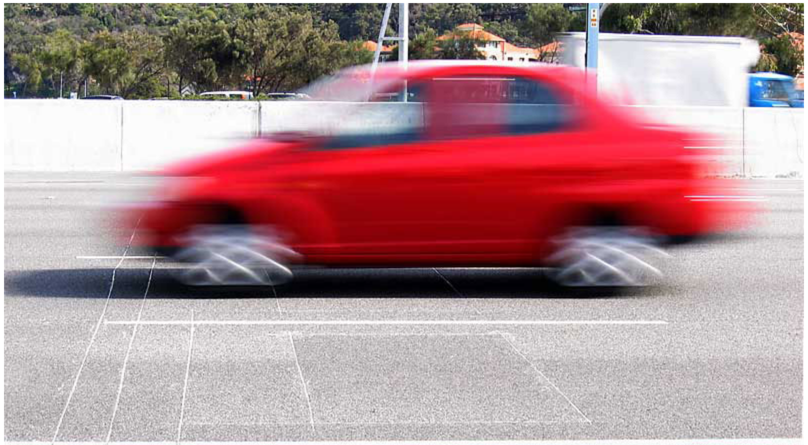
TRAFFIC MONITORING PROGRAMS



State Traffic Monitoring

Permanent Counters

Commonly inductive loops

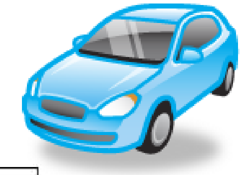


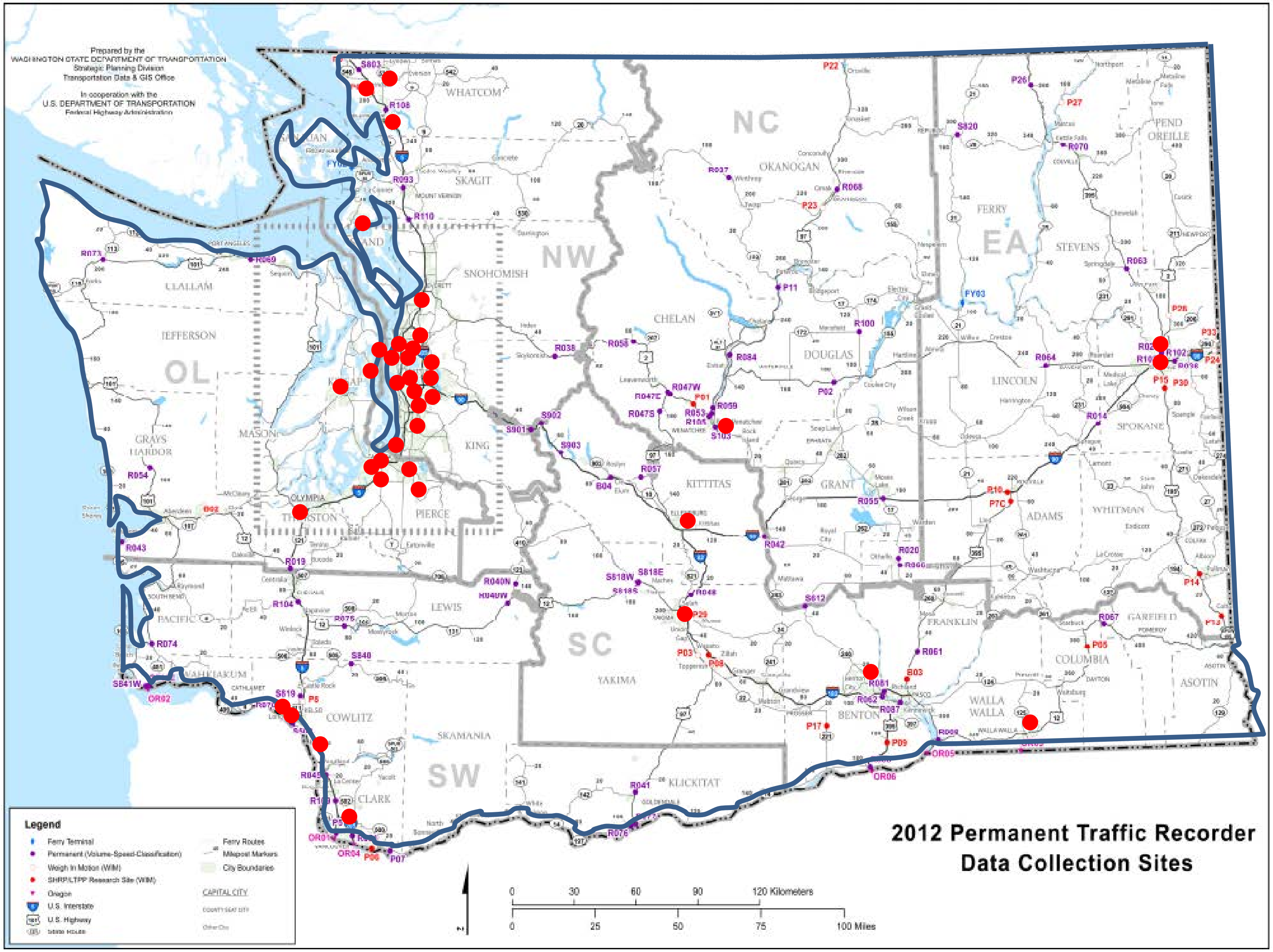
Metro Count Accessed 6/13/13 http://mtehelp.tech-metrocount.com/article.aspx?key=mc5805

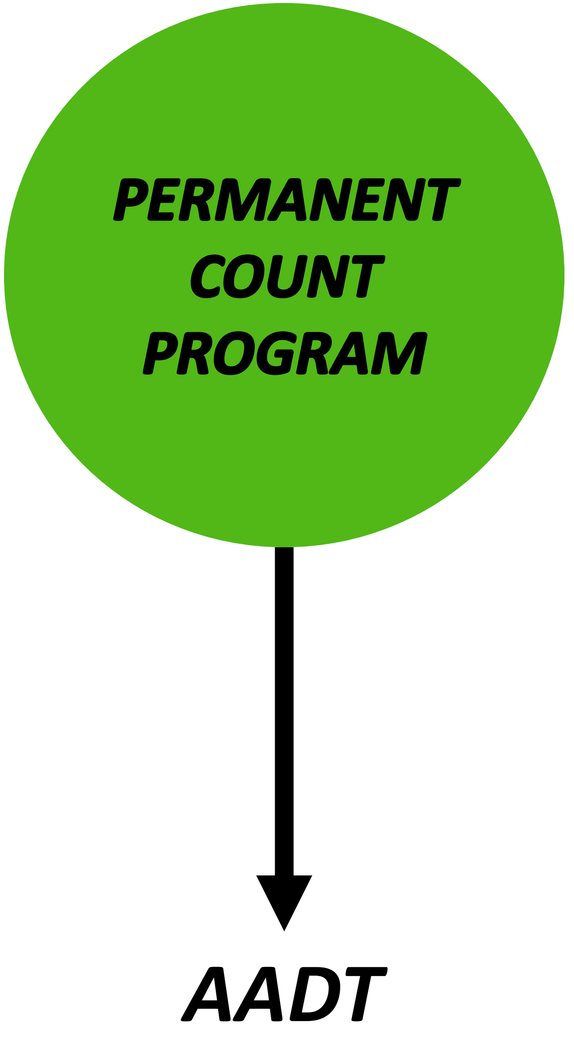
Short Duration Counters

Commonly pneumatic tubes

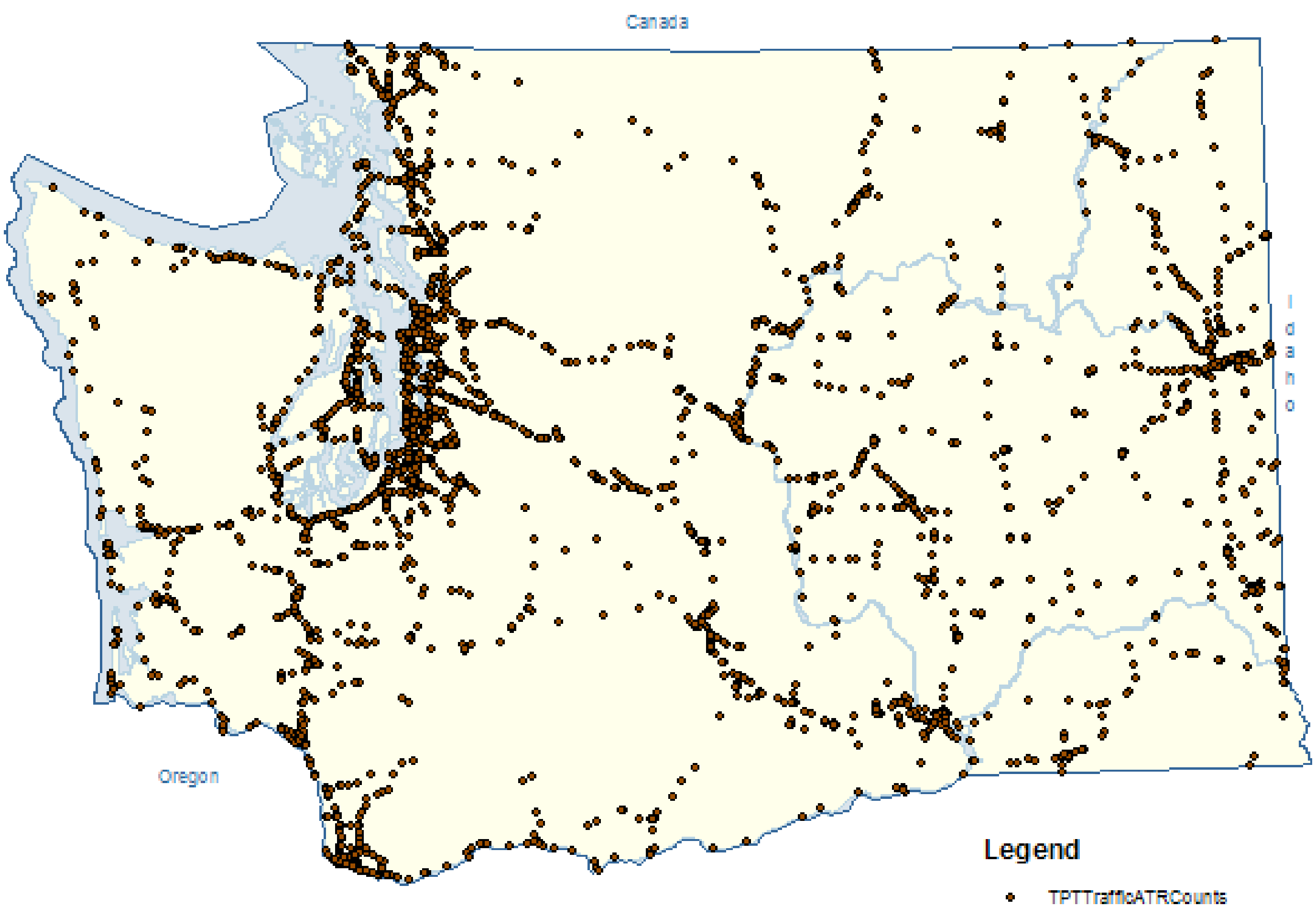
Permanent Counters

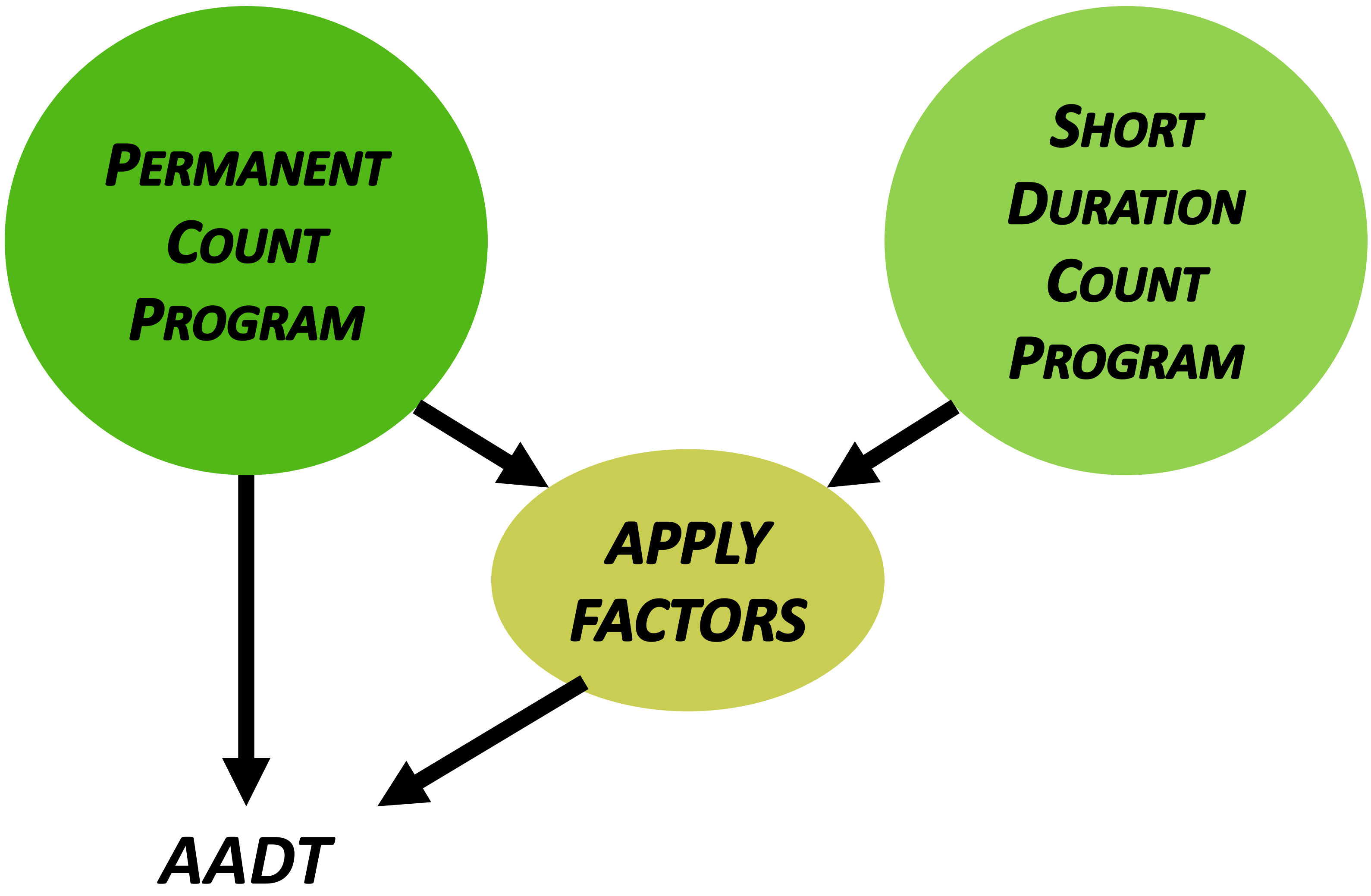


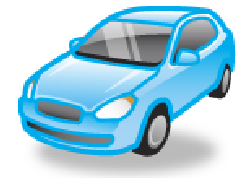



PERMANENT
COUNT
PROGRAM
AADT

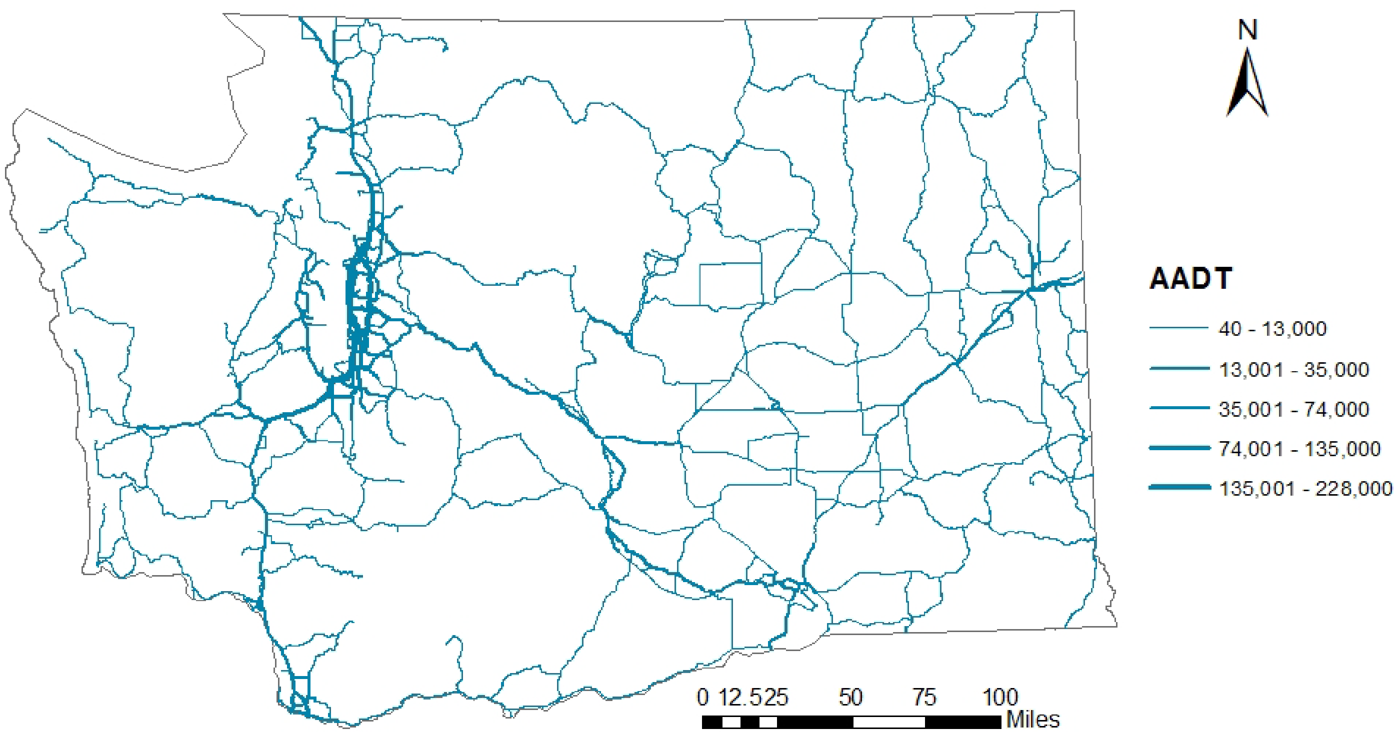
Short Duration Counters




PERMANENT COUNT PROGRAM
SHORT DURATION COUNT PROGRAM
APPLY FACTORS
AADT



AADT and VMT



Sum (AADT X Segment Length) over network to compute Vehicle Miles Traveled (VMT)

Can we apply these methods
to biking and walking?

AADB:
Annual Average Daily Bicyclists

AADT for bicyclists!

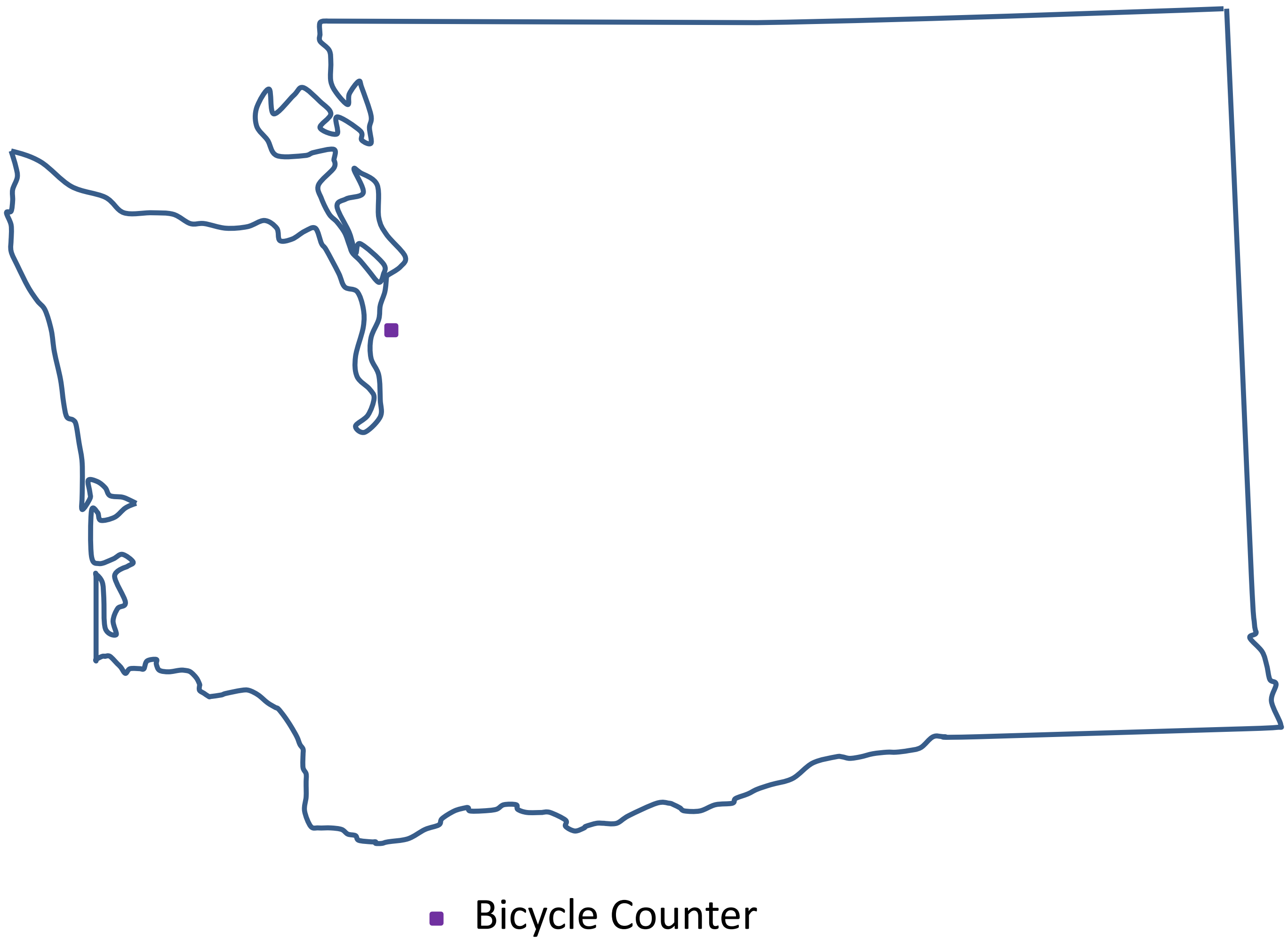
Acronyms

- Bicycle Miles Traveled (BMT)
- Pedestrian Miles Traveled (PMT)

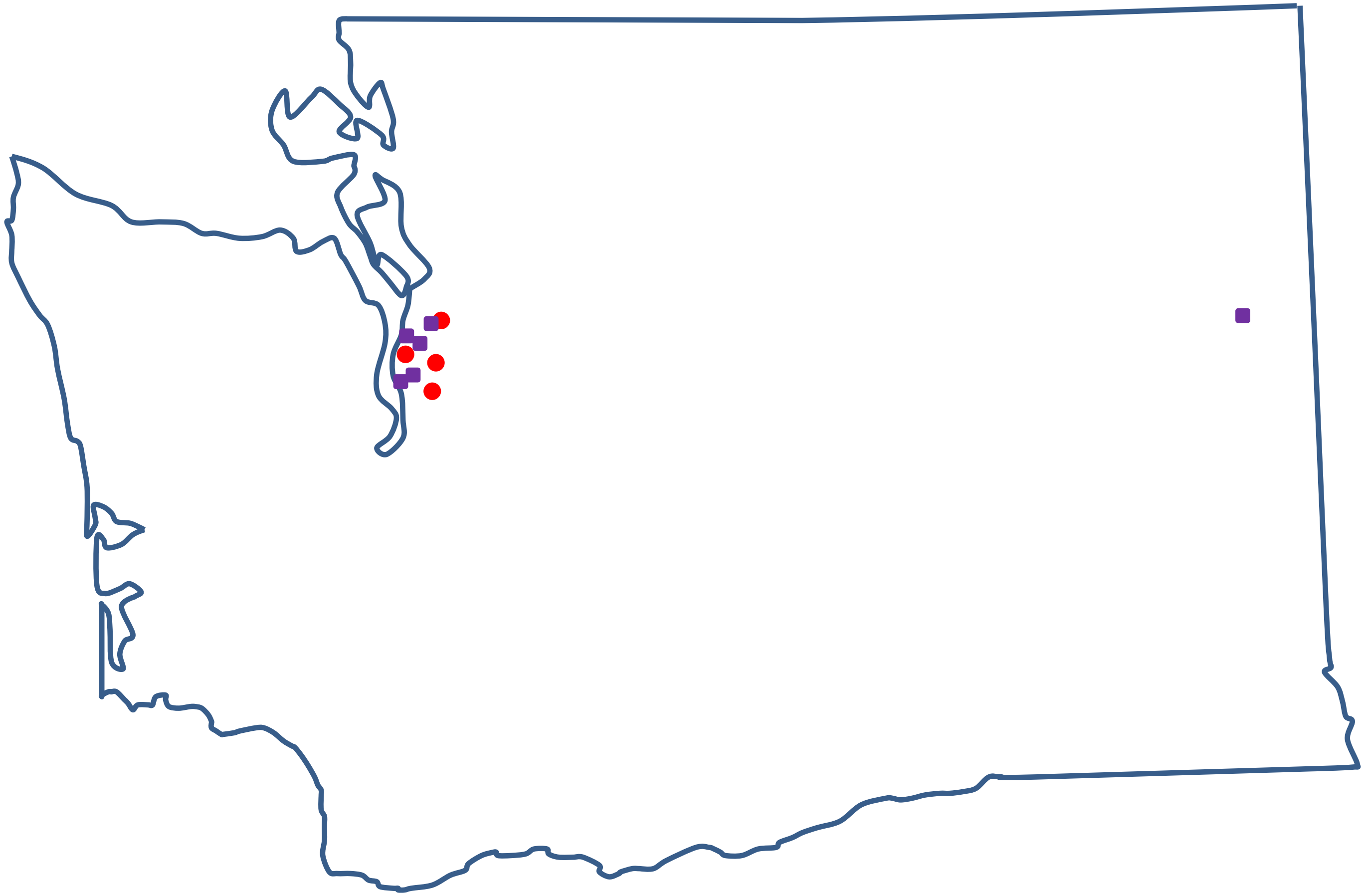
- Annual Average Daily Bicyclists (AADB)
- Annual Average Daily Pedestrians (AADP)

DATA

Permanent Counters in 2012



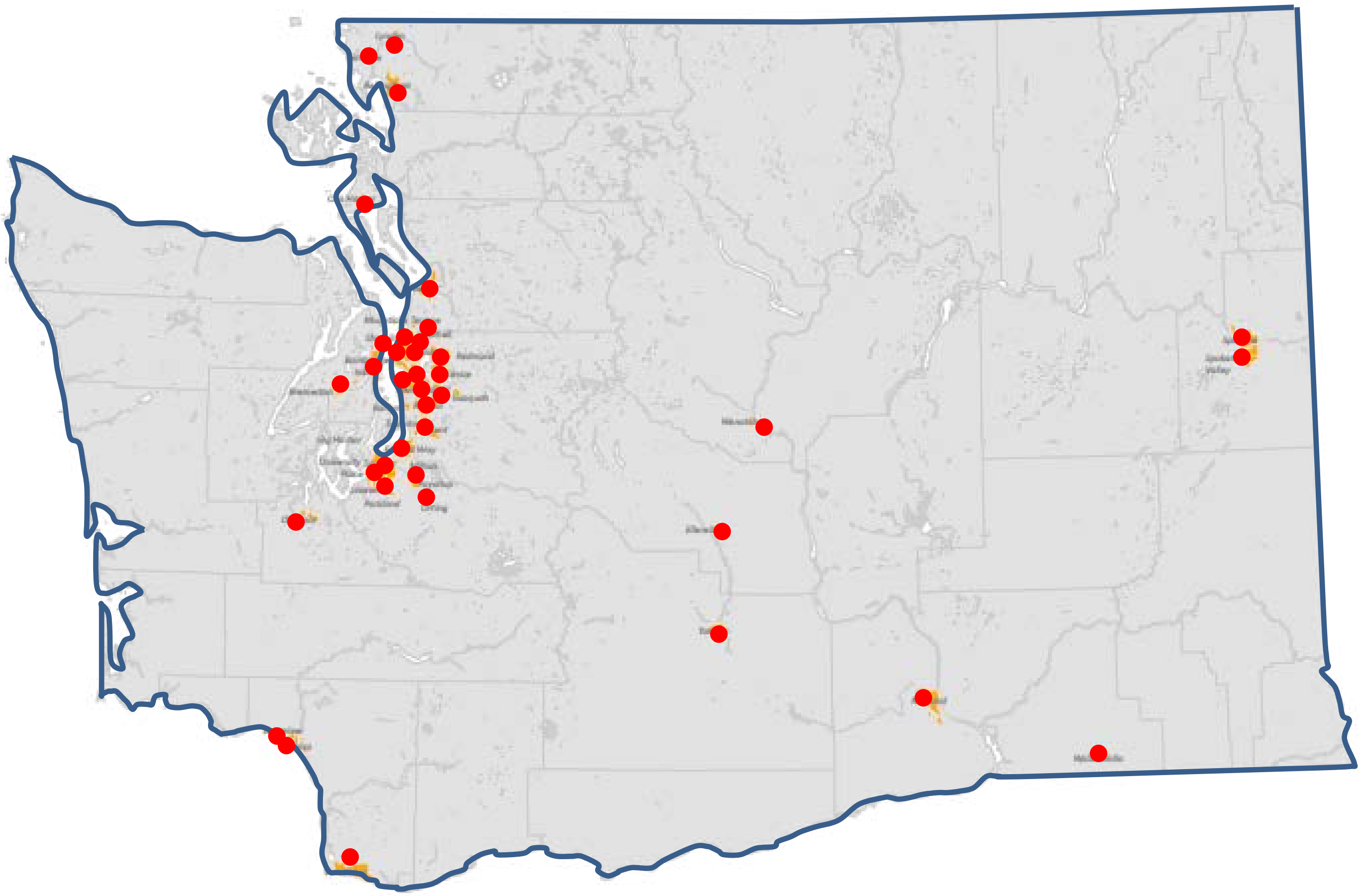
Permanent Counters now



- Bicycle Counter
- Bicycle and Pedestrian Counter

Short Duration Counts

2012 WASHINGTON STATE BICYCLE AND PEDESTRIAN DOCUMENTATION PROJECT



Annual Sept/Oct, volunteer manual counts, morning and evening peak hours

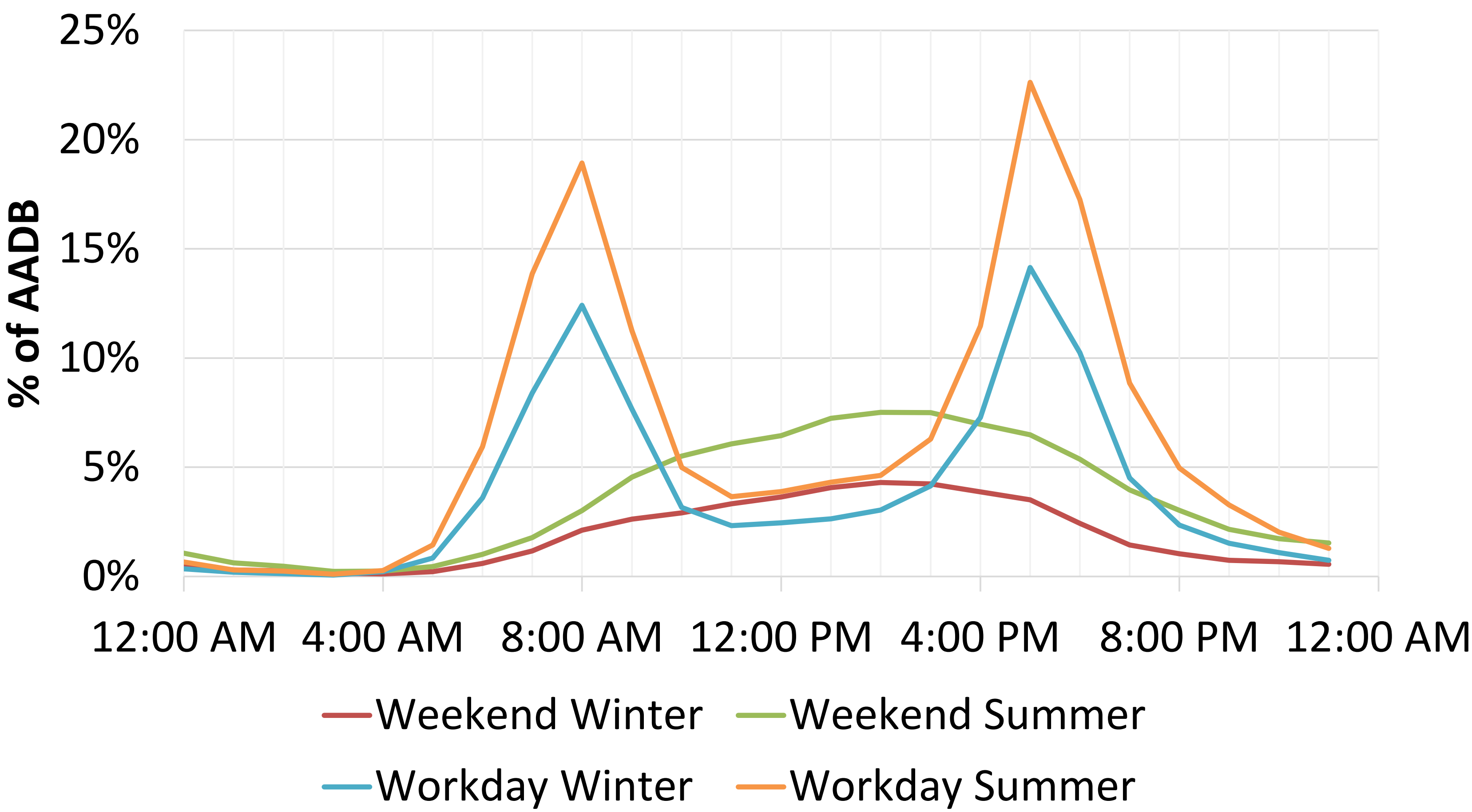
Seattle

- Manual Counts
- 50 locations
- 4 times per year
  - 10:00 AM to noon Weekdays
  - 5:00 PM to 7:00 PM Weekdays
  - Noon to 2:00 PM Saturdays

Traffic Patterns

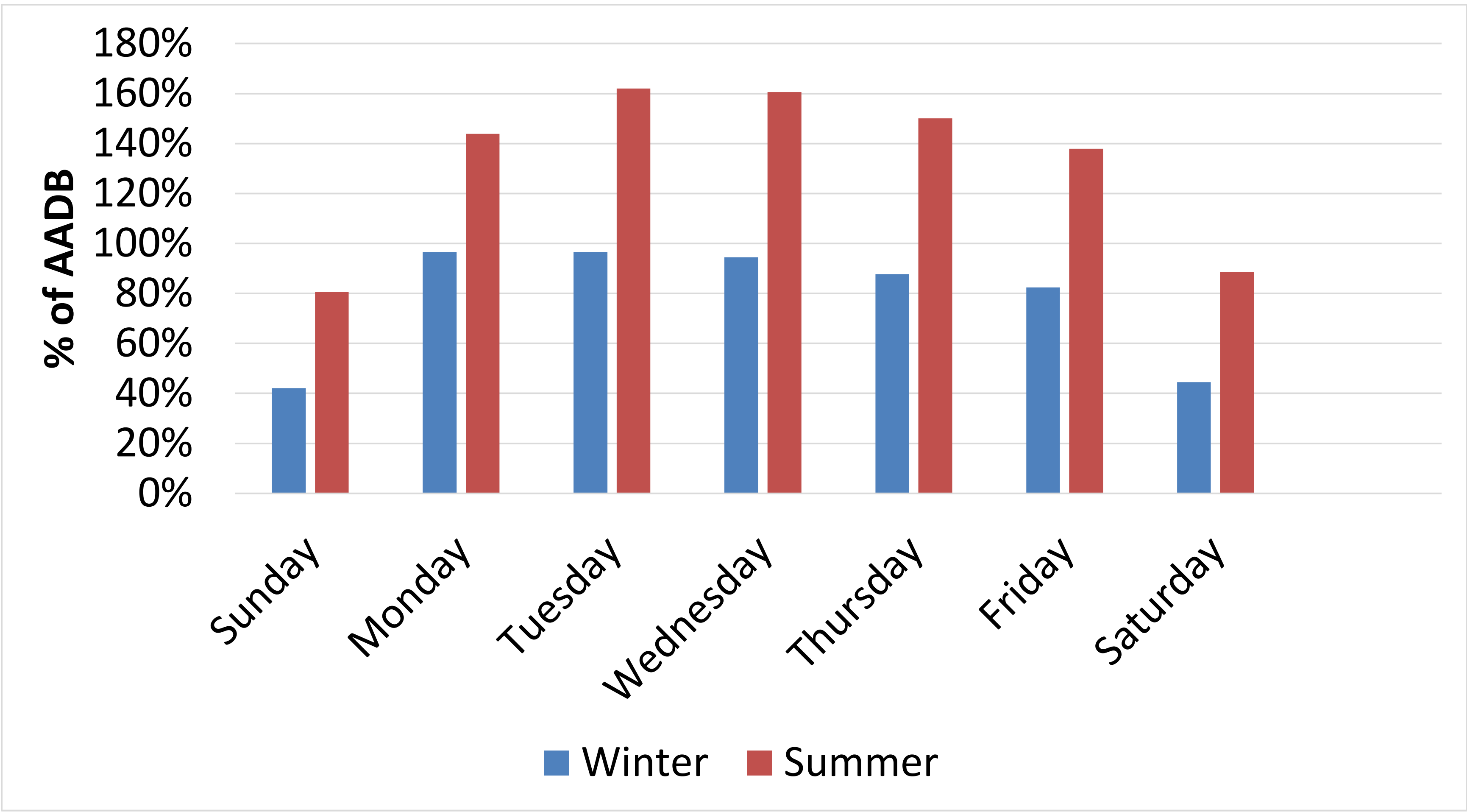
- Seattle – one year of data

Fremont Bridge, Seattle

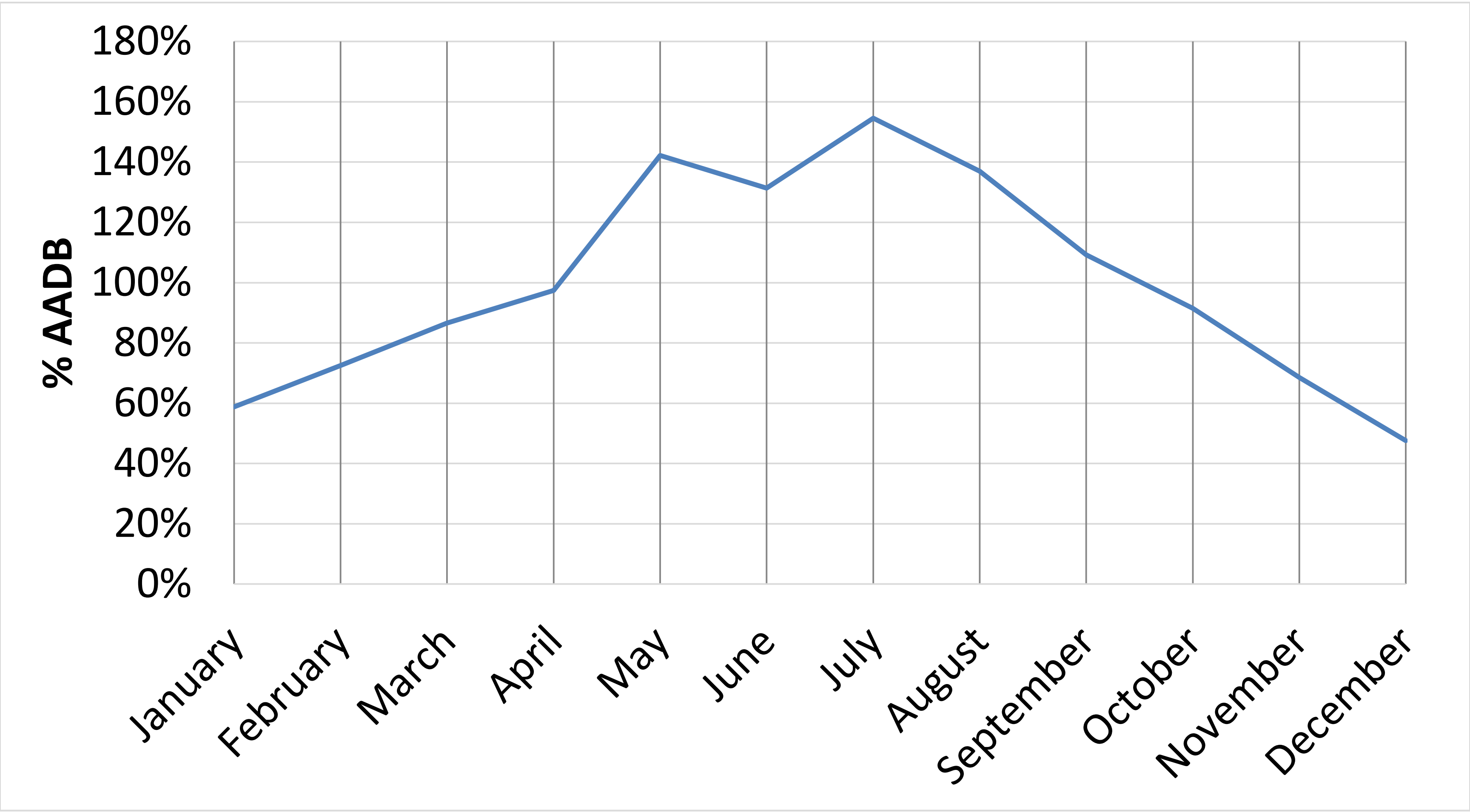


Annual Average Daily Bicyclists (AADB) = 2,461

Fremont Bridge, Seattle



Fremont Bridge, Seattle



Annual Average Daily Bicyclists (AADB) = 2,461

Factoring Method

Adapted from Traffic Monitoring Guide

$$AADB = C_{known} * M * D$$

C_{known} = hourly count

M = Monthly Factor

D = Daily/Hourly Factor

Monthly Factor

December

$$M = \frac{AADB}{MADB} = \frac{2{,}000}{1{,}000} = 2$$

Daily counts in December are half of AADB.

where

MADB = Ave daily bike count in that month

Created Monthly Factors

Month	Monthly AADB	Factor
January	1,448	1.7
February	1,787	1.4
March	2,132	1.2
April	2,400	1.0
May	3,502	0.7
June	3,237	0.8
July	3,806	0.6
August	3,373	0.7
September	2,691	0.9
October	2,254	1.1
November	1,688	1.5
December	1,173	2.1

Created Daily/Hourly Factors

	7-8 AM Week-day	8-9 AM Week-day	10-11 AM Week-day	11-Noon Week-day	4-5 PM Week-day	5-6 PM Week-day	6-7 PM Week-day	Noon-1 PM Satur-day	1-2 PM Satur-day
January	9.0	6.1	26.5	32.3	11.0	5.5	8.1	28.3	21.0
February	8.8	6.0	28.4	33.4	11.2	5.4	7.8	17.1	16.3
March	9.9	7.1	29.4	39.3	13.2	6.3	8.6	13.9	12.5
April	8.2	6.2	25.7	31.4	10.0	5.3	6.7	26.9	33.1
May	8.7	6.7	29.9	41.0	12.1	5.6	7.5	21.4	17.5
June	9.3	7.1	27.8	34.8	11.4	5.7	7.3	16.2	14.4
July	10.3	7.5	25.7	33.9	12.0	6.2	7.9	19.2	18.0
August	9.8	6.8	24.6	33.4	11.7	5.7	7.1	22.1	19.8
September	8.7	5.8	23.7	31.6	10.8	4.9	6.2	27.6	24.5
October	14.5	15.2	17.4	17.0	14.4	15.3	22.0	25.1	22.8
November	8.1	5.8	24.0	31.0	9.4	5.5	8.4	17.0	19.9
December	8.6	5.6	24.2	33.6	10.1	5.3	8.3	24.7	25.1

Should these be factors be applied across the state?

NO

Non-motorized Data

Volume data:

Type	Pros	Cons
Survey/travel diary	Representative sample	No facility level info
GPS	Route choice included	Usually self-selection bias
Continuous and short-term counts	Facility level	Many locations needed

Spatial Variables:

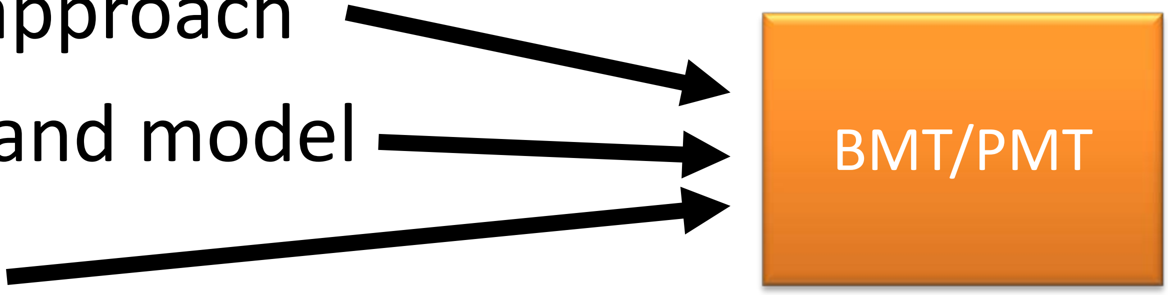
- Facility type, land use, geography
- Socio-demographics, population

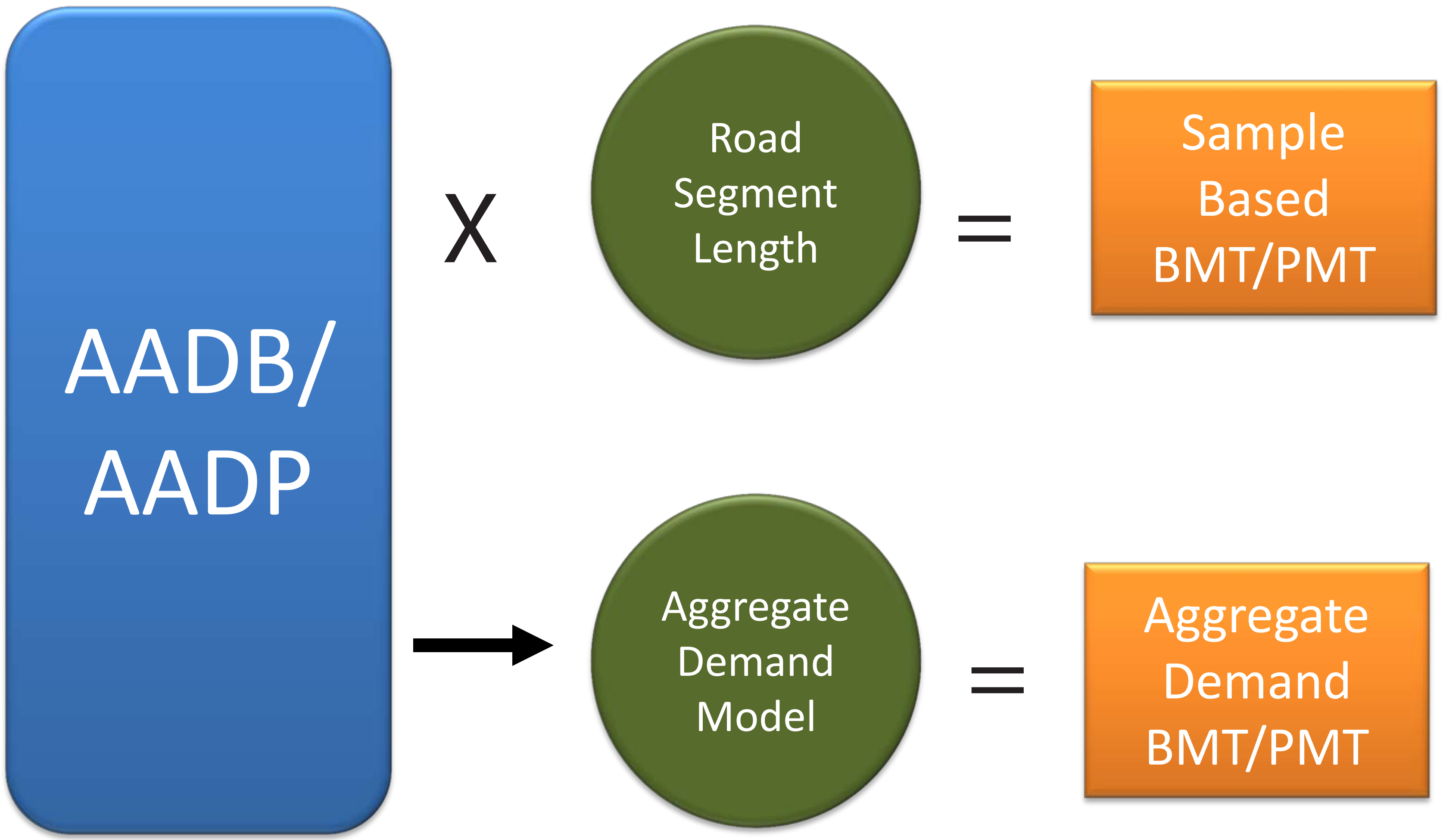
METHODS

Estimating Pedestrian and Bicycle Miles Traveled (PMT/BMT) in Washington State

Pedestrian/Bicycle Volume Estimates

- Sample-based approach
- Aggregate demand model
- Travel surveys



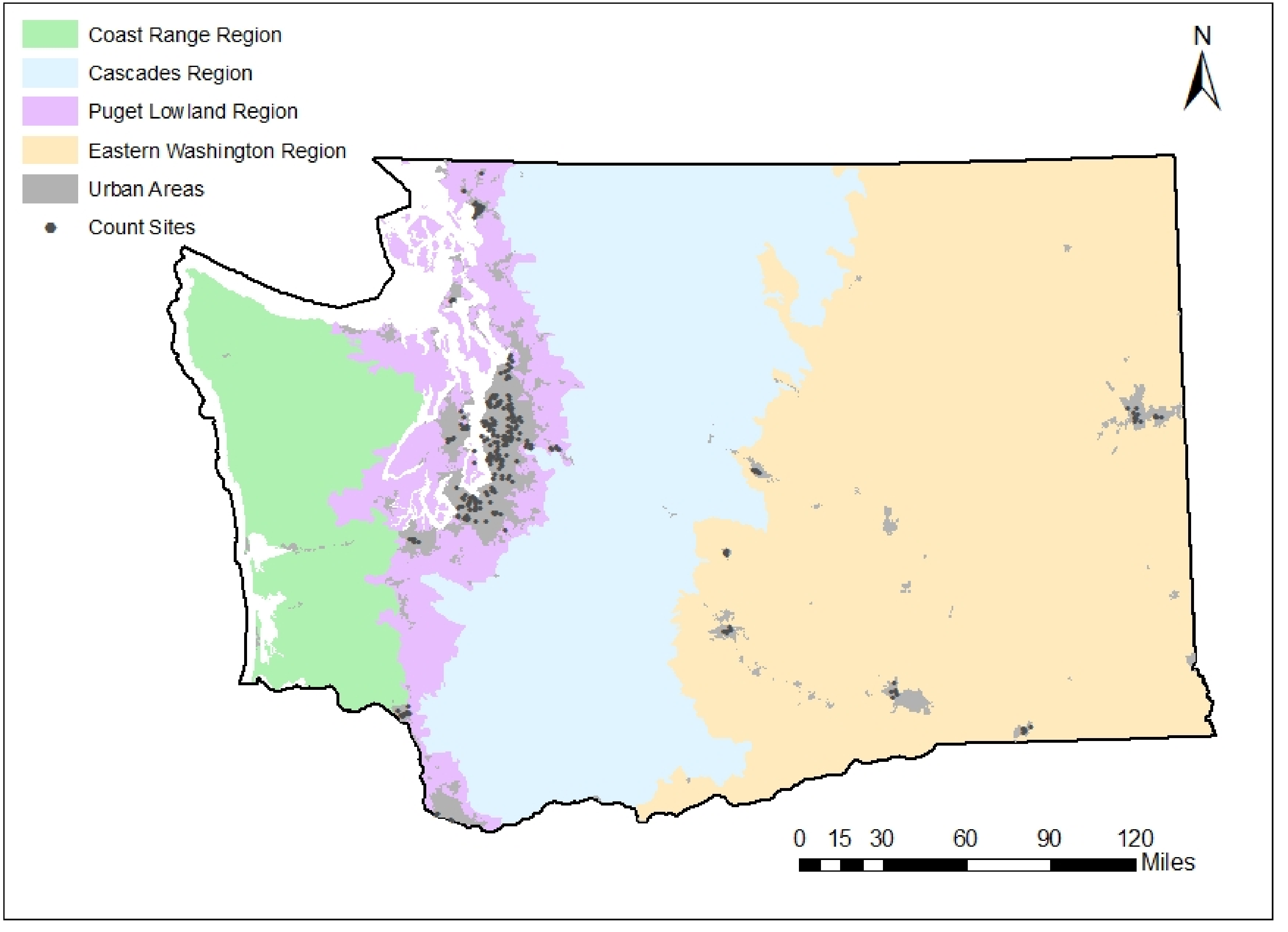

AADB/
AADP
X
Road
Segment
Length
=
Sample
Based
BMT/PMT
Aggregate
Demand
Model
=
Aggregate
Demand
BMT/PMT

Count-based Method

- Stratified Random Sample
  - Where to count?
  - Which strata (attributes) impact bike/ped volumes?

Sampling Groups

Attribute	Recommended Categories	Number of Categories
Level of urbanism	Urban Rural	2
Road or path type	Arterials & highway, Local Roads, collectors, & paths	2
Geographic and climatic regions	Coast Range Puget Lowland Cascades Eastern Washington	4


Coast Range Region
Cascades Region
Puget Lowland Region
Eastern Washington Region
Urban Areas
Count Sites
N
0 15 30 60 90 120
Miles

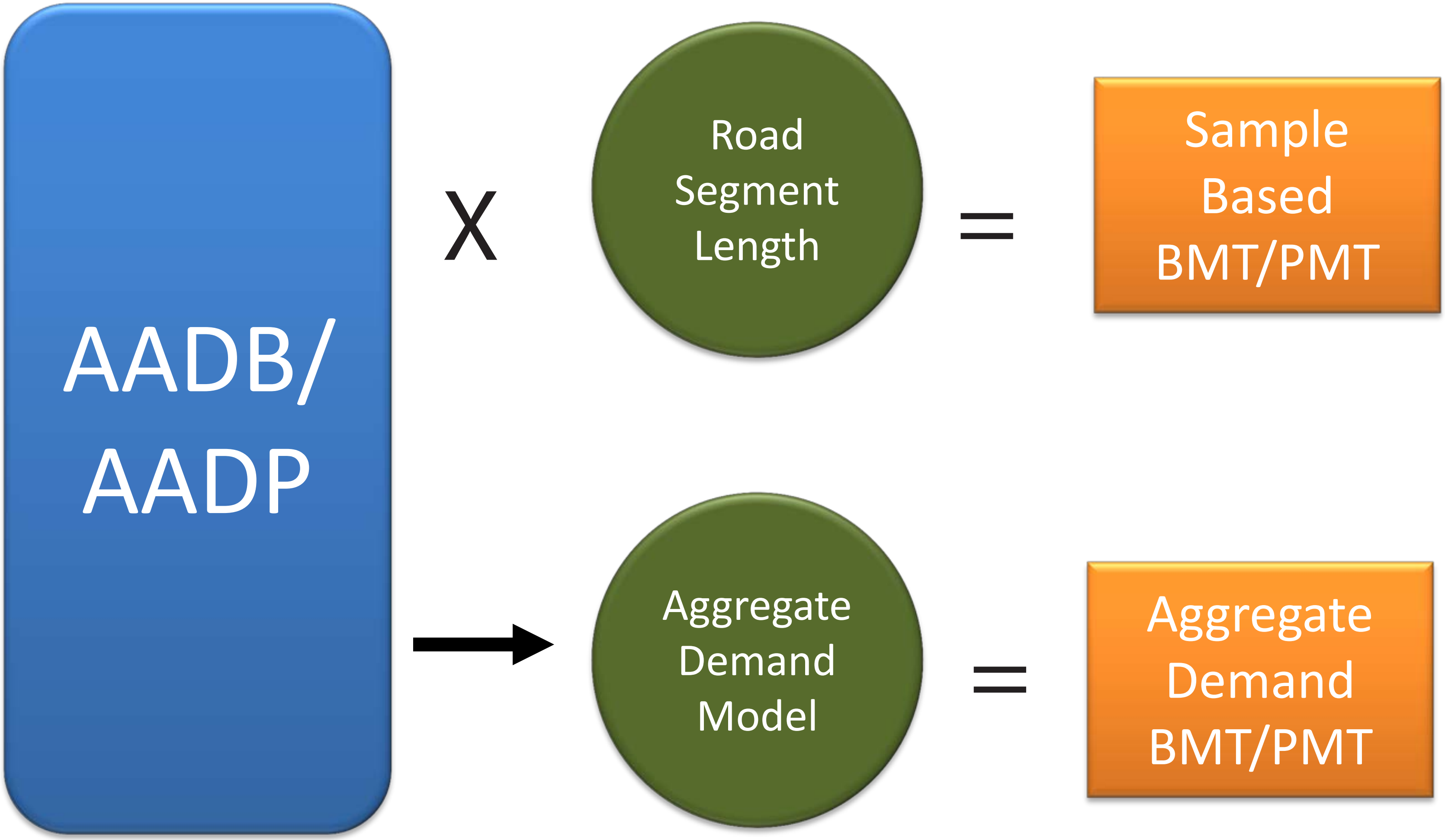
Sample-based Method

- Groups

  4 Regions X 2 Urban/Rural X 2 Road Type=

  16 Groups
- Compute center lane miles for each
- Compute Average Annual Daily Bicycle and Pedestrians (AADBP) for each.
- Compute PMT or BMT

  = Miles X AADBP X 365 days/year


AADB/
AADP
X
Road
Segment
Length
=
Sample
Based
BMT/PMT
Aggregate
Demand
Model
=
Aggregate
Demand
BMT/PMT

Aggregate Demand Model

- Dependent Variable: AADB and AADP
- Independent Variables
  - Facility type: This variable has three categories.
    - Local and collector roads
    - Arterial roads and highways
    - Trail
  - Bridge: This is a dummy variable which indicates if the bicyclist or pedestrian is crossing a bridge.
  - Population density: Density of population in the census tract
  - Percent of the population aged 18 to 54
  - Percent of the population with a four year degree or more
- Ordinary Least Squares Regression

National Household Travel Survey (NHTS) Method

- “Back of the envelope” method
- Uses research from Pucher et al.
- NHTS and Census Data
- Puget Sound Regional Travel Survey

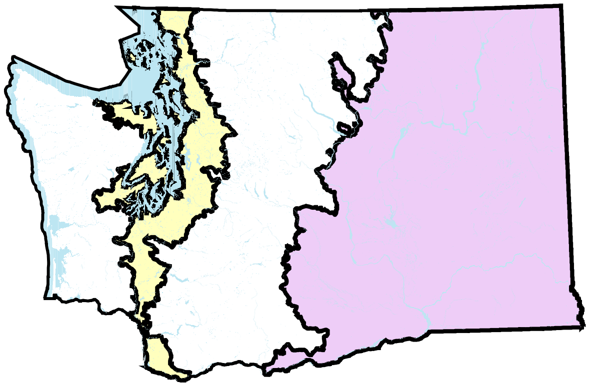
RESULTS

Sample-based Estimates

- Using the available data, PMT and BMT only estimated in 4 of 16 sampling groups.
- Trail traffic highest.
- Estimates are biased toward over estimation, since count sites were deliberately chosen at locations where bicycle and pedestrian activity tend to be high.
- This bias can be corrected in the future by randomly sampling count locations.

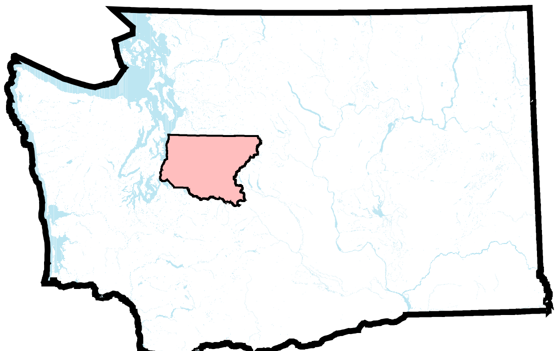
Estimates Using Count-Based Method (Millions of Miles)

Region	PMT	BMT
Puget	3,500	1,200
Eastern	1,400	300



Aggregate Demand Estimates

- Too data intensive to compute statewide during scope of project
- To calculate BMT and PMT statewide :
  - Associate road and trail segments throughout the state with the corresponding census tract and American Community Survey (ACS) data.
  - Apply the explanatory variables to each segment to estimate AADB and AADP for the segment.
  - Multiply AADB and AADP by the length of the segment.
  - Sum all of the segments and multiply by 365.



NHTS Estimates

- 415 households surveyed in Washington State
- 891 individuals in the 2009 NHTS
- 96 (11%) reported making at least one bike trip in the past week
- 645 individuals (72%) reported making at least one walking trip in the past week
- Only 2 and 9 individuals biked and walked to work in the past week, respectively
- Necessary to use nationwide data in order to produce an acceptable sample size of bicyclists and walkers.

Statewide Estimates Using National Survey Method (in Millions of Miles)

	PMT	BMT
Estimate	700	200

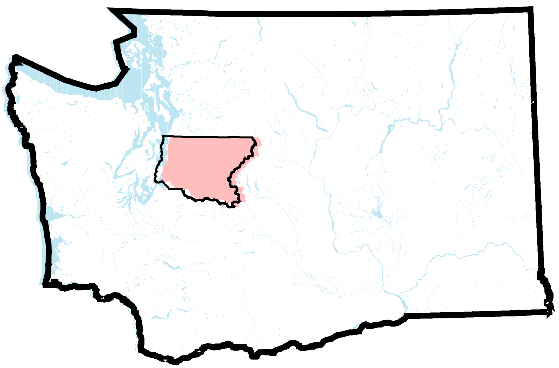
* The confidence interval (CI) only accounts for error from the National Household Travel Survey as reported by Pucher et al. 2011 (Pucher, Buehler et al. 2011). Actual error is much higher.

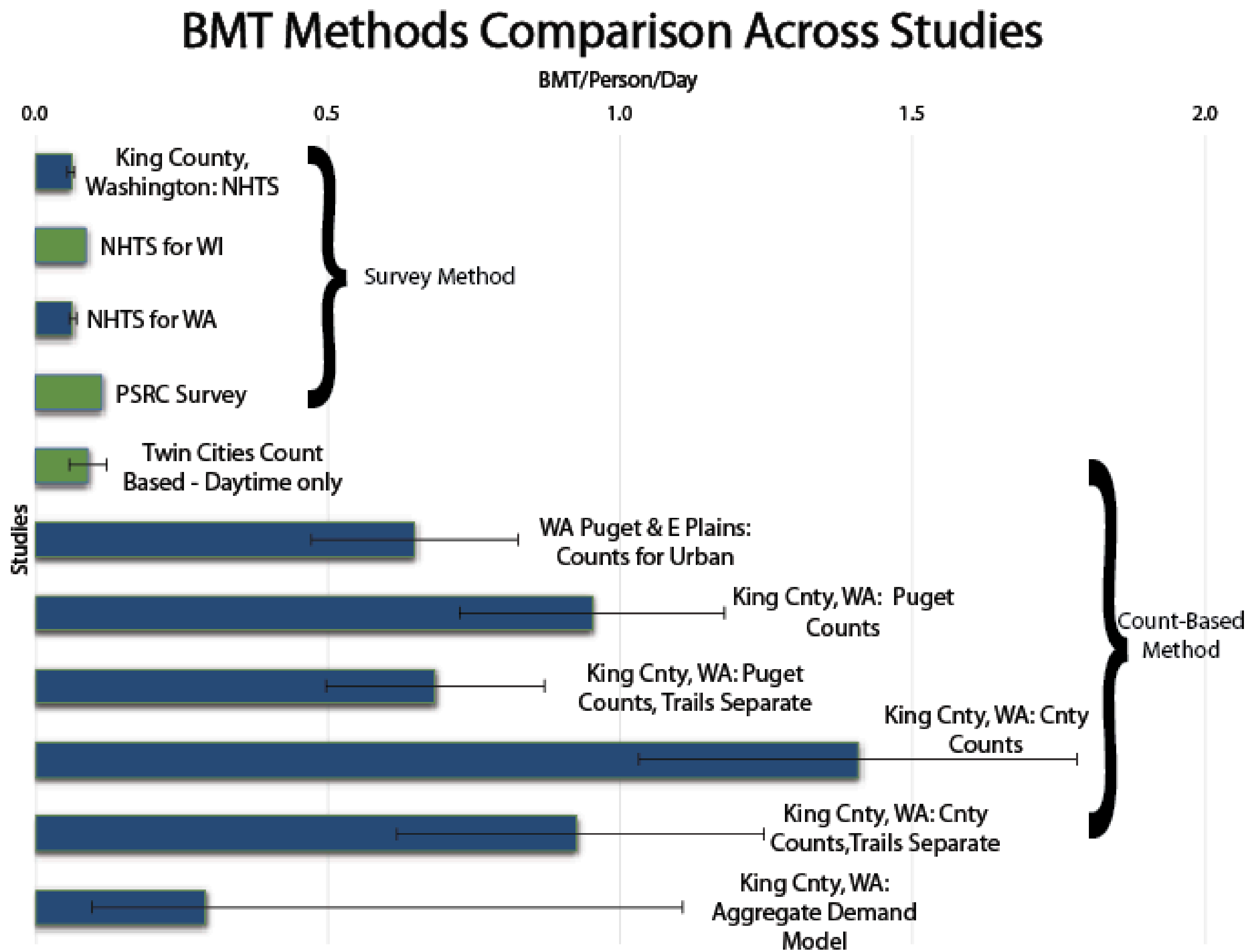
King County Comparison

Annual PMT and BMT for King County within the Puget Lowlands (Millions of Miles)

Method	Lower PMT	PMT	Upper PMT	Lower BMT	BMT	Upper BMT
National Survey Data	190	200	210	40	45	50
Count Based Method (All Puget Sites)	1,240	1,900	2,560	540	710	880
Count Based Method (All Puget Sites Trails and Local Separated)	1,160	1,800	2,430	370	510	650
Count Based Method (King County Sites Only)	1,290	2,190	3,090	770	1,050	1,330
Count Based Method (Trails and Local Separated)	1,430	2,360	3,280	460	690	930
Aggregate Demand Model	100	560	3,000	50	220	910

57,000 Million Miles VMT in 2011 for WA (FHWA)




BMT Methods Comparison Across Studies
BMT/Person/Day
0.0
0.5
1.0
1.5
2.0
Studies
King County, Washington: NHTS
NHTS for WI
NHTS for WA
PSRC Survey
Survey Method
Twin Cities Count Based - Daytime only
WA Puget & E Plains: Counts for Urban
King Cnty, WA: Puget Counts
King Cnty, WA: Puget Counts, Trails Separate
King Cnty, WA: Cnty Counts
King Cnty, WA: Cnty Counts,Trails Separate
King Cnty, WA: Aggregate Demand Model
Count-Based Method

CONCLUSIONS & RECOMMENDATIONS

Conclusions

Approach	Pros	Cons
Sample-based	Data are at the facility level.	- Data tend to be biased towards high count locations. - It is harder to sample pedestrian locations.
Aggregate demand model	More accurate estimate of PMT and BMT. Especially useful for pedestrian travel.	Difficult to do at the state level.
Travel survey	Expanding existing dataset is easier than creating new dataset.	Data are not at the facility level.

Recommendation: Better Data Needed

- Count program:
  - In coming years:
    - Expand program to include rural areas and mountain regions
    - Install at least 1 permanent counter in each of the 16 groups
  - In the coming decades:
    - At least 7 permanent counters per group
    - Ideally count 7 days per location
    - At least 150 short duration count sites per group
    - Select sites using random stratified sampling techniques
- Travel survey: over sample WA

Discussion & Questions

Krista Nordback, P.E., Ph.D.

nordback@pdx.edu

503-725-2897

Mike Sellinger

mikesellinger@altaplanning.com

Taylor Phillips

tphill2@pdx.edu

Transportation Research and Education Center

Portland State UNIVERSITY

TREC

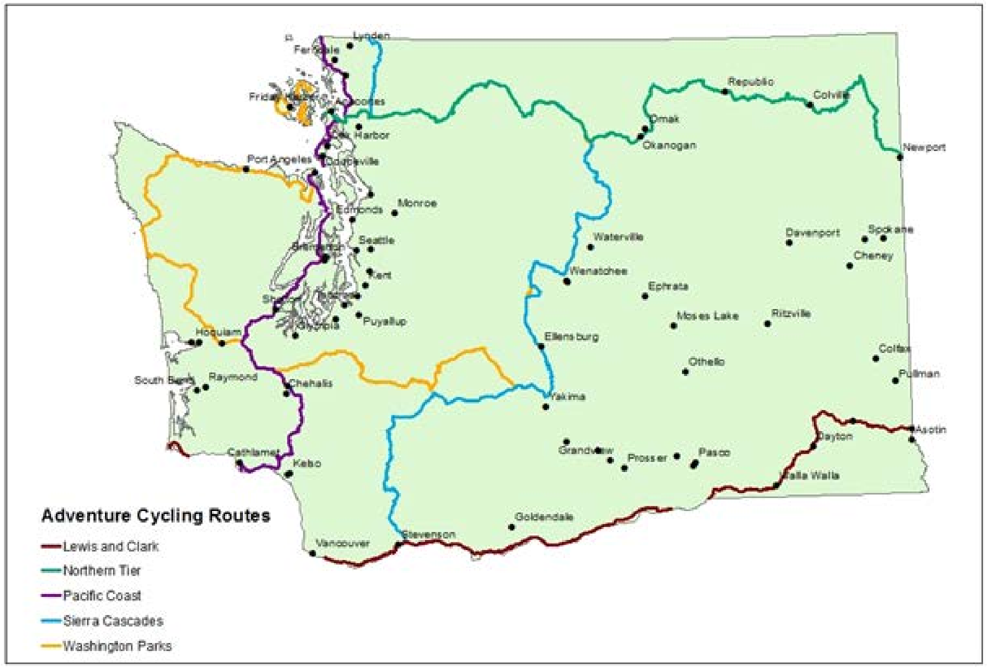
Why measure walking & biking?

If we don't count it, it doesn't count.

Conclusions

- Existing count data are not sufficient for BMT/PMT estimation
- More data needed
- Random sampling needed to get better representation
- Combining with GPS data potential
- For bikes – count based approach OK
- For peds – aggregate approach more appropriate

Adventure Cycling

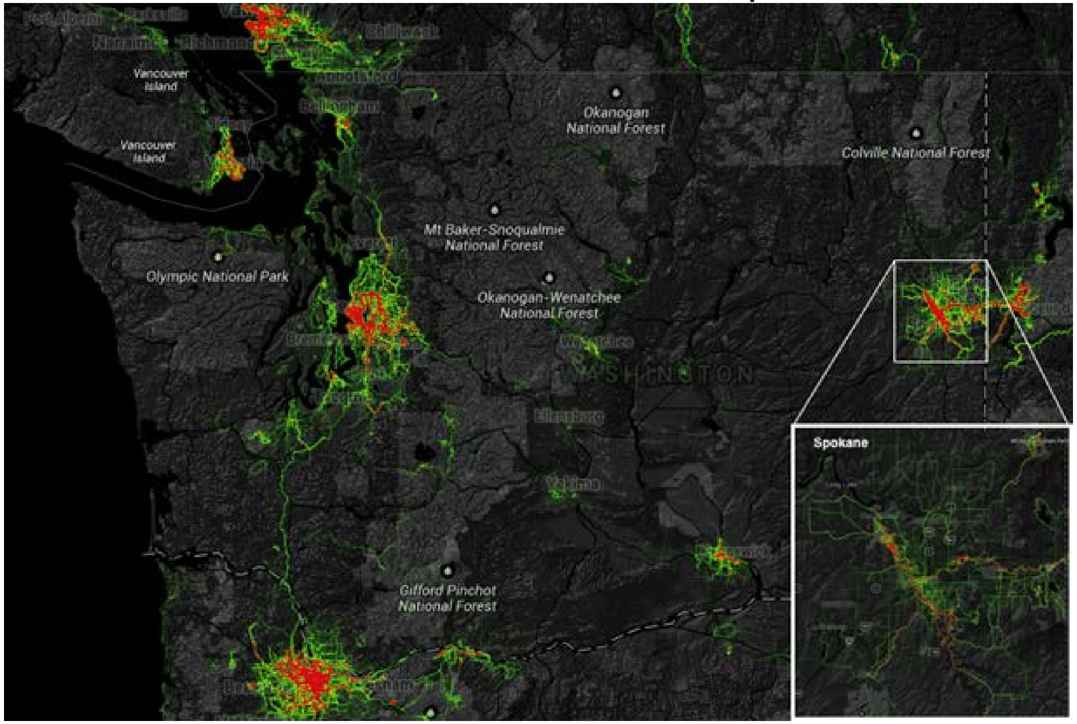


Adventure Cycling Route Mileage Estimates

Adventure Cycling		Map Sales by Year				
Route Name	**Section Number**	**2011**	**2012**	**2013**	**Total Route Mileage**	**Miles Biked 2013 (Map Sales * Route Mileage)**
Pacific Coast	1	728	819	694	317	220,000
Northern Tier	1	389	387	364	419	152,520
Sierra Cascades	1 &2	542	561	449	897	402,750
Washington Parks	1 &2	367	369	438	1,046	458,150
Lewis and Clark Trail	7	283	263	252	324	81,650
Totals		2,309	2,399	2,197	3003	**6,597,590**

Ride with GPS & Strava Data

Strava Global Heat Map



Ride with GPS Data

Number of GPS Uploaded Trips Across Years	
2005	48
2006	54
2007	58
2008	438
2009	1,001
2010	2,878
2011	6,285
2012	12,885
2013	21,888
2014	7,451
Total	**52,986**

Organized Group Rides

Name	**Start Location**	**Distances**	**Number of riders**	**Miles Ridden**
Seattle to Portland	Seattle	203	**10,000**	**2,030,000**
Chilly Hilly	Bainbridge Island	34	**3,005**	**102,170**
Flying Wheels Summer Century*	Redmond	40	1,570	62,800
		100	1,570	157,000
Totals			**3,139**	**219,800**
Bike MS*	Mt. Vernon	Day 1	1,800	
		22	34	737
		59	34	1,977
		78	34	2,613
		97	34	3,250
		Day 2	1,000	
		50	500	25,000
		75	500	37,500
Totals			**1,800**	**71,076**
RSVP	Seattle	187	**1,400**	**261,800**
RSVP 2	Seattle	187	**1,365**	**255,255**
Cycle the WAVE	Bellevue	12	134	1,608
		25	225	5,625
		42	300	12,600
		62	225	13,950
Totals			**884**	**33,783**
Kitsap Color Classic*	Kitsap	24	404	9,696
		57	404	23,028
Totals			**808**	**32,724**
Seattle Bike-n-Brews*	Seattle	25	391	9,775
		50	391	19,550
Totals			**782**	**29,325**
Obliteride	Seattle	25	224	5,600
		50	240	12,000
		100	159	15,900
		180	69	12,420
Totals			**692**	**45,920**
Grand Totals			**23,875**	**3,081,853**

*For rides where total riders were not given for each distance, ridership was distributed evenly between mileage options

Miles of Road/Trails

Region	Level of Urbanism	Road/Path Type	Total Miles
Coast Range	Urban	Arterial	409
		Collector	739
		Trail	6
	Rural	Arterial	128
		Collector	13,062
		Trail	69
Puget Lowlands	Urban	Arterial	4,042
		Collector	20,730
		Trail	344
	Rural	Arterial	183
		Collector	15,380
		Trail	163
Eastern Washington	Urban	Arterial	2,574
		Collector	7,140
		Trail	108
	Rural	Arterial	1,448
		Collector	54,407
		Trail	376
Cascades	Urban	Arterial	219
		Collector	352
		Trail	4
	Rural	Arterial	576
		Collector	33,526
		Trail	124
Total Centerline Miles in Washington State			**156,109**

Aggregate Demand Estimates

The equation for the bicycle model is:

$$\log(AADB + 1) = 0.620 + (1.766 \times 10^{-5})x_1 + 0.010x_2 + 0.009x_3 + 0.212x_4 + 0.625x_5 + 0.635x_6 \quad \textbf{(5-2)}$$

The equation for the pedestrian volume model is:

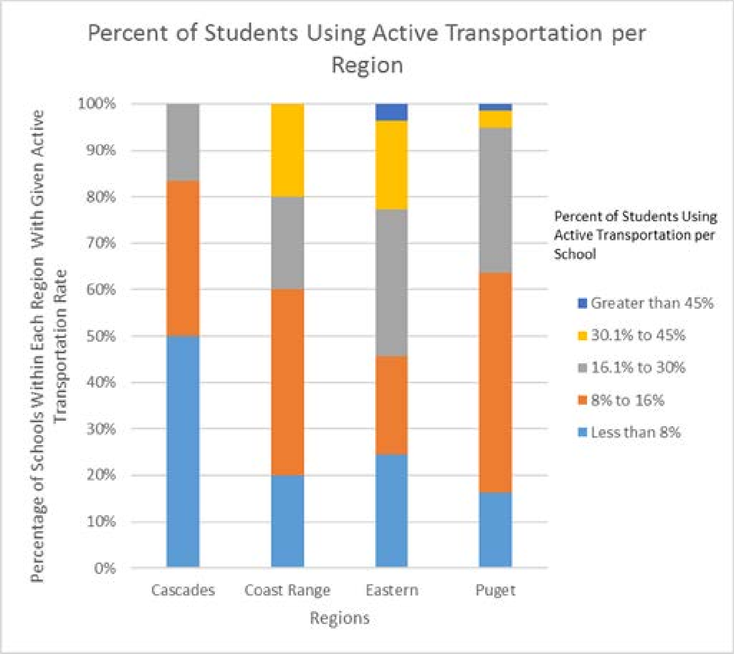
$$\log(AADP + 1) = 1.342 + (3.784 \times 10^{-5})x_1 + 0.012x_2 + 0.001x_3 + 0.095x_4 + 0.187x_5 + 0.117x_6 \quad \textbf{(5-3)}$$

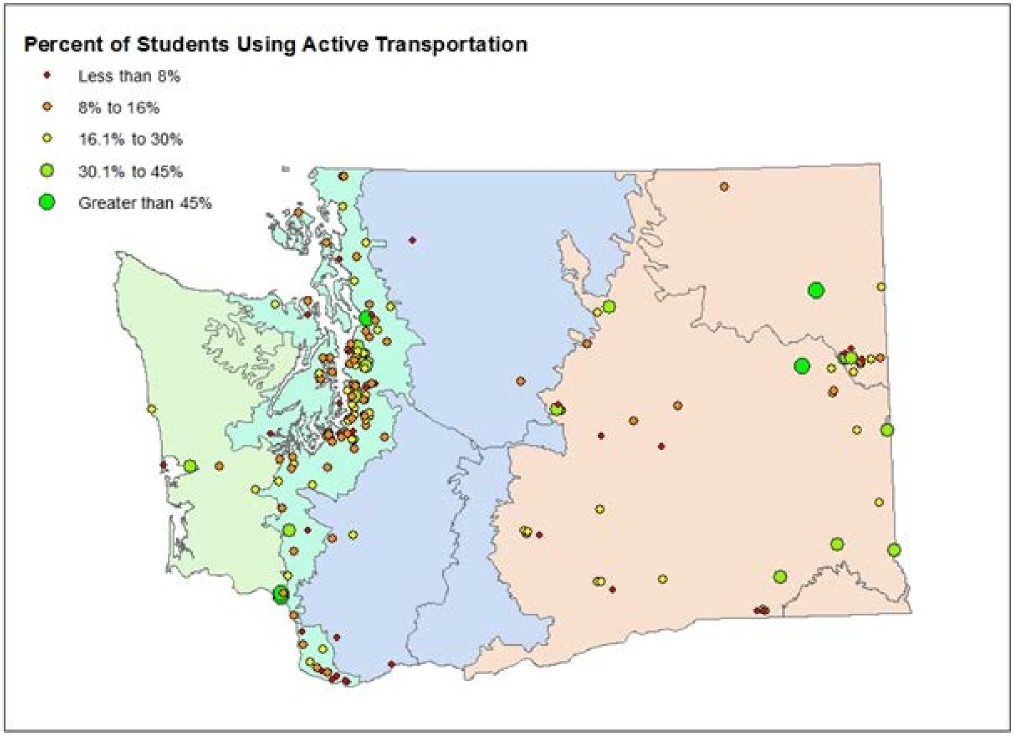
where

x_1 = Population density (people/square mile)
x_2 = Percent of the population between 18 and 54
x_3 = Percent of the population with a four-year degree
x_4 = Arterial (1 if count site is located on an arterial, 0 otherwise)
x_5 = Bridge (1 if count site is located on a bridge, 0 otherwise
x_6 = Trail (1 if count site is located on a trail, 0 otherwise)

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
Bicycle Model: log(AADB) is dependent variable					
(Constant)	.620	.119		5.215	.000
Population Density	1.766E-05	.000	.145	3.759	.000
% of Pop 18-54	.010	.002	.179	4.665	.000
College Degree	.009	.001	.255	7.977	.000
Arterial	.212	.044	.161	4.761	.000
Bridge	.625	.125	.159	4.978	.000
Trail	.635	.063	.343	10.023	.000
Pedestrian Model: log(AADP) is dependent variable					
(Constant)	1.342	.142		9.481	.000
Population Density	3.784E-05	.000	.251	5.959	.000
% of Pop 18-54	.012	.003	.191	4.546	.000
College Degree	.001	.001	.015	.399	.690
Arterial	.095	.053	.070	1.790	.074
Bridge	.187	.147	.047	1.272	.204
Trail	.117	.074	.063	1.585	.113

Safe Routes to School





Count Data

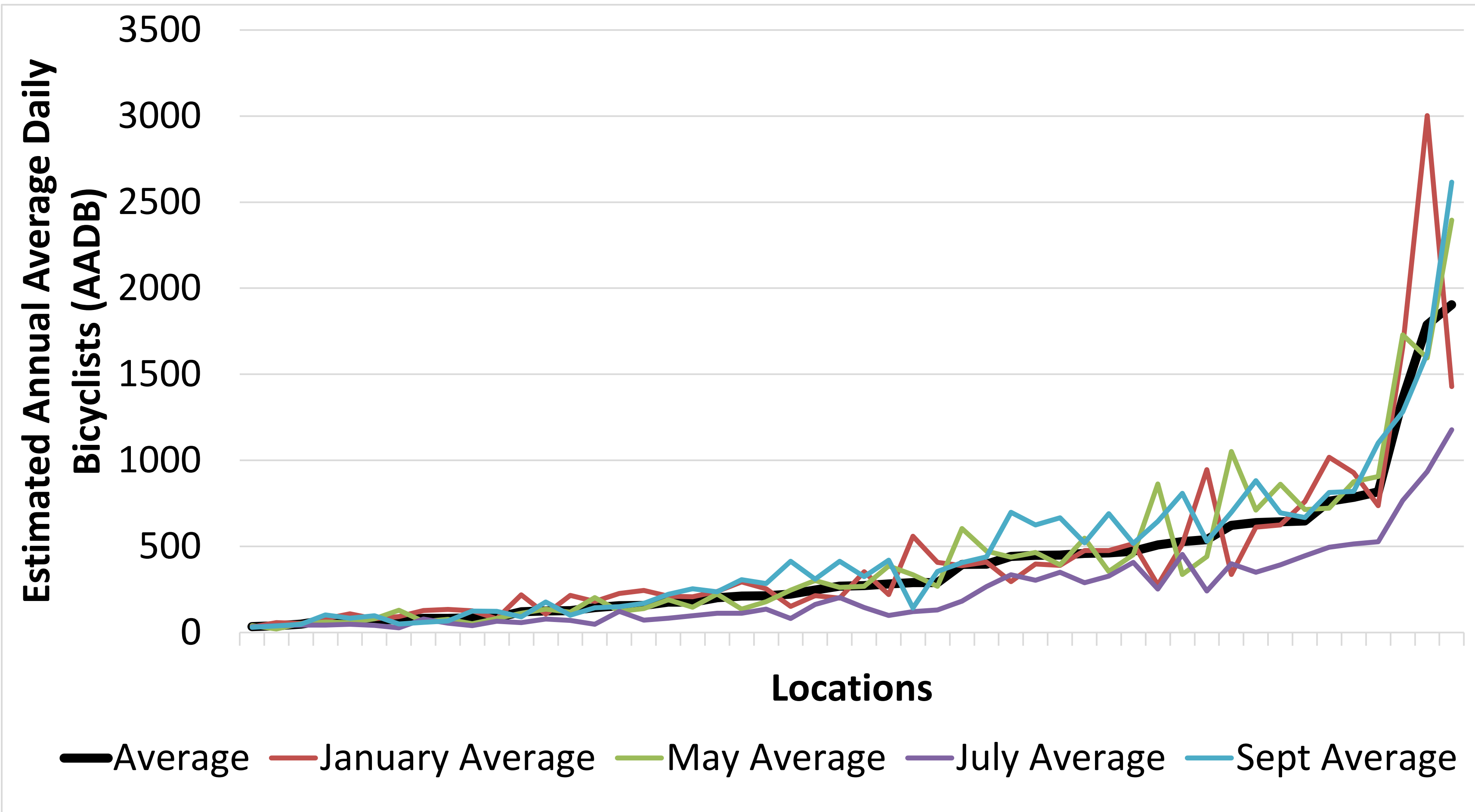
- State’s Count Program
- Olympia bike counts
- Seattle bike counts

Olympia

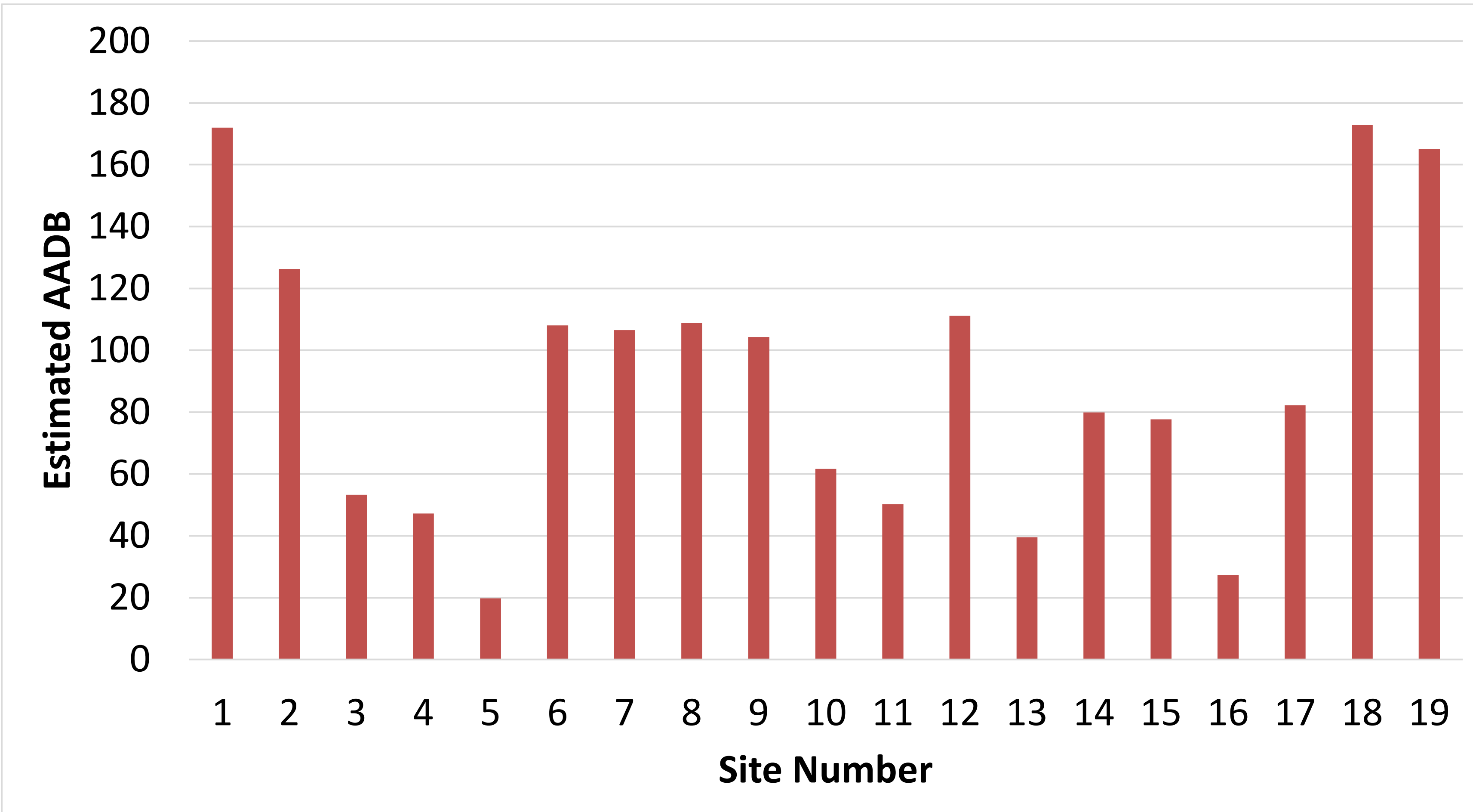
- TimeMark tube co
- 7 day counts
- Three times per year (March, June, October)

Year	Number of Locations
2008	9
2009	17
2010	17
2011	17
2012	19

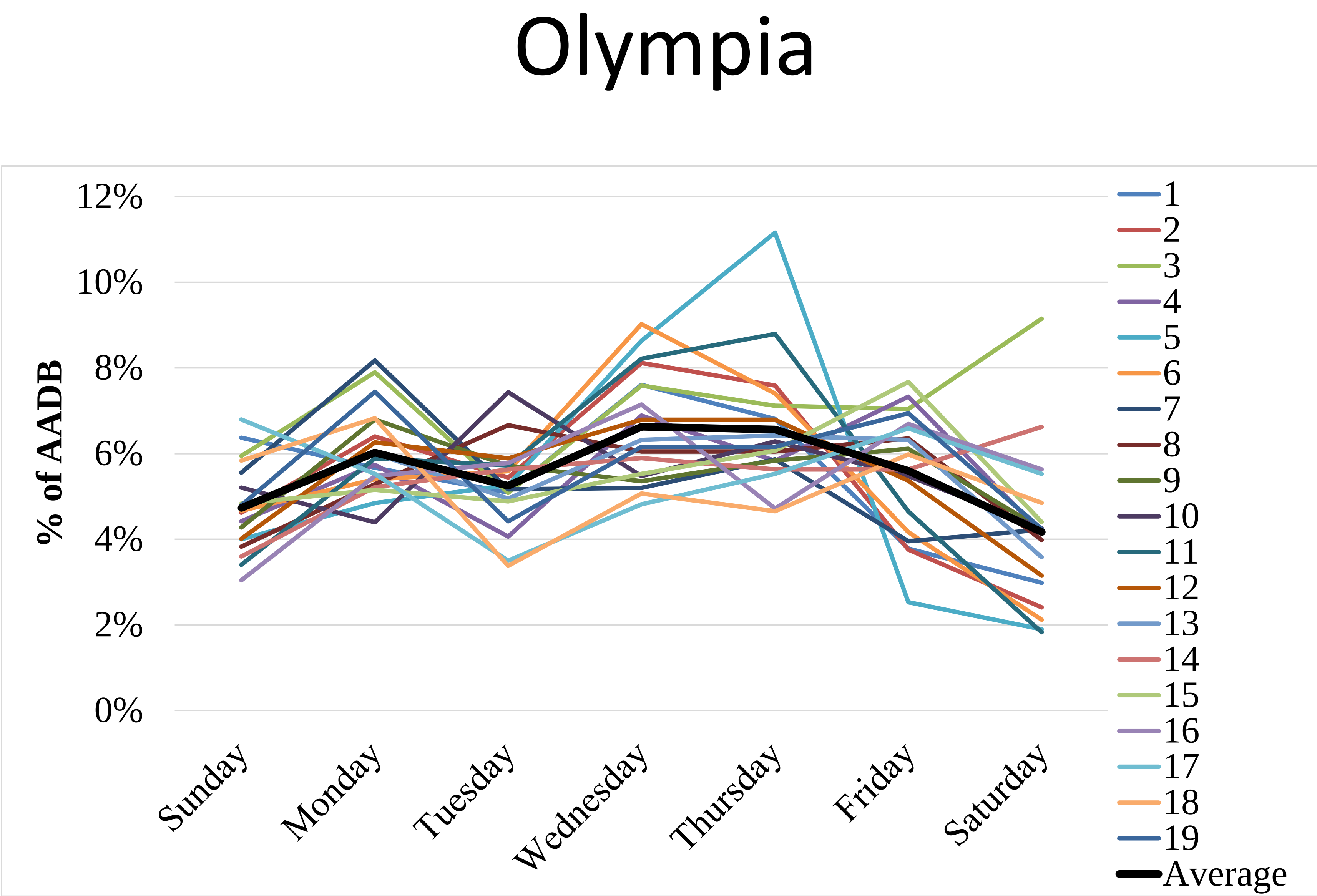
Seattle


Estimated Annual Average Daily Bicyclists (AADB)
3500
3000
2500
2000
1500
1000
500
0
Locations
Average
January Average
May Average
July Average
Sept Average

Olympia



200
180
160
140
120
100
80
60
40
20
0
Estimated AADB
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Site Number


Olympia
% of AADB
12%
10%
8%
6%
4%
2%
0%
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Average

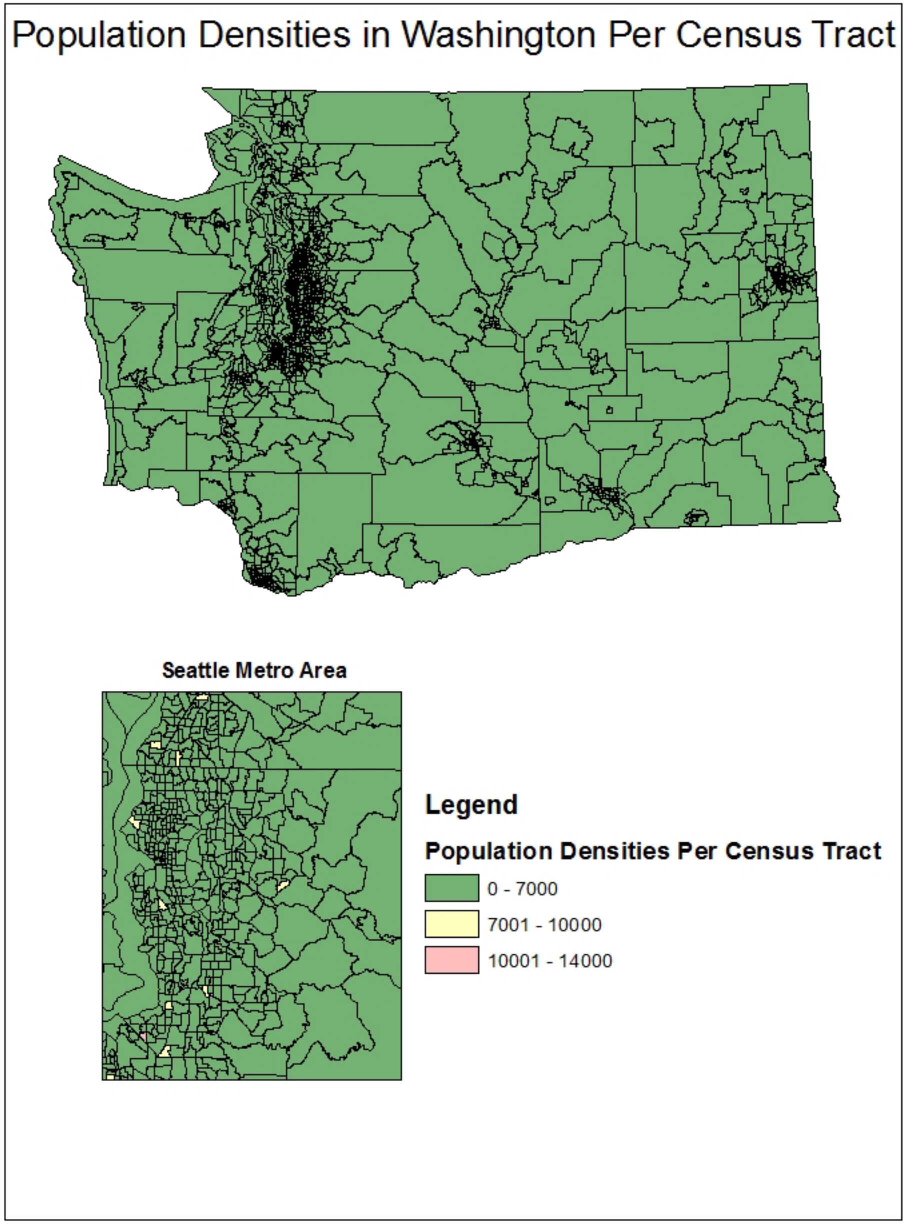
SUBURBAN CLASSIFICATION

Literature

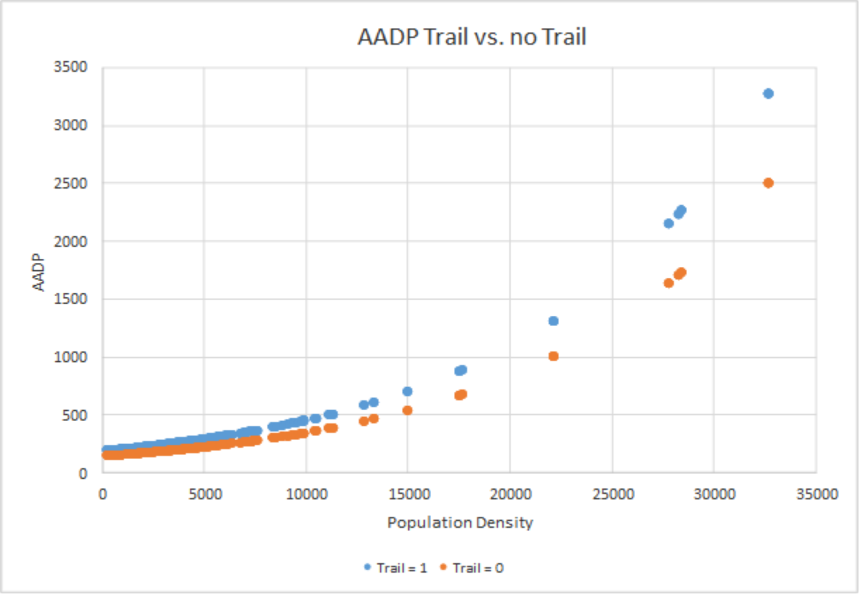
- U.S. Dept of Agriculture – Rural-Urban Commuting Area Codes
- Ramsey & Bell (2014) – Smart Location Database
- Guiliano & Small (1991) – Subcenters

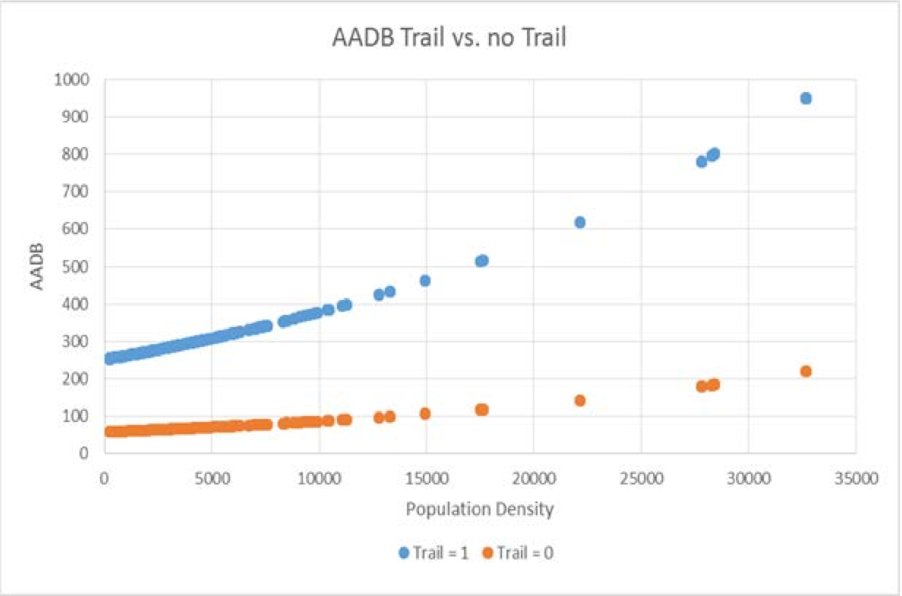
Washington State Densities

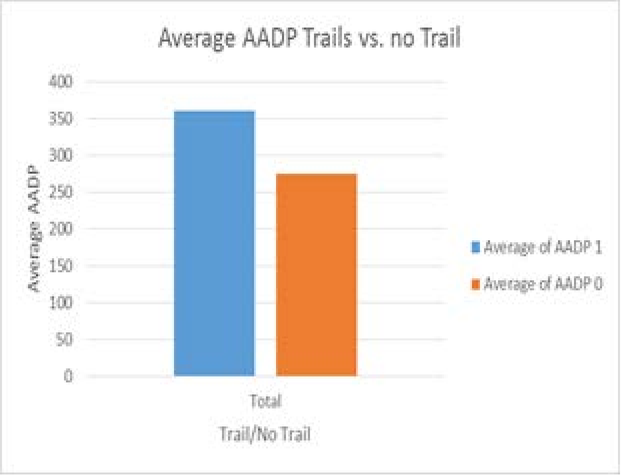
Not enough population density to warrant suburban vs urban distinction

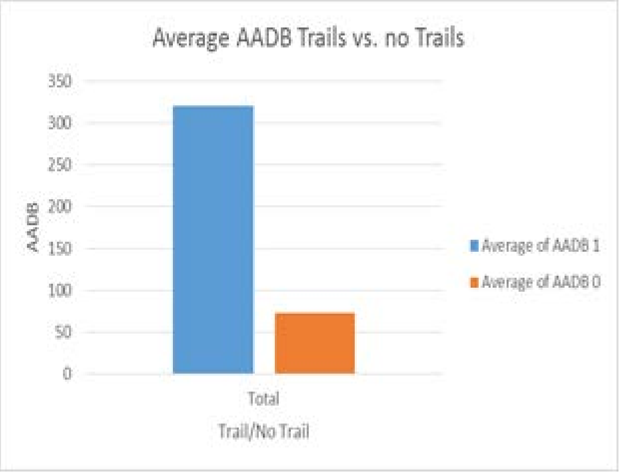


Trails


AADP Trail vs. no Trail
3500
3000
2500
2000
1500
1000
500
0
AADP
0
5000
10000
15000
20000
25000
30000
35000
Population Density
Trail = 1
Trail = 0


AADB Trail vs. no Trail
1000
900
800
700
600
500
400
300
200
100
0
AADB
0
5000
10000
15000
20000
25000
30000
35000
Population Density
Trail = 1
Trail = 0


Average AADP Trails vs. no Trail
400
350
300
250
200
150
100
50
0
Average AADP
Total
Trail/No Trail
Average of AADP 1
Average of AADP 0


Average AADB Trails vs. no Trails
350
300
250
200
150
100
50
0
AADB
Total
Trail/No Trail
Average of AADB 1
Average of AADB 0

Past work

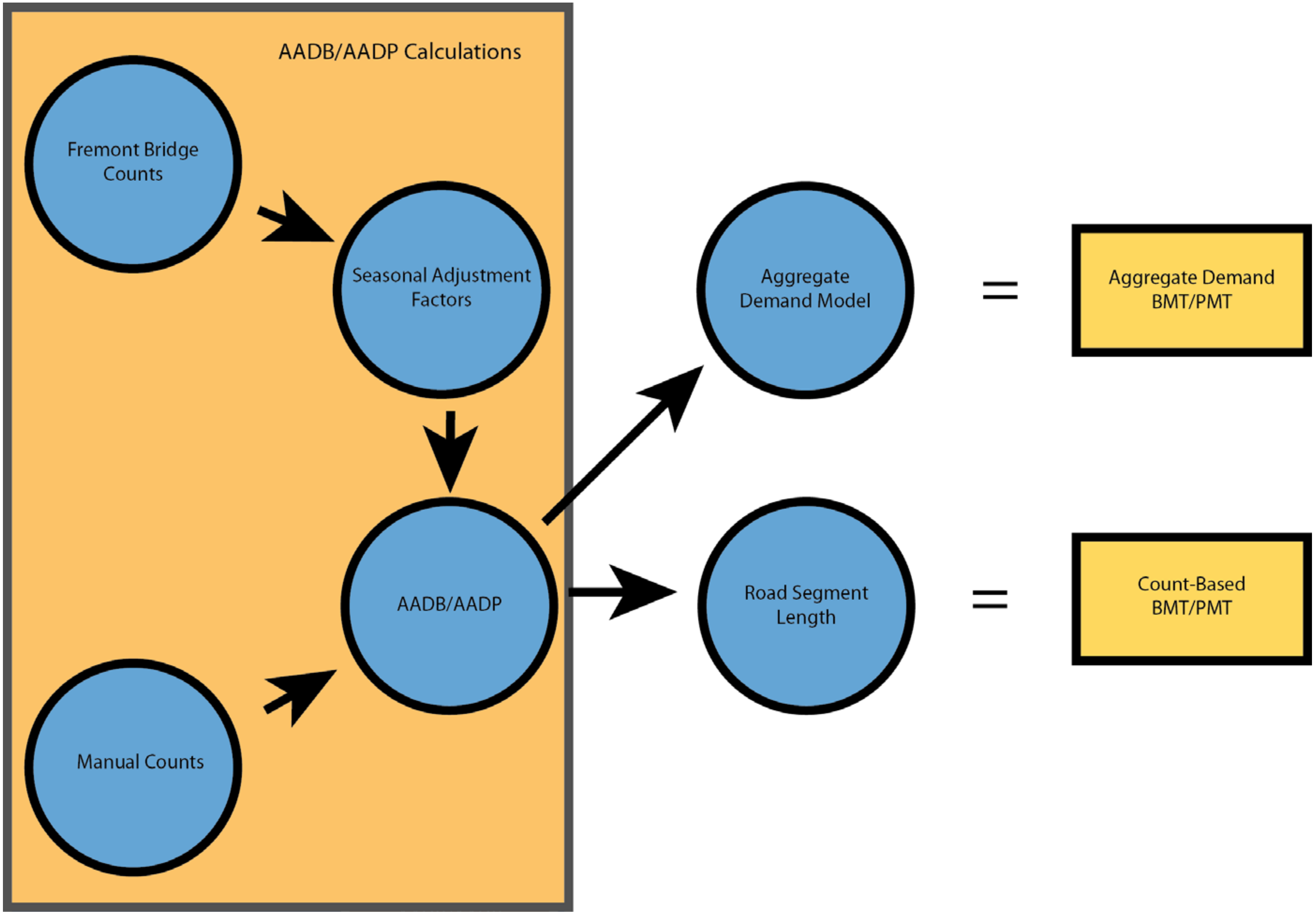
- Phase 1 – Recommendations to Improve State's Count Program
  - Identify Data Sources
  - Identify Methods
  - Recommend Changes
- Phase 2 – Methods for Estimating Bicycling and Walking
  - Prepare existing count data
  - Outline a method to use count data to compute BMT/PMT

Motivation

SAFETY: Accurate estimation of bicyclist and pedestrian volumes are critical to evidence-based safety analysis of bicycling and walking.

HEALTH:

- Exposure to air pollutants
- Changes in physical activity


AADB/AADP Calculations
Fremont Bridge Counts
Seasonal Adjustment Factors
AADB/AADP
Manual Counts
Aggregate Demand Model
Road Segment Length
=
=
Aggregate Demand BMT/PMT
Count-Based BMT/PMT

Motivation

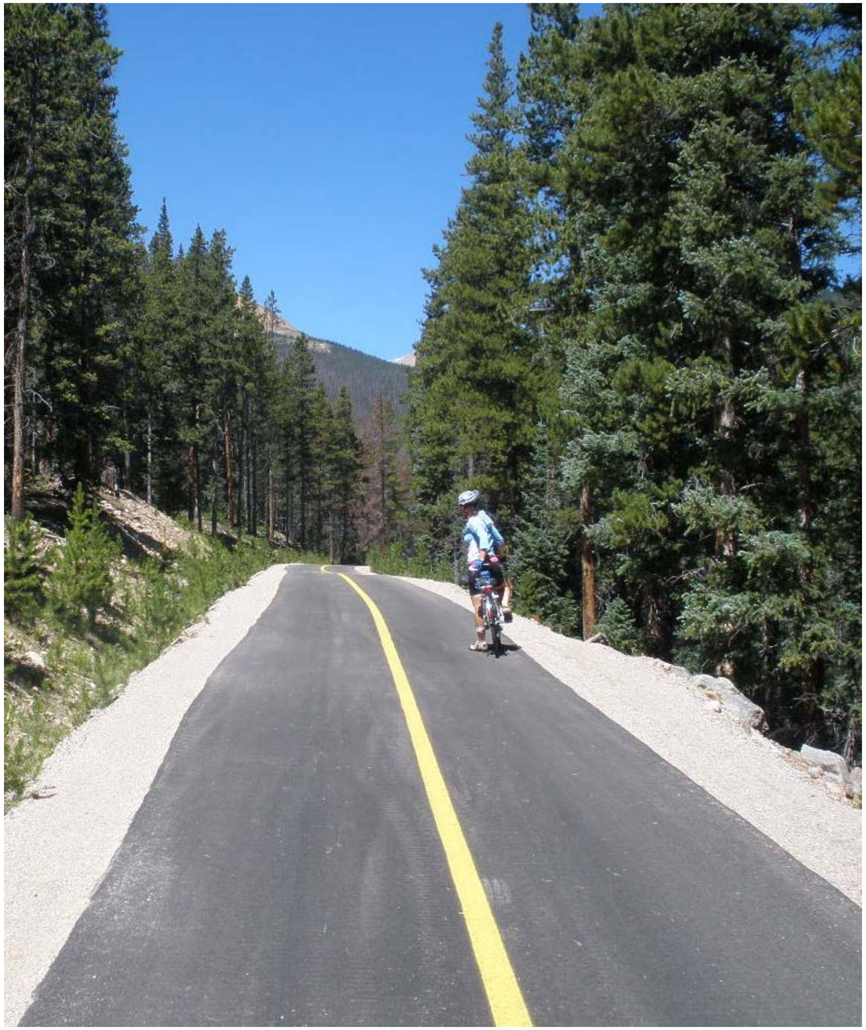
VMT is an accepted metric for motorized travel.

A comparable metric is needed for walking and cycling. Needed by

- Policy makers
- Engineers
- Planners
- Researchers

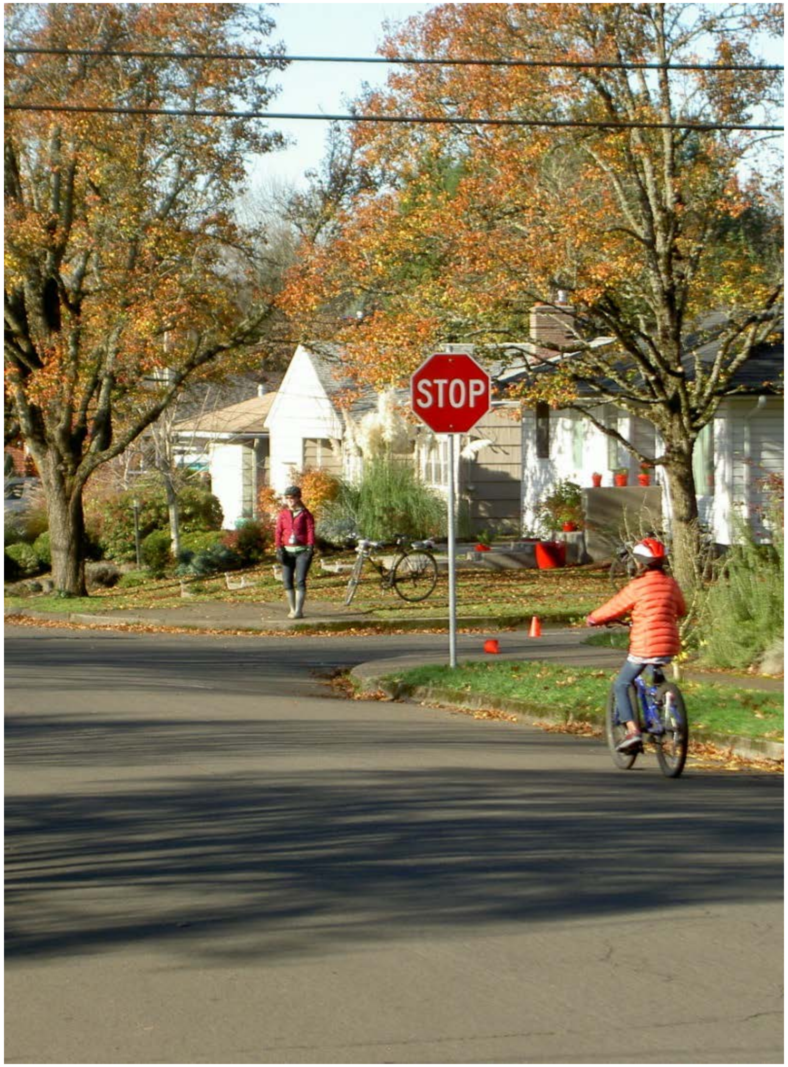
Aggregate Demand (cont.)

- To calculate BMT and PMT statewide :
  - Associate road and trail segments throughout the state with the corresponding census tract and American Community Survey (ACS) data.
  - Apply the explanatory variables to each segment to estimate AADB and AADP for the segment.
  - Multiply AADB and AADP by the length of the segment.
  - Sum all of the segments throughout the state.
  - Multiply by 365 to get estimates for annual PMT and BMT.

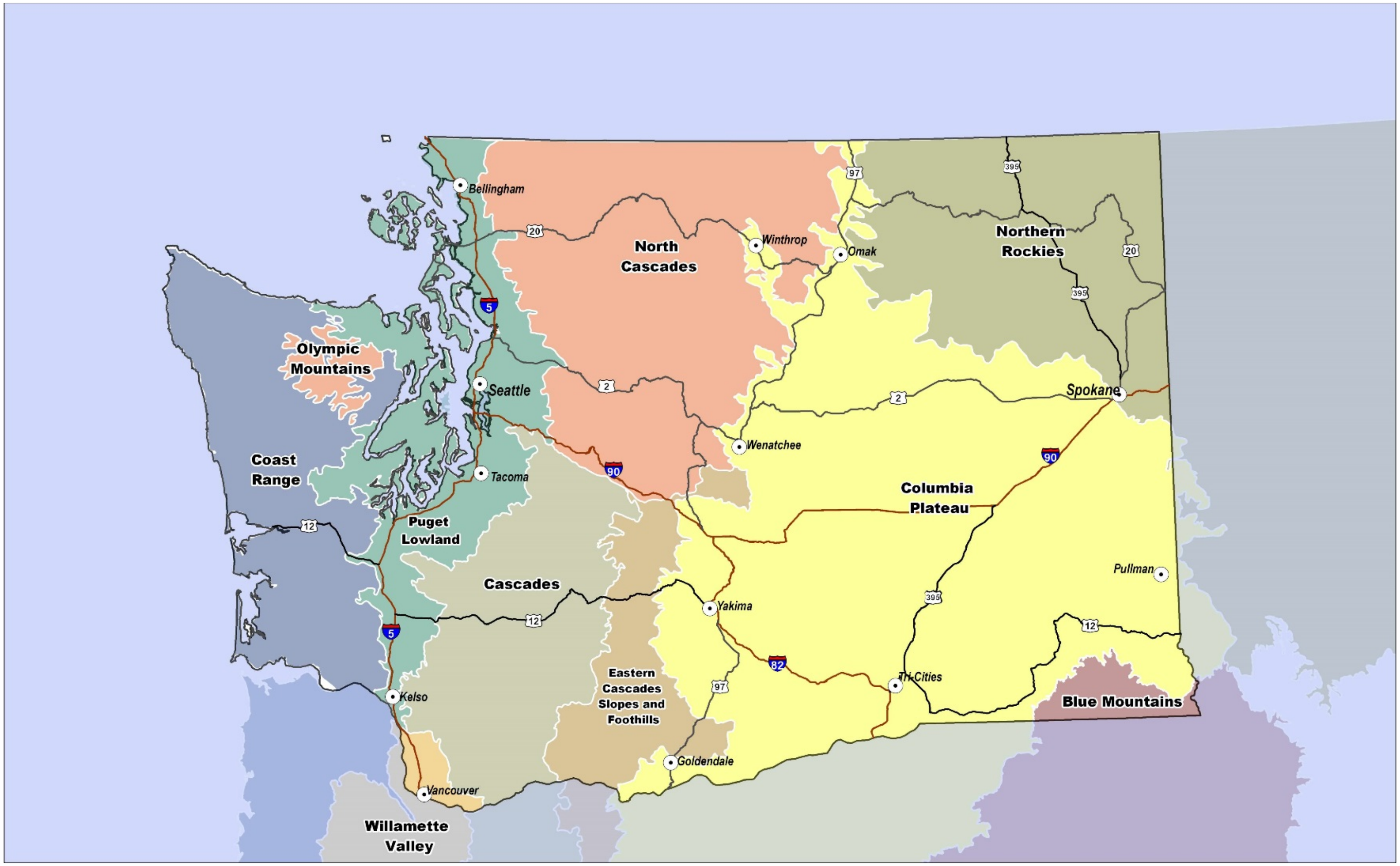


Urban vs. Rural

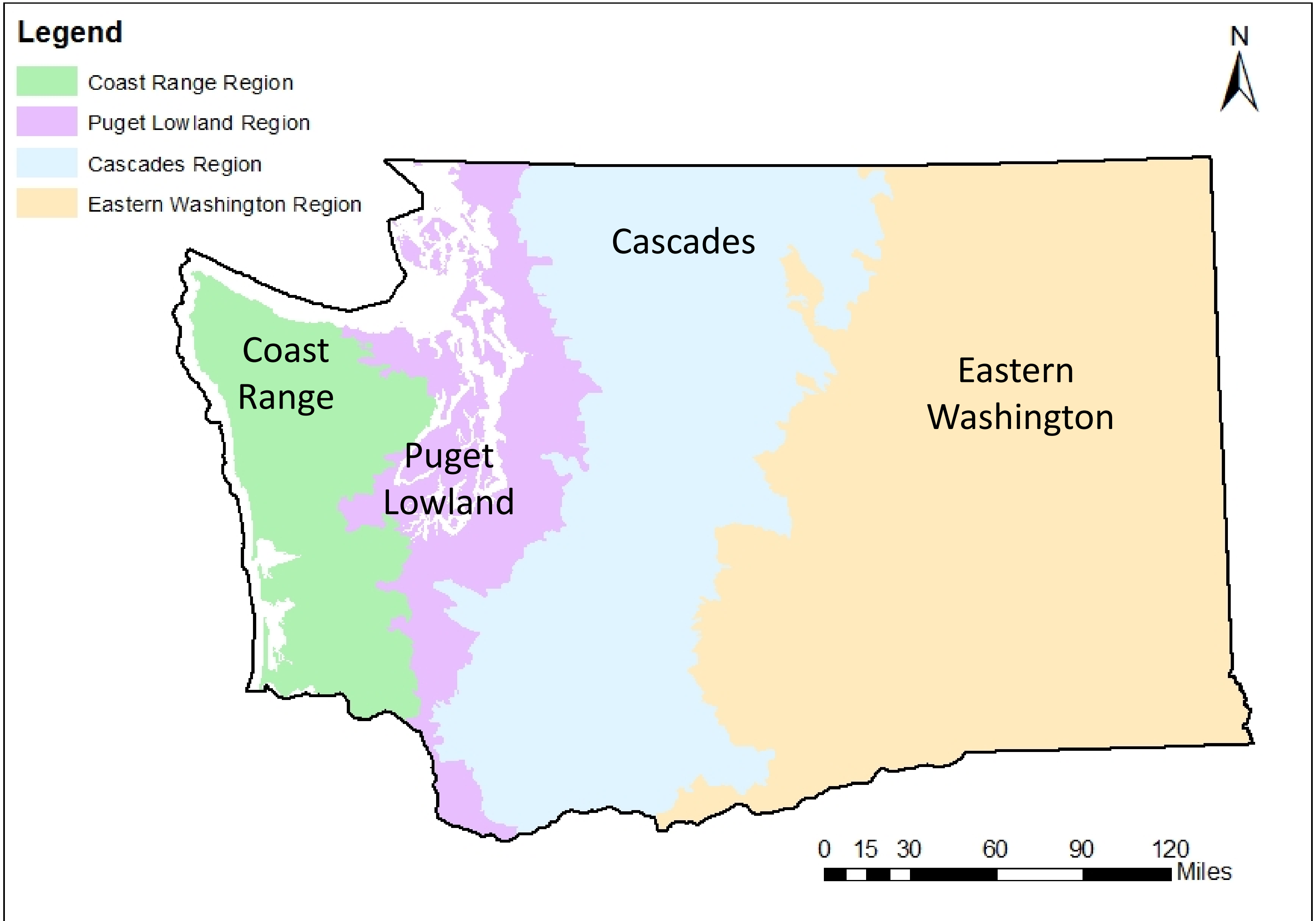
Arterial/Highway vs. Local/Collector/Path



WSDOT EcoRegions



http://www.wsdot.wa.gov/publications/fulltext/Roadside/eco_regions_v9.jpg



Legend
Coast Range Region
Puget Lowland Region
Cascades Region
Eastern Washington Region
N
Cascades
Coast Range
Puget Lowland
Eastern Washington
0 15 30 60 90 120
Miles

Available Data in 16 Groups

Sampling Groups			Number of Continuous Stations Available	Stations Available in State's Count Program
Region	Level of urbanism	Road/Path Type		
Coast Range	Rural	Arterial/Highway	0	0
	Rural	Local/Collector/Path	0	0
	Urban	Arterial/Highway	0	0
	Urban	Local/Collector/Path	0	0
Puget Lowland	Rural	Arterial/Highway	0	1
	Rural	Local/Collector/Path	0	0
	Urban	Arterial/Highway	1	157
	Urban	Local/Collector/Path	1	99
Cascades	Rural	Arterial/Highway	0	0
	Rural	Local/Collector/Path	0	0
	Urban	Arterial/Highway	0	0
	Urban	Local/Collector/Path	0	0
Eastern Washington	Rural	Arterial/Highway	0	0
	Rural	Local/Collector/Path	0	0
	Urban	Arterial/Highway	0	37
	Urban	Local/Collector/Path	0	6
			Total	304

Note: There are 13 count sites for which the location is ambiguous or unknown.

Comparison of Studies