DESIGN AND IMPLEMENTATION OF PEDESTRIAN AND BICYCLE-SPECIFIC DATA COLLECTION METHODS IN OREGON

Final Report

SPR 754

RESEARCH
Oregon Department of Transportation

DESIGN AND IMPLEMENTATION OF PEDESTRIAN AND BICYCLE-SPECIFIC DATA COLLECTION METHODS IN OREGON

Final Report

SPR 754

by

Miguel Figliozzi, Chris Monsere, Krista Nordback,
Pamela Johnson and Bryan Blanc
Portland State University
Department of Civil and Environmental Engineering

for

Oregon Department of Transportation
Research Section
555 13th Street NE, Suite 1
Salem OR 97301

and

Federal Highway Administration
400 Seventh Street, SW
Washington, DC 20590-0003

June 2014

Technical Report Documentation Page

1. Report No.

FHWA-OR-RD-14-15

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

DESIGN AND IMPLEMENTATION OF PEDESTRIAN AND BICYCLE-SPECIFIC DATA COLLECTION METHODS IN OREGON

5. Report Date

June 2014

6. Performing Organization Code

7. Author(s)

Miguel Figliozzi, Chris Monsere, Krista Nordback, Pamela Johnson and Bryan Blanc

8. Performing Organization Report No.

SPR 754

9. Performing Organization Name and Address

Oregon Department of Transportation
Research Section
555 13th Street NE
Salem, OR 97301

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

Oregon Dept. of Transportation
Research Section
555 13th Street NE
Salem, OR 97301

and

Federal Highway Admin.
400 Seventh Street, SW
Washington, DC 20590-0003

13. Type of Report and Period Covered

Final Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Although there is a growing need to access accurate and reliable pedestrian and bicycle data, there is no statewide system to collect data or plan future data collection efforts in the state of Oregon. To address these issues this research conducted a comprehensive review of pedestrian and bicycle data collection methods and counting technologies. Oregon data sources were also compiled and AADT estimation techniques were reviewed and applied to Oregon data. A pilot study was conducted to test bicycle and pedestrian counting methods at signalized intersections with 2070 controllers. The report also provides a summary of recommendations regarding factoring methods and the implementation of a statewide non-motorized data collection system.

17. Key Words

BICYCLE AND PEDESTRIAN, DATA COLLECTION, AADT, STATEWIDE SYSTEM

18. Distribution Statement

Copies available from NTIS, and online at http://www.oregon.gov/ODOT/TD/TP_RES/

19. Security Classification (of this report)

Unclassified

20. Security Classification (of this page)

Unclassified

21. No. of Pages

123

22. Price

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH					**LENGTH**				
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
AREA					**AREA**				
in^2	square inches	645.2	millimeters squared	mm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.093	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	m^2	meters squared	1.196	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	kilometers squared	km^2	km^2	kilometers squared	0.386	square miles	mi^2
VOLUME					**VOLUME**				
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.									
MASS					**MASS**				
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T
TEMPERATURE (exact)					**TEMPERATURE (exact)**				
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

The authors would like to thank all the members of the Technical Advisory Committee (TAC) for their comments and support: Lyn Cornell, Sheila Lyons, Sue Geniesse, Gary Obery, Julie Yip, Steve Lindland (ODOT), and Bruce Moody (FHWA).

The authors also acknowledge the support of: Tiffany Slauter (ODOT Region 1 Traffic Signal Manager) for providing access to 2070 controller data; Don Crownover (ODOT Traffic Monitoring Coordinator) for providing access to tube detector and video data; and Jessica Horning (ODOT Transit and Active Transportation Liaison) for sharing bicycle and pedestrian data sources. We would also like to thank Rodger Geller at the Portland Bureau of Transportation and Sirisha Kothuri (PSU) for sharing their knowledge and bicycle data. We are also grateful to John Mermin, Deena Platman, Mel Huie, and Robert Spurlock for sharing METRO's non-motorized data collection methods and continuous count data.

DISCLAIMER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Although there is growing interest in formalized programs to count bicycle and pedestrian activity, today there are no Federal or State requirements for non-motorized traffic monitoring. No statewide comprehensive bicycle and pedestrian data collection system has been fully implemented. A few states, including Colorado and Minnesota, are in the process of developing bicycle and pedestrian data collection guidelines. One of the challenges of developing such a system for bicycle and pedestrians is that there are no examples of a comprehensive bicycle and pedestrian data collection system.

In order to identify gaps in data collection for bicycle and pedestrians, it is appropriate to compare bicycle and pedestrian traffic data collection efforts to existing motor vehicle traffic data collection methods. The most comprehensive motor vehicle data collection system is the Highway Performance Monitoring System (HPMS) implemented by the Federal Highway Administration (FHWA) in cooperation with the state DOTs. The HPMS data is used (among many other applications) to allocate federal funding for road projects and to estimate VMT (vehicle-miles traveled) figures. HPMS requirements include annual reporting and a minimum three year traffic counting cycle. HPMS also requires a sufficient number of continuous automated traffic recorders (ATR) with automated vehicle classification, as well as minimum 48-hour short-term count duration. In addition to average annual daily traffic (AADT), data requirements include functional class designations, condition of each road segment, and detailed vehicle classification *(FHWA 2013)*. The Traffic Monitoring Guide (TMG) gives detailed recommended procedures for collecting and processing motor vehicle traffic data for the HPMS.

1.1 MAIN FINDINGS

The objective of this research is to provide guidance for the State of Oregon as it seeks to develop a statewide data collection system for bicycle and pedestrian data; Section 6 presents a summary of recommendations to achieve this objective. Some of the recommendations include:

- System design, sampling, site selection, and factoring should respect regional differences. Regional differences include factors such as climate, geography and population densities. These differences are important because predominant trip purpose, climate, geography and population density may all have major effects on bicycle and pedestrian traffic patterns and volumes.

- The determination of each type of adjustment factor requires a non-trivial amount of field data collection and posterior data analysis. Errors obtained by using adjustment factors can be high when there is not enough continuous count data available or there are periodic equipment failures from lack of calibration or maintenance. Higher AADT accuracy without higher counting costs can be obtained if data collection days are scheduled so that unfavorable data collection days are avoided and/or more advanced AADT estimation methods are applied (*Figliozzi et al. 2014*).

- Collaborating with other jurisdictions to simplify data collection methods and to share equipment, data collection protocols, and data will minimize overlap of counts and data and potentially save money and resources for all stakeholders. If collaboration is possible, training staff and contractors to correctly install and use new equipment across jurisdictions will also be necessary to ensure data quality.

- In order to make the best use of existing equipment and to develop the most extensive system of cost-effective counters, it is recommended that ODOT take advantage of their system of 2070 controllers (and future controller deployments/upgrades). Intersections properly equipped with 2070 controllers, the appropriate software, bicycle loop detectors, and pedestrian phase push buttons can be used for collecting continuous bicycle volumes and pedestrian phase actuations; 2070 controllers and data can be complemented by other data collection technologies.

- Permanent counting equipment should be deployed at locations with significant traffic and where it is possible to develop factors that can be applied to other short-term counting stations in the region/area. The deployment of permanent counting stations can be carried out in phases; initially it is recommended to perform short-term validation and counting (if necessary with temporary data collection equipment) before deciding on the location of any permanent counting site. Further research is recommended to optimize the phasing and location of permanent sites.

- Leverage new data sources that contain route and demographic data that traditional counting data cannot capture. Smartphone route data can be employed to complement existing counts and may increase data coverage in a cost-effective way. In addition, smartphone route and count data may be used to better locate both permanent and temporary counting sites. Further research is recommended to study how ongoing data collection efforts in Oregon can be used to complement traditional count data and help locate permanent and temporary counting sites.

1.2 REPORT ORGANIZATION

The reminder of this report is organized as follows:

- Chapter 2: A review of existing bicycle and pedestrian data collection programs in Europe and North America
- Chapter 3: A summary description of bicycle and pedestrian data collection equipment
- Chapter 4: A catalog of ongoing continuous bicycle and pedestrian data collection efforts in Oregon
- Chapter 5: A review of factoring methods review and data analysis using Oregon pedestrian and bicycle data.
- Chapter 6: Summary of recommendations to implement a statewide non-motorized data collection system.

The results of a pilot study testing some technologies for data collection are included as a standalone document.

2.0 BICYCLE AND PEDESTRIAN DATA COLLECTION PROGRAMS

This chapter is a review of the published literature as of June 2013 of bicycle and pedestrian data collection programs at other state DOT's and in northern European countries. There are two sets of literature review tables included in Appendix A: 1) a review of counting programs in the U.S. and 2) a review of counting programs in Europe. Both sets of tables contain reports and studies of non-motorized data collection methods. The literature review tables for U.S. programs summarize data collection technology, data collection type, collection frequency, site selection and methods. The literature review tables for international counting programs summarize data collection technology, collection frequency, site selection and methods.

2.1 DATA COLLECTION METHODS

Pedestrian and bicycle data collection methods vary widely for each jurisdiction and research/data collection purpose. For most agency reports and documents referenced in the literature review tables data collection of non-motorized data is primarily related to safety and infrastructure investments. In contrast, research reports/papers are more concerned with the performance of data collection equipment used in non-motorized data collection and data trend analysis.

In general, data collection sites are chosen to cover different types of facilities (e.g. commuter vs. recreational) and local knowledge of areas of high non-motorized usage. Although some agencies in the U.S. are moving to mostly automated data collection equipment and practices (e.g. Colorado), most bicycle and pedestrian data is still collected manually as part of the National Bicycle and Pedestrian Documentation Project *(Hengel et al. 2011a*) (*Schneider et al. 2005*).

In Europe, Australia and New Zealand, most decisions about bicycle infrastructure are made based on household surveys and do not require data collection to verify usefulness of non-motorized facilities (*Thiemann-Linden and Mettenberger 2012*); however, London includes bicycle traffic as part of their roadway data collection system *(Department for Transport 2012*) Data collection software use is determined by the equipment available in the agency or provided by the manufacturer of the data collection equipment. In the reports included in this literature review there is little information on the actual databases used or how data is stored, however it was common to have data in an comma delimited (.csv) or a spreadsheet format *(Department for Transport 2012) (Schneider 2012)*.

The Traffic Monitoring Guide Chapter 4 entitled “Traffic Monitoring for Non-Motorized Traffic” recommends asking three basic questions before designing non-motorized data collection system:

- What are you counting?
- Where are you counting?
- How long are you counting?

Other data collection choices that need to be made for each site in a system include:

- Manual or Automated counts?
- Short-term or continuous data collection?
- Temporary or permanent counting stations?

Specific details about data collection equipment are covered in Chapter 3, Data Collection Technologies, of this report.

2.1.1 Best-Practice Data Collection Methods

Data collection methods refer to a step by step process for organizing the implementation of a data collection system. A list of the most detailed non-motorized method guidelines found in the literature follows.

2.1.1.1 Both Bicycles and Pedestrians

Pedestrian and Bicycle Data Collection Methods in United States Communities, FHWA (*Schneider et al. 2005*)

Although this document from 2005 is somewhat dated it is valuable because it summarizes 29 non-motorized data collection projects in local communities across the U.S. Most of the communities reviewed in this document followed a general data collection process that included:

- Identifying the data collection purpose, such as:
    - Documenting changes in pedestrian and bicycle activity, safety and facilities over time
    - Determining peak hour and seasonal variation
- Organizing and implementing the data collection
- Collecting the data

- Storing the data
- Analyzing the data
- Developing reports to share the data with staff, elected officials, granting agencies, and the public

Traffic Monitoring Guide, Chapter 4 FHWA (*FHWA 2013*)

Recommended steps for non-motorized permanent data collection include:

- Review existing continuous counting program
- Develop an inventory of available continuous count locations and equipment
- Determine the traffic patterns to be monitored
- Establish pattern/factor groups
- Determine the appropriate number of continuous monitoring locations
- Select specific count locations
- Compute, monthly, day-of-week (DOW), and hour-of-day (HOD) factors to use in annualizing short duration counts

Colorado Department of Transportation *(Turner et al. 2012)*

CDOT has designed a non-motorized data collection method that uses the "business process for non-motorized traffic data" and is similar in scope and detail to the motorized traffic data collection process. The main elements for this process include:

- Import or load local agency non-motorized data
- Assign count type (i.e., special study versus monitoring site)
- Subject data to a quality assurance/ quality control (QA/QC) process
- Establish and assign non-motorized factor groups
- Apply an annualization and factoring process

Count type refers to the purpose of the count; for example, a before and after count of a new bicycle or pedestrian facility improvement or a long-term, fixed counting site to record continuous traffic volumes. A quality assurance and quality control process, in this context, is to conduct more than one type of data collection, preferably during the same time and location, and compare values to detect errors. Non-motorized factor groups refer to:

- Commuter and school based trips
- Recreation/ utilitarian
- Mixed trip purposes

It is recognized that these three groups have different peak hours and may use different facilities.

2.1.1.2 Pedestrians

How to do Your Own Pedestrian Count, Los Angeles, CA *(Schneider 2012)*

This is a presentation of a pedestrian data collection count in Los Angeles, CA; the method used was:

- Conduct manual counts
- Verify manual counts by conducting automated counts at the same location
- Clean up automated data counts
- Correct for undercounting
- Develop/apply adjustment factors

2.1.2 Issues in Data Collection Systems Design

A consistent statewide method for collecting non-motorized data has not yet been established. Existing reports and documents present some useful guidelines for data collection systems design. In particular, clearly defining data collection purpose and data collection metadata seems to be an obvious prerequisite. Given the constraints imposed by budget limitations, the development of methodologically sound and reliable data systems is challenging; not all competing data purposes can be accommodated with the same type of data and detail. Among the key purposes found in literature we found:

- Understanding cycling and walking trends and patterns
- Evaluating the effectiveness of existing facilities
- Justifying spending on new facilities
- Designing better facilities in the future
- Improving safety statistics (i.e. including an estimate of exposure to counts)

Coordination across jurisdictions and with existing highway (traffic) data collection practices is another important gap. In order to have comprehensive bicycle and pedestrian data collection system in Oregon it will be necessary and advantageous to coordinate with other jurisdictions to share data collection information (as is done with vehicle counting programs). It is likely that in urban areas, most of the non-motorized traffic will be conducted on lower functional streets and shared paths, often outside of ODOT jurisdiction. Sometimes origin-destination trips (especially bicycle trips) may cross several jurisdictions and facility types.

The Traffic Monitoring Guide, Chapter 4 emphasizes that:

> *"….non-motorized traffic will typically have higher use on lower functional class roads and streets as well as shared use paths and pedestrian facilities, simply because of the more pleasant environment of lower speeds and volumes of motorized traffic. Conversely, motorized traffic monitoring focuses on higher functional class roads which provide the quickest and most direct route for motorized traffic (FHWA 2013). "*

In a report for the Colorado DOT, Turner et al. recommended that CDOT should create non-motorized data warehouses that can:

> *"… accept and encourage local agency submission of non-motorized traffic data into Colorado DOT's traffic data warehouse. As with the motorized data, this single central repository provides a focal point for all non-motorized traffic data within Colorado. It also helps to ensure that any short-duration counts collected by local agencies are factored appropriately and consistently among all local agencies. The details of non-motorized traffic data submittal to Colorado DOT should follow the same basic process and formats that local agencies use when submitting motorized traffic data (Turner et al. 2012)."*

Some state DOTs (e.g. Vermont) have struggled with inter-jurisdictional coordination *(Blue 2011)* because data collection methodologies used across jurisdictions were not consistent. This lack of consistency led to different types of data collection efforts and the failure to estimate non-motorized AADT traffic volumes.

2.2 SITE SELECTION METHODS

Most count locations are chosen using qualitative measures and knowledge of existing bicycle and pedestrian facility use. For research studies in data collection methods, sites are usually chosen where data collection equipment exists *(Kothuri et al. 2011; Nordback et al. 2013)* which decreases overall bicycle and pedestrian data collection costs.

2.2.1 Best-Practice Site Selection Methods

The following are examples of specific qualitative measures used to choose bicycle and pedestrian counting sites.

2.2.1.1 Both Bicycles and Pedestrians

Traffic Monitoring Guide, Chapter 4, Traffic Monitoring for Non-Motorized Traffic *(FHWA 2013)*

To select specific count location, the Traffic Monitoring Guide gives the following recommendations:

- Determine if bicycle and pedestrian traffic will be counted separately
- Focus on choosing locations that are most representative of prevailing non-motorized traffic patterns
- Choose a site that is especially conducive for collection with the specific monitoring equipment

San Diego County, CA *(Jones et al. 2010)* **80 manual sites, 5 automated sites**

In San Diego County 80 locations were chosen for manual peak period counts and 5 locations for automated 24-hour counts. Count locations were chosen to represent:

- Presence and type of bicycle facilities, including a facility with no bicycle accommodations
- High pedestrian crash areas
- Areas identified for future smart growth
- Locations near transit stops (trolley, bus, ferry)
- Locations near planned or recently completed bicycle and pedestrian projects
- Variety of land uses and demographics
- Random count locations were considered but required a high number of count locations.

2.2.1.2 Pedestrians

Alameda County, CA *(Schneider et al. 2009)* **50 manual sites, 11 automated sites**

For this pedestrian data collection study, 50 manual count sites and 11 automated count sites were chosen using the criteria below:

- Neighborhood with varying range in incomes
- Many locations within a quarter mile radius of a school
- Half mile radius from light rail

- Range of volumes

Trenton, NJ *(Ozbay et al. 2010)* **5 automated sites**

In this study, evaluating the effectiveness two types of automated pedestrian counters, test site locations criteria included:

- Facilities and users. Pedestrian facilities needed to exist.
- Accident occurrence. Location should have pedestrian safety issues
- Appropriate structures for mounting equipment
- Volume and low volume sites

2.2.1.3 Bicycles

Hamilton, New Zealand *(Lieswyn et al. 2011)* **12 continuous counting sites**

In Hamilton New Zealand site selection is also based on qualitative measures. The criteria include:

- Network coverage criteria including the selection of locations with high bicycle volumes to maximize the data accuracy and principal origins / destinations, and screen lines
- A mix of on-road and off-road facilities, especially considering potential impacts from the proposed completion of contiguous off-road routes
- A mix of tidal directions based on peak period considerations
- Site specific factors including pavement surface, the effect of curves, parking and lane lines upon the typical line taken by riders, and intersections

2.2.2 Gaps in Site Selection Methods

No quantitative method is known for site selection but needs to be developed *(FHWA 2013).* There is no academic or rigorous evaluation of the advantages of a formal set of count location selection rules or ad-hoc methods. Although there are general recommendations about locating counts to evaluate before/after conditions, there is no clear differentiation between:

- Locational differences for permanent and temporary counters
- Bicycle vs. pedestrian data collection and specific site location characteristics
- Impact of land use, demographics, or trip purpose on effective location characteristics

2.3 DATA COLLECTION FREQUENCY/ DURATION

Developing a set of continuous, automated counts is preferred in order to understand the temporal traffic patterns of pedestrians and cyclists. However, the most common data collection time duration for manual counts is two hours. Two hours is the length of time used for manual counts for the National Bicycle and Pedestrian Documentation Project and is a reasonable duration of time to expect volunteers to conduct counts. A key issue for manual or short-term counts is how to account for variability associated to day of the week, time of day, seasonal and weather conditions.

2.3.1 Best-Practice Data Collection Frequency/ Duration

2.3.1.1 Pedestrians

Alameda County, CA *(Schneider et al. 2009)* **2 hour counts**

For this study, data were collected for 13 weeks during these time periods:

- Tuesday, Wednesday, and Thursday

  4 pm to 6 pm

  5 pm to 7 pm (National bicycle and Pedestrian Documentation collection times)

  2 pm to 4 pm near schools

- Saturday

  9 am to 11 am

  12 pm to 2 pm

  3 pm to 5 pm

2.3.1.2 Bicycles

Hamilton, New Zealand *(Lieswyn et al. 2011)* **Continuous data at 2 sites, short-term at 10 sites, peak hour manual counts**

This implemented bicycle data collection system includes:

- Two permanent sites, one on road and one off road that records continuous data.
- Ten permanent sites where data is collected for two to ten weeks of data annually

All sites have annual peak period manual counts for calibration and for collecting additional information such as gender, age, behavior and turning movements

Department for Transport, London Automated Data Collection, UK *(Department for Transport 2012)* **Continuous and 12 hour manual counts**

This data collection system collects all modes of travel, including bicycle (Pedal Cycles). The actual number of counting stations was not available but there are hundreds of counting sites provided online. This UK system uses a combination of:

- Continuous automated counts
- Manual counts over a 12 hour period sometime between March and October [1]

Data users can interact with a map and download Estimated Annual Average Daily Traffic (AADT) volumes for all vehicle types, including “PedalCycles” in a .csv Excel file[2].

2.3.2 Gaps in Data Collection Frequency/Duration

In order to fully understand bicycle and pedestrian travel, it is necessary to collect continuous data for bicycles and pedestrians. Traffic patterns for bicycles and pedestrians are different from each other and from motor vehicle traffic patterns and need to be better understood *(Nordback et al. 2013; Lieswyn et al. 2011).* Continuous counts serve as a way to develop factors for expanding short-duration counts to annual estimates. Specific gaps in data collection methods include:

- Best or optimal ratio between permanent and temporary data collection sites
- Determination of data collection frequency/duration as a function of facility type, land use characteristics, or trip purpose
- Integration of bicycle and pedestrian data with vehicle/traffic data on short duration studies

As anticipated in the introduction to this section there are significant gaps in terms of systematic and detailed guidelines to design bicycle and pedestrian data collection efforts. The next chapter describes data collection technologies.

2.4 SUMMARY

Overall some of the key findings of the literature review are:

1. There are significant gaps in terms of systematic and detailed guidelines to design bicycle and pedestrian data collection efforts. Most efforts seemed to be based on ad-hoc rules or pragmatic judgment of the agencies.
2. Bicycle and pedestrian counting efforts are in many cases conducted/reported simultaneously even though the literature suggests that bicycle and pedestrian trip characteristics are

---

1 http://assets.dft.gov.uk/statistics/releases/traffic-estimates-2010/traffic-estimates-2010-methodology.pdf)
2 http://www.dft.gov.uk/traffic-counts/cp.php

different and data collection technologies not necessarily compatible. Thus, in each section of the review, we have grouped documents that cover 1) bicycle and pedestrians together, 2) pedestrians only, or 3) bicycles only.

Although most European countries and cities have high levels of bicycle and pedestrian mode share, the international documents contained in this report have little evidence of comprehensive data collection systems beyond household surveys or local (cities) efforts. The typical response we obtained from European agencies is similar to the one provided via email by Leif Jönsson, from Malmö Sweden (source):

“There is no national strategy for how to count bicyclists and pedestrians. Each municipality uses its own strategy. In Malmö we have two fixed counting stations for cyclists. Here are cyclists counted using directional sensing detectors in the asphalt. We also have about 250 points annually counted manually. In the case of pedestrians, we count only on one of our pedestrianized streets using video surveillance. Nationally we do not count much cycling and walking, it is mainly the municipalities that do this. In Malmö we have set up permanent counting stations on the two main bicycle routes. Otherwise, we have tried to cover all the major bicycle routes in the city with manual annual counting’s. If necessary, also pedestrians are counted manually, but it does not occur very often.”

The international reports included in this review are intended to be examples of bicycle and pedestrian plans that are being implemented in other countries mostly without detailed information in terms of systematic data collection efforts along cycling and pedestrian facilities.

All reports/documents referenced in the Literature Review Tables address issues relevant to the goals of this study. However, the three most relevant reports are:

- Traffic Monitoring Guide, Chapter 4, Traffic Monitoring for Non-Motorized Traffic by the Federal Highway Administration is an introduction to bicycle and pedestrian data collection goals and design considerations and will be referred to throughout this summary (FHWA 2013).

- A Methodology for Counting Pedestrians at Intersections: Using Automated Counters to extrapolate Weekly Volumes from Short Manual Counts is a research report that designs a methodology for estimating pedestrian volumes *(Schneider et al. 2009).*

- Automatic Bicycle Counting Program Development in Hamilton, New Zealand *(Lieswyn et al. 2011).*

3.0 NON-MOTORIZED DATA COLLECTION EQUIPMENT

This chapter summarizes existing data collection equipment that can be deployed to count bicycles and pedestrians. A description of each technology, including typical applications, installation as well as advantages and disadvantages is presented. If available, we provide equipment accuracy, an Oregon deployment example, and the estimated cost of the technology (equipment costs only).

3.1 SELECTION OF DATA COLLECTION EQUIPMENT

In the last decade, many technological improvements have been made for non-motorized data collection. However, non-motorized data collection is not widespread. Many of these emerging technologies have not been thoroughly tested for accuracy or reliability. Some motor vehicle data collection technology can be used for non-motorized data collection, but the unique nature of bicycle and pedestrian travel does not always allow for these methods to be directly transferred to non-motorized data collection. There are even significant differences between data collection equipment for bicycles and for pedestrians. Some technologies can count both bicycles and pedestrians but most data collection technologies are made for bicycles or pedestrians separately. Inductive loops and pneumatic tube counters, commonly used for motor vehicle detection can be used for bicycle counting but are not appropriate for pedestrian counting.

There are two main questions to ask when choosing the appropriate non-motorized data collection equipment for a location;

3. “*What are you counting?*” refers to the type of mode you are interested in counting, such as bicycles only, pedestrians only, or both bicycles and pedestrians.

4. “*How long are you counting?*” refers to the decision to collect short-term or continuous counting *(FHWA 2013).*

Other questions that may need to be considered when deciding on which type of equipment to purchase include:

- What type of facility (trail, mixed- use trail, bike lane, bike boulevard, sidewalk, etc.) are you counting on?
- How are you counting?
- What is the size of the budget?
- What counting equipment does your agency already own?
- What type of data collection software is used?
- How can existing data collection equipment be maximized?

3.2 INDUCTIVE LOOPS

Inductive loops, traffic signal controllers and pedestrian actuation are being presented together in this report because of their potential to be the ideal bicycle and pedestrian traffic data collection system for ODOT. The combination of 2070 traffic signal controllers, pedestrian actuation logging, and inductive loops for bicycles are currently being at some intersections managed by ODOT.

Inductive loops are a common traffic counting and monitoring device for both motor vehicles and bicycles. Inductive loops circulate a low alternating electrical current through a wire coil embedded in the pavement. The wire coil produces an electromagnetic field. When an object containing a ferrous or other metal passes through the electromagnetic field, a detection is recorded *(FHWA 2013)*. Note that the inductive loop itself does not do the counting. A card and logger are needed to complete the data collection. Since the loops are installed to be permanent, they would ideally be used for continuous counting.

For the purposes of bicycle data collection, care must be taken in choosing loop location. The ideal location for inductive loops for bicycle traffic volumes is in designated bike facilities, mid-block, where bicycles are in free flow conditions *(FHWA 2013)*. On-road applications should avoid locations where vehicles may drive over loops designated for bike counts; the presence of motorized vehicles driving near or over the bicycle loops may lead to over-counting. ODOT has a testing procedure for inductive loops; see Testing Procedure for Vehicle Detectors in Appendix B.

There are several loop configurations such as quadruple, diagonal quadruple, chevrons, elongated diamond patterns, as well as rectangular. Examples of existing inductive loops in Oregon are shown in Figure 3.1: Examples of Inductive Loop Configurations for Bicycle Detection in Oregon and Colorado. The sensitivity of inductive loops can be adjusted in order to detect bicyclists. The placement of loop detectors can be used to infer travel direction by installing a loop in each specified travel lane, or by installing two loops in series, illustrated in Figure 3.2. It is always recommended to determine the accuracy of the loops and adjust their sensitivity by conducting a manual count or video count and comparing results.

A review of inductive loops installations in the U.S. found that loops consistently detect bicyclists as long as they are installed correctly. The size of the loop is important. Loops need to be compact enough so that motor vehicles are not detected but large enough that bicycles are detected *(Goodridge 2013)*. For Type D configurations, a 3’ by 3’ configuration with a 45 degree angle provides the most reliable bicycle detection. See Figure 3.3 *(Shladover et al. 2009; Styer and Leung 2013)*.

In addition to loop configuration, correct sensitivity settings of the loops are also necessary for accurate counting. Sensitivity of the loops is adjusted on the loop input card in the controller cabinet. Because of the minimal amount of metal in bicycle tire rims (which are the most common component of the bicycle that is detected by the inductive loops) unique procedures for setting loop sensitivity for bicyclists may need to be developed. If the settings are too low, bicycles will not be detected. If the settings are too high, motor vehicles could be detected by the loops designated for bicycles. A study conducted by the FHWA in 2008 by David Gibson, P.E. found that the ideal setting for inductive loop for bicycles was 6 *(Gibson 2008)*.

At the time of this report, ODOT Region 1 Signal Manager, Tiffany Slauter estimated the installation of an inductive loop to be approximately $300 to $340 to cut the pavement for loop insertion and run the wire to the nearest junction box in the pavement and $3.40 per foot to run cable to the signal controller cabinet. These costs do not include planning, the necessary controller cabinet or card or the logger. An estimate of an EcoCounter inductive loop detector system costs $2,000-$3,000 for the hardware and does not include loop materials and installation.

a. Diamond Bicycle Loop Detector at 99W and Hall Boulevard, Tigard, OR

b. Diamond Bicycle Loop Detector at 99W and Hall Boulevard, Tigard, OR

c. Quadrupole Bicycle Loop Detector at 99E and Couch St., Portland, OR

d. Double Diamond Bicycle Loop Detector on the I-205 Path at SE Yamhill St., Portland, OR

e. Parallelogram Loop Detector Used for Bike Lane Signal Actuation in Boulder, CO

f. Parallelogram Loop Detector Used for Bike Lane Signal Actuation Loop in Boulder, CO

Figure 3.1: Examples of Inductive Loop Configurations for Bicycle Detection in Oregon and Colorado

Figure 3.2. Example of an Inductive Loop Placement for Inferring Direction Source: FHWA

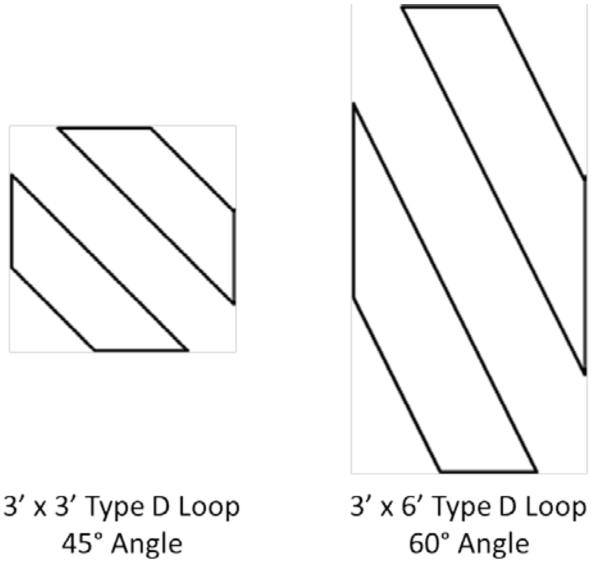


Figure 3.3. Type D Inductive Loops Source *(Styer and Leung 2013)*

Accuracy of inductive loops for bicycles can vary depending on sensitivity adjustments, placement and installation. In Boulder, Colorado, one study compared inductive loop counts to manual counts and found that loop detector error was 4 percent on average *(Nordback and Janson 2010)*. In the Netherlands, loop detectors were found to have an approximate error of 8 percent. A study of three inductive bicycle loop counters in Minneapolis along the Midtown greenway, a paved multi-use path, found errors in the three inductive loops tested to be 27, 7 and 5 percent. Additionally, the usable days of data for each of the three counters averaged 79 percent. 21 percent of the days of continuous inductive loop counts were unusable because of detector malfunction *(Lindsey et al. 2012)*.

A preliminary study of the use of 2070 signal controllers and 170 controllers (170 controllers are an older generation; 2070 controllers are the latest generation) for recording bicycle counts and pedestrian actuation was conducted in Portland, OR *(Kothuri et al. 2012)*. In the study by Kothuri et al., the accuracy of the inductive loops for bicycles was evaluated using video. One of the intersections evaluated used a Type 170 controller; the other two intersections in the study used 2070 controllers. The mean absolute percent error (MAPE) of the inductive loops for bicycle counts was between 16.7 and 18.3 percent. It was found that some cyclists were not riding over the inductive loops at the locations studied which may lead to undercounting bicyclists.

Finally, in September 2013 ODOT performed a video data collection effort to estimate the accuracy of the inductive loops install on the I-205 multi-use path. The loops were found to have an accuracy of approximately 80 percent.

3.3 DATA LOGGING WITH TYPE 170 AND 2070 CONTROLLERS

In addition to managing the coordination of traffic signals and collecting motor vehicle data, traffic signal controllers also have the ability to log pedestrian actuations and bicycle volumes from inductive loops. There are two main types of controllers used at signalized intersections in Oregon; type 2070 and type 170. Signal controllers use inputs from loop detectors, pedestrian push buttons, and fire truck preemption detectors to operate the traffic signal in a manner that is responsive to travelers. Type 170 controllers have 44 inputs but only 12 of them can be used for traffic counting purposes with the most common firmware, W4IKS™[3].There are other firmware types, such as BiTrans™[4], that can track a larger number of inputs. However, ODOT currently uses W4IKS™ with their 170 controllers.

2070 controllers are superior to the 170 controllers; 2070s have more functionality and have 32 channels that can be used for counting purposes with a common software package used at ODOT (Voyage by Northwest Signal, Inc.). Both Portland Bureau of Transportation (PBOT) and ODOT use Type 170 and 2070 controllers at controlled intersections.

The 170 and 2070 controllers have an open-architecture; i.e. specifications and standards are open and are available to all manufacturers and users (not a proprietary system/product). Multiple companies manufacture 2070 controllers but all units use the same protocols and can function together regardless of the manufacturer *(Caltrans 2002)*.

Inductive loop wires are routed to the controller channel designed for counting. The counts can be uploaded to an Advanced Traffic Management System (ATMS) (such as TransSuite™ or NW Central) and archived. If the location is not on a central communications network but there is a router or cell phone service, the count data can be sent via intranet or wirelessly

---

[3] http://www.wapitimicrosystems.com/Wapiti%20W4IKS%20Data%20sheet.pdf
[4] http://edoqs.com/bitrans-signal-software

Pedestrian phase actuation can be recorded using a custom logic in the 170 controller that tallies the number of times in a period that the pedestrian phase is served and stores the result in a count bin that can be later retrieved by TransSuite™ *(Kothuri et al. 2012)*. The Voyage firmware on a 2070 controller is also capable of counting the number of times that a pedestrian phase is served within a period.

Figure 3.4. 2070 Controller.
Source: http://www.mccain-inc.com/controllers/2070-controllers/item/2070-controllers/2070l.html

The advantage of using a 2070 controller to collect non-motorized data is that the data collection system is already installed and operating to be demand responsive and/or to provide signal coordination. For bicycles, inductive loops may already be set up for signal actuation or can be installed relatively economically. Induction loops at the stop bar may not be a reliable source of counts. For counting purposes it is recommended to install inductive loops 50-100 feet upstream of the stop bar or at a location where bicycles do not stop. At intersections with pedestrian actuation, actuations are already being recorded and only need to be downloaded. If the pedestrian phase is on recall, using phase logging as a measure of activity is not useful since every cycle the phase will be logged as served.

For both 170 and 2070 controllers, the main purpose of pedestrian push buttons is to place a call in the controller so that the pedestrian phase is provided at the next opportunity. While pedestrian push button activity does not translate directly to pedestrian volumes, the information can still be useful in determining the level of pedestrian activity at an intersection. Pedestrian push button activity can be recorded using a custom logic in the controller that forces the detector counts into TransSuite™ for retrieval *(Kothuri et al. 2012)*.

Using push button activity for recording pedestrian activity is a relatively new concept and it is still at the research/validation stage. Besides installing the necessary software, the only additional cost of collecting pedestrian pushbutton actuations is the downloading and evaluation of the data. Data collection costs are reduced if a router or wireless data transmission service is available or the controller is on a central signal system.

3.4 PNEUMATIC TUBE COUNTERS

Pneumatic tube counters are a low-cost, portable traffic counting technology used for counting bicycles and motor vehicles. Pneumatic tube counters are typically used for short-term counts, although they are sometimes used for long-term counting. One example of a long-term count utilizing tubes is the bicycle counting setup on the Hawthorne Bridge in Portland, shown in Figure 3.5.

Pneumatic tube counters consist of a rubber or composite tube attached to a portable data logger. The data logger records a pulse of air sent through the tube when a vehicle rolls over the tube. For accurate counting, the sensitivity of each device to detect a change in pressure as a wheel compresses the tube is critical. Tube diameter and length are also critical factors. The device counts each air pulse. Pneumatic tube counters are capable of distinguishing direction when two tubes are properly spaced according to manufacturer's instructions. Tubes can also distinguish vehicle types when using a unique algorithm in the software that matches axle spacing patterns.

Figure 3.5. Permanent Pneumatic Tube Counter on the Hawthorne Bridge

Tubes can be used on any solid surface road, path or sidewalk. The tubes are attached to the surface, perpendicular to the direction of travel. Tubes are pulled taut and attached with screws, or on side of a path or road, using stakes. The logger box, usually hidden from view, is locked to a fixed object to avoid theft. It is best to span tubes the entire width of the path or road in order to record all bicyclists. Secure installation of the tubes is critical to avoid hazards from loose tubes on road or path. Because tubes are easily visible to the public, vandalism can be common. Theft and vandalism can be avoided through proper site selection and a secure installation.

Pneumatic counter systems from EcoCounter™ which include a logger, a steel box and tubes cost approximately $2,000-$3000 per unit *(Hengel et al. 2011a)*.

A research study in Colorado examined the accuracy of pneumatic counters that can distinguish bicycles from motor vehicles *(Hyde-Wright et al. 2014)*. Two common brands of tube counters;

EcoCounter and the MetroCount™ were evaluated. It was observed by the authors that bicycle counts in a bike lane or shoulder farthest away from the logger were less accurate. To evaluate the accuracy of counts at different distances along the pneumatic tube to the logger, bike crossings were tested at 4, 27 and 33 feet; the deployment is illustrated in Figure 3.6.

In order for the pneumatic tubes to record the direction of the traffic, two tubes need to be placed at a specified distance recommended by the manufacturer. Two different distances between tubes were tested utilizing the MetroCount™ ™ tubes: two and five feet. The manufacturer's recommended distance between tubes for the EcoCounter™ of 11.75 inches (30cm); EcoCounter™ equipment was also tested for accuracy, illustrated in Figure 3.6 .

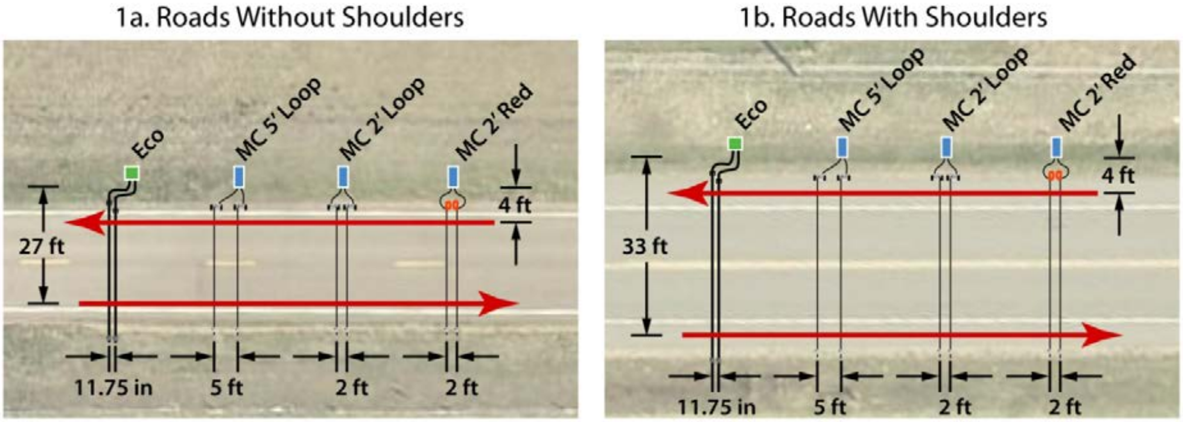


Figure 3.6: Configurations of Test Pneumatic Tubes in Boulder, CO *(Hyde-Wright et al. 2014)*

A common method for fastening the pneumatic tubes to the ground is to use a bracket designed to hold the tube securely and also provide holes for stakes, nails or screws to fasten the tubes to the ground. Crimping of the tube at the attachment location is possible during installation and may affect the ability of the air pulse to be detected by the logger. Hyde-Wright et al. tested three different methods for attaching the tubes, illustrated in Figure 3.7.

To distinguish bicycles from motor vehicles with pneumatic tube counters manufacturers have developed advanced sorting algorithms based on the distance between axles and the wheel configuration of each vehicle. There are few studies that have tested the accuracy of these algorithms. Hyde-Wright et al. found that the algorithms were typically counting pairs or groups of bicycles as trucks with duel axles; occlusion issues were also observed. The manufacturer's algorithms were not considering difference in speed between motor vehicles and bicycles. Hyde-Wright et al. attempted to develop a better classification scheme to distinguish bikes from vehicles. They compared their new algorithm to EcoCounter and MetroCount algorithms.

1c. Metal Bracket- used to secure the Eco-Counter's tubes

1d. Vinyl Tubing + Metal Bracket- used to secure MC 5′ Loop and MC 2′ Loop

1e. Red Rubber Hose- used to secure MC 2′ Red

Figure 3.7. Pneumatic Tube Attachment Methods Tested in Boulder, CO *(Hyde-Wright et al. 2014)*

A weighted average accuracy and a weighted 95 percent confidence interval were calculated for a number of different set ups. It was found that counts closer to the logger were more accurate. When Hyde-Wright et al. bicycle counting algorithm was added to the MetroCount™ equipment the 4-foot distance bike count was 95 percent accurate and the 27-foot distance counts were 55 percent accurate. The MetroCount™, using its own counting scheme had an accuracy of 68 percent at 4-foot distance and 43 percent at 27-foot distance. Both MetroCount™ results used a distance of 5 feet between tubes. All tests made with a 2-foot distance were less accurate than 5-foot distances. EcoCounter proprietary algorithms had an accuracy of 95 percent at 4 and 27-foot distance and 57 percent accuracy at 33 feet.

This research also found that EcoCounter tubes, attachments and algorithms were equal to the configuration of the MetroCounters with the vinyl tubing, metal bracket, and Hyde-Wright et al. algorithm at short distances. At 27 feet, the EcoCounter was superior with a sustained accuracy of 95 percent. All counter configurations accuracy are 60 percent or lower for tubes over 33 feet. Hyde-Wright et al. gave the final recommendation to use an EcoCounter for roads up to 27 feet wide. Modified MetroCount™ tubes can be used using two separate counters; one on each side of the road to increase their accuracy.

3.5 INFRARED SENSORS

Infrared sensors are commonly used to count pedestrians and bicycles. Because infrared sensors cannot distinguish between pedestrians and cyclists they are commonly used in combination with inductive loops or tube counters. Bicyclists are detected by the loop or tube and then subtracted from the infrared counter to calculate pedestrian volumes. Infrared sensors are usually installed permanently, although they can be used as temporary counters, depending on the type used. Infrared sensors are nondescript and resist vandalism. They are usually mounted onto a post or other vertical object at a height of three feet, or hip distance to capture as many persons as possible. There are two different types of infrared sensors; active and passive *(FHWA 2013)*. Both types have issues with occlusion.

3.5.1 Active Infrared Sensors

The active infrared sensor sends a beam of light between a receiver on one side of a counting area and a target placed on the other side. When the beam is broken, an event is registered in the receiver. Because of the nature of the detection, installation of the active infrared sensors can be more challenging. It requires two vertical mounting locations directly across from each other *(FHWA 2013).*

Figure 3.8. TrailMaster TM1550 Active Infrared Trail Monitor
Source: http://www.nhbs.com

The cost of active infrared sensor is approximately $1,000 (Hengel, Tresidder, and Berkow 2011a). The accuracy of eight TrailMaster™ active infrared units was tested in Minneapolis, Minnesota. The units were installed on multi use trails and paths with separate bicycle and pedestrian facilities. Each unit had over one year's worth of data and, on average, the percentage of useable data was 90 percent. The accuracy of the counts was validated using manual counts. The mean error of the active infrared counters was 10.2 percent *(Lindsey et al. 2012).*

3.5.2 Passive Infrared Sensors

Passive infrared sensors detect a heat differential in the detection area. Unlike the active infrared, the equipment is only installed on one side of the path/sidewalk/road perpendicular to the path. The accuracy does increase if the sensor is pointed towards a wall or other large fixed object or building. They are usually installed on a vertical post and the beam crosses the path or sidewalk. Metro MPO is collecting pedestrian counts at 15 locations on nature trails in the Portland metropolitan region using TRAFx™ infrared counters. An image of a Metro infrared counter in Clackamas County is shown in Figure 3.9.

Figure 3.9. Metro Regional Park TRAFx™ Infrared Counter in Canemah Park, Clackamas County Source: Metro

Figure 3.10. EcoCounter Pyroelectric Infrared Sensor *(EcoCounter 2013)*

The cost of a passive infrared sensor is between $1,000 and $3,500 *(Hengel et al. 2011a)*. Because the passive infrared detects heat differentials, accuracy may decrease in temperatures close to body temperature, although there is no evidence of this *(FHWA 2013)*. The reported accuracy is between 75 and 95 percent *(Hengel et al. 2011a)*.

In Alameda County in California, a pedestrian traffic study used a combination of manual counts and infrared sensors. The infrared sensors used were the EcoCounter™ Pyroelectric Dual Infrared Sensors. Manual counts were collected at 50 intersections and five infrared sensors were rotated among a subset of the 50 of the intersections. Although no definitive values for counting errors was reported, the authors stated that there were consistent rates of undercounting during high pedestrian traffic (>400 pedestrians per hour) and low pedestrian traffic (<100 pedestrians per hour). The infrared sensors also undercounted due to weather and dark conditions. It was found that the percentage of undercounting was not related to the pedestrian volume; therefore, it may be possible that proportional adjustment factors would result in somewhat accurate weekly volumes estimates *(Schneider et al. 2009)*.

3.6 MAGNETOMETERS

Magnetometers detect changes in the normal magnetic field caused by a ferrous metal object, similar to inductive loops. Magnetometers are designed for motor vehicles but some newer models have been designed to detect bicycles. The devices are permanently installed in the path of traffic, zero to six inches below the pavement surface. The units are battery powered and need to be removed and replaced at the end of the battery life; about every 10 years. Data is collected using two-way radio communications *(Sensys Networks, Inc. 2014a)*.

Figure 3.11. VSM240 Wireless Flush-Mount Magnetometer Sensor
Source: http://www.precisiontrafficsafety.com

Magnetometers are sensitive enough to detect bicycles passing across a 4-ft (1.2-m) span when the electronics unit is connected to two sensor probes buried 6 inches (16 cm) deep and spaced 3 feet (0.9 m) apart *(Klein et al. 2006)*. Since the range of detection is only within a few feet, it would require more than one sensor to be installed across a path. Costs for the sensors are given via quote only, but installation costs are minimal since there is no need for conduits or saw cuts. Accuracy has not been studied independently at this point in time *(FHWA 2013)*.

3.7 PRESSURE AND SEISMIC SENSORS

Pressure sensors and seismic sensors are installed on natural surface paths or paved surfaces, just below the surface. Pressure sensors operate by detecting changes in force on the sensor. Seismic sensors detect energy waves through the ground. Pressure sensors are ideal for paths where they can be hidden below a dirt or gravel path. Some models are able to distinguish between bicycles and pedestrians *(FHWA 2013)*.

No studies of accuracy could be found. A manufacturer claims 95 percent accuracy *(EcoCounter 2013)* but this number has not been validated by independent studies.

Before After

Figure 3.12. Installation of the EcoCounter Acoustic SLAB *(EcoCounter 2013)*

3.8 THERMAL IMAGING CAMERAS

Thermal imaging cameras combine passive infrared technology with automated imaging processing video. Portland Bureau of Transportation (PBOT) is one agency that is currently experimenting with a thermal imaging camera, FLIR, for bicycle and pedestrian recognition. The cost of the FLIR camera is $2200 and the logic board is $2600.

3.9 RADAR/MICROWAVE

Radar detection operates by emitting electromagnetic pulses and deducting information about the surroundings based on the reflected pulses. Accuracy of this technology for counting bicycles and pedestrians has not been well documented *(Kittelson & Associates 2012)*. PBOT is currently experimenting with counting bicycles with radar technology

Figure 3.13: MicroRadar^{TM} by Sensys
Source: http://www.sensysnetworks.com/products/microradar/

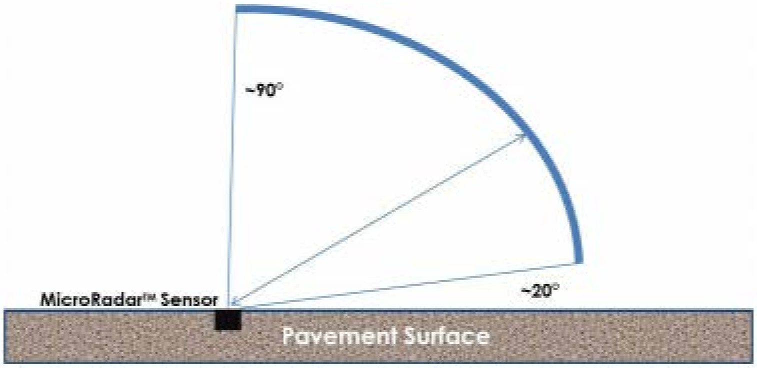


Figure 3.14: Range of Detection for a MicroRadar Sensor
Source: http://www.sensysnetworks.com/products/microradar/

Some radar devices, such as the VSN240-M MicroRadarTM Sensor, are capable of differentiating between bicycles and vehicles. The unit looks similar to a magnetometer as shown in Figure 3.13. MicroRadarTM is installed in the pavement, just below the surface. The device emits low power, high frequency pulses which bounce off objects and return energy profiles of objects passing through the field of detection. An algorithm determines the presence and the type of vehicle (or bicycle) based on the characterization of the energy profile. These sensors can detect bicycles or vehicles passing within six feet of the device, or can be deployed specifically at bicycle lanes for a range of up to eight feet in one direction. The range of detection is vertical and 70° towards the surface as shown in Figure 3.14. The unit needs to be installed so that the range of detection is facing the bicycle lane. Batteries within the devices last about eight years before replacement is necessary. As with the magnetometers, the sensors have a wireless connection with a nearby data logger. The data logger can then direct the information to signal cabinets or data hosts, depending on the purpose of the sensor *(Sensys Networks, Inc. 2014b).* Cost or research relating to accuracy of bike detection could not be found. According to Gary Obery, ODOT Alternate Mode Traffic Engineer, ODOT has tested the units in their signal shop in Salem. ODOT found that the MicroRadar detected most bicycles and differentiated between bicycles and motor vehicles. It did not distinguish between bicycles and pedestrians.

Microwave radar detectors emit a microwave beam. When an object enters the beam area it reflects microwave energy back to the unit which creates a pulse that is detected by the unit *(Klein et al. 2006)*. Some microwave detectors can distinguish between bicycles and motor vehicles *(Styer and Leung 2013)*. IntersectorTM Microwave Detector was tested by Caltrans and found to detect bicycles in mixed traffic. No study or reference was found for counting bicyclists with microwave, only to detect bicyclists.

The cost of an Intersector^{TM} Microwave Detector unit is approximately $5000.00 *(Styer and Leung 2013)*. Caltrans conducted a study in Chico, CA found that the Intersector^{TM} Microwave Detector was 95 to 100 percent accurate for detecting bicycles *(Styer and Leung 2013)*.

3.10 VIDEO

There are two types of video technology used for evaluating non-motorized traffic; manual video recording and automated video image processing. Manual counting is not an automated counting technology. It requires a significant amount of staff time. Automated video image processing is still in the developmental stage.

3.10.1 Manual Video Recording

Video recording can be used for collecting both bicycle and pedestrian data. Not only can it be used to record traffic volumes but also behavior, gender, and bicycle helmet use. In order to retrieve counts or data from video, it must be replayed and data must be recorded manually. This is an accurate but labor intensive method of data collection. Video review requires approximately 3 hours of labor for every hour of recorded video, depending on traffic volumes and data collected. The ideal use of video technology is to verify manual or other types of counting equipment.

Humboldt County, California implemented a pilot study to develop a cost effective way to monitor non-motorized traffic on their State highway system *(Manhard Consulting 2011).* After determining their ideal counting system attributes, the California Department of Transportation (Caltrans) worked with a contractor to develop a custom system design. A security camera was chosen for the system. The initial cost of each unit was approximately $1,800.

A comparison was made between the person hours needed to process the data from the video and the labor needed to process manual survey methods. For the six sites that were tested, manual count person hours were 160 to 280 percent greater than person hours for evaluating video. Manual count hours included time spent for site reconnaissance, field preparation, travel, data sheet set-up, field surveying and data processing data entry and verification. Note that, depending on the site, more than one person might be needed for a manual count. For video evaluation, labor included site reconnaissance, field preparation, travel, camera system installation, camera system takedown, data sheet set-up, data completeness checks, digital data review and processing data entry, and verification. The project found that video data collection for non-motorized traffic produced the greatest cost savings for sites in rural settings, in remote locations, lightly trafficked sites, simply configured sites, and sites that were capable of being monitored with one camera.

The cost of a video camera unit developed for traffic data collection is approximately $2,000-$5,000 *(CountingCars.com 2014).* Accuracy of manual video is based on installation and diligence of manual labor to evaluate images. Video can be evaluated as many times as necessary and has the potential to have 100% accuracy. Hence, manual video is a useful tool for evaluating other types of traffic detection devices.

3.10.2 Automated Video Image Processing

Video image processing uses a sophisticated visual pattern recognition algorithm to count bicycles and pedestrians. This technology is in the development phase for counting bicycles and pedestrians outdoors, but has mostly been used successfully in academic studies *(Somasundaram et al. 2012).*

An estimated cost of an automated video processing unit is $1,200 - $8,000 *(Alta Planning and Design 2009)*. In addition there is the labor cost to process each hour of video, ranging from $50 to $100 per hour. Reported accuracy is approximately 95 percent *(Hengel et al. 2011a).*

3.11 VALIDATION

It is important to note that one of the drawbacks to the new and rapidly expanding choices of non-motorized data collection equipment is contractors and technicians lack of familiarity and experience with the new technology and installation. It is important to choose an installer that is familiar with the equipment and understands the limitations of the technology.

Video validation is always recommended as later discussed in the recommendations section. It is recommended that periodically and immediately after new equipment is installed, the accuracy and reliability of the equipment is verified. Video should also be used to validate counts because bicycles and pedestrians do not always follow the road network or use the facilities where the counting equipment is installed (e.g. bicycles using the sidewalk instead of the bicycle lane).

The next chapter describes existing data collection efforts in Oregon.

4.0 EXISTING DATA COLLECTION EFFORTS IN OREGON

A limited number of government agencies in Oregon collect automated bicycle and pedestrian data. The following is a summary of known data collection efforts as of November 2013. This list only includes automated data collection efforts (the focus of this research project). There may be other data collection efforts in Oregon that are not known by the authors or listed herein; these efforts may include manual counts or data collection efforts necessary for specific projects (i.e. not part of a long-term systematic data collection effort).

4.1 CITY OF PORTLAND

The City of Portland has the longest and possibly the most extensive non-motorized automated data collection effort in Oregon. Most of the data collected is for bicycles. However, there is no cohesive or uniform system for collecting bicycle and pedestrian data in Portland. The City of Portland collects short duration pneumatic tube counts around the city. In addition, Portland has installed a set of permanent EcoCounter™ pneumatic tubes on the Hawthorne Bridge, which has the highest known bicycle traffic volumes in the state of Oregon.

The earliest known annual and permanent automated count data from the Hawthorne Bridge began in 2005 and was most likely collected with a JAMAR™ brand tube counter before the current EcoCounter™ unit was purchased. Most of the non-bridge pneumatic tube bicycle counts are short-term with durations that go from one week to several weeks. The City of Portland also uses inductive loop counters in bike lanes at 15 locations and one inductive loop on the Springwater Trail. Six of the loop detectors are located on SE 82nd Avenue. Some of the loop detectors are only recording in one direction. Data from 15 loop detectors at signalized intersections are available to the public on the PORTAL website[5]. Portland maps[6], the City of Portland's online GIS based mapping and data storage site, also contains summary bicycle counts on some streets/arterials. The City of Portland also has produces annual bicycle count reports.

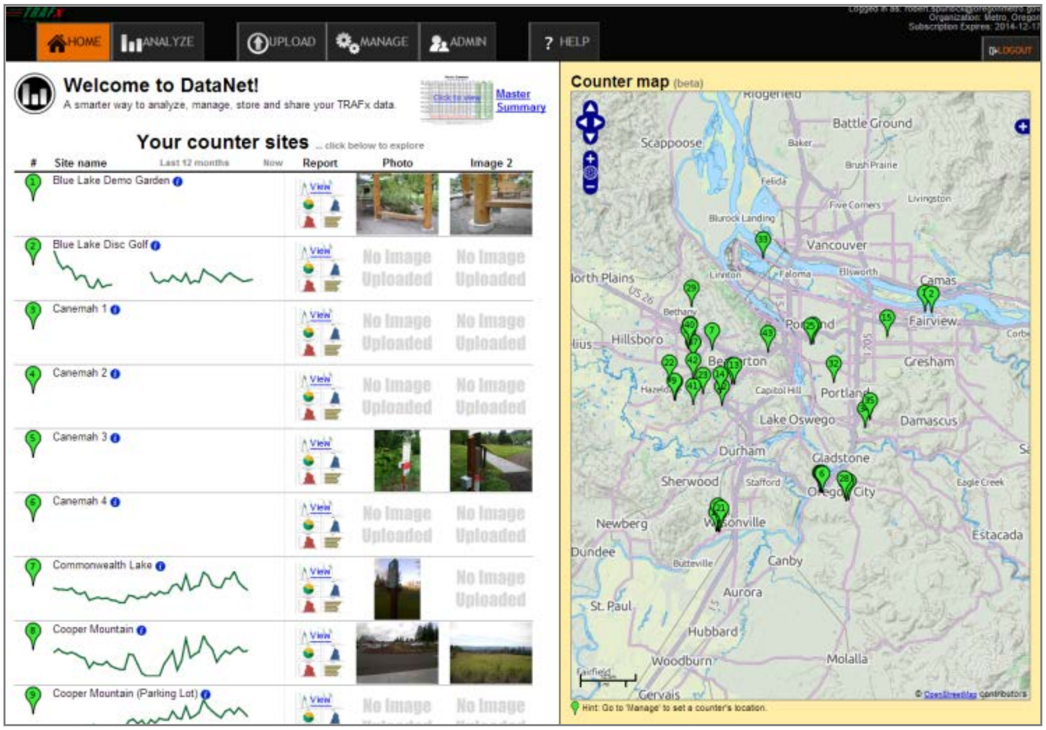
4.2 METRO

Metro MPO is collecting automated pedestrian counts at 28 locations on nature trails in the Portland metropolitan region using TRAFx™ infrared counters and one EcoCounter™ EcoCombo™. The EcoCounter™ EcoCombo™ combines infrared and inductive loop technologies to count bicyclists and pedestrians separately. Some of the counters are permanent and some of them are used for short-term counts. The TRAFx™ data is stored on the TRAFx™ DataNet™ website as shown in Figure 4.1.

---

[5] http://demo.portal.its.pdx.edu/Portal/index.php/pedbike

[6] http://www.portlandmaps.com



Welcome to DataNet!

A smarter way to analyze, manage, store and share your TRAFx data.

Master Summary

Your counter sites ... click below to explore

#	Site name	Last 12 months	Now	Report	Photo	Image 2
1	Blue Lake Demo Garden			View		
2	Blue Lake Disc Golf			View	No Image Uploaded	No Image Uploaded
3	Canemah 1			View	No Image Uploaded	No Image Uploaded
4	Canemah 2			View	No Image Uploaded	No Image Uploaded
5	Canemah 3			View		
6	Canemah 4			View	No Image Uploaded	No Image Uploaded
7	Commonwealth Lake			View		No Image Uploaded
8	Cooper Mountain			View		
9	Cooper Mountain (Parking Lot)			View	No Image	No Image

Figure 4.1. TRAFx Data Net ™

Source: DataNet™

4.3 TUALATIN HILLS PARK AND RECREATION DISTRICT

Tualatin Hills Park and Recreation District (THPRD) also uses TRAFx™ infrared counters on multi-use paved trails to count both bicycle and pedestrians. THPRD has approximately 18 count stations. Metro and THPRD share the same TRAFX™ DataNet™ site to store and display counts.


Blue Lake Garden

Canemah

Figure 4.2. Infrared Counters in Tualatin Source: DataNet™

4.4 ODOT

ODOT is collecting bicycle data on the I-205 multi-use path in Portland using inductive loops. The loops were installed for bicycle data collection sometime in the 1980's and the project was dropped a few years later. However, the loop counter was recently re-activated and started collecting data. A photo of this loop detector is shown in Figure 4.3.

Figure 4.3. I-205 Path Inductive Loops

ODOT also has access to bicycle inductive loop and pedestrian push button data that is recorded by 2070 controllers. The raw data is being logged in Region 1[7] but the data is not being analyzed for pedestrian and bicycle counting purposes. Additionally, ODOT recently installed an EcoCounter Multi™ counter for bicycles and pedestrians on the new Historic Columbia River Highway Trail near Cascade Locks, Oregon.

4.5 CENTRAL LANE MPO

Central Lane MPO collected short-term, 24 hour pneumatic tube counts in Eugene and Springfield, OR during the summer months. 48 count locations were chosen in the Eugene-Springfield area. Four tube counters by EcoCounter are rotated among the count locations over the summer and fall months. Central Lane MPO provides an interactive map with bicycle counts on their public website *(Roll 2013)*. This MPO has plans to expand substantially its automated data collection system.

4.6 JACKSON COUNTY ROADS AND PARKS

Jackson County is collecting bicycle and pedestrian counts at one location on the Bear Creek Greenway in Ashland. They also have two EcoCounter™ temporary counting units and will soon be purchasing two more units.

---

[7] From conversation with Tiffany Slauter, Region 1 Signal Manager

4.7 SUMMARY

As described in this section, at the state level there is limited automated data collection for bicycles and pedestrians. These data collection efforts, summarized in Table 4.1 are not coordinated at the state-wide level.

In total there are 116 known automated non-motorized data collection sites: 67 for bicycles, 15 for pedestrians, 49 for both bicycle and pedestrians combined. Two of these counters count bicycles and pedestrians separately. Most of the counts use pneumatic tubes and inductive loops for bicycles and infrared units for pedestrians. Most of the pedestrian counts are on multi-use paths or other recreational facilities. A majority of these counts are located in the Portland Metro Region and the Willamette valley region. Each agency has their own procedures for collecting the counts including locations, durations and equipment.

Next chapter discusses methodologies and issues related to the analysis of permanent count data and factors applied to short-term counts.

Table 4.1: Oregon bicycle and Pedestrian Permanent Count Locations

City	Owned by	Detector Type	Location	Dates Available	Number	Path or Road	AADB	Pattern
Portland, OR	Cycle Oregon	Eco Counter tubes	Hawthorne Bridge	August 2009 and after,	1	Hawthorne Bridge sidewalks	4,417 (2012)	Commute
Portland, OR	City of Portland	Tube counters	Temporary locations & a new permanent site on SW Moody Ave. cycle track	2005 and after	1	Path		
Portland, OR	City of Portland	Inductive loops, but they only cover one side of the trail on each side of the road crossing, so cyclists will be double counted or not counted at all	Springwater Trail at 82nd		1	Path		
Portland, OR	City of Portland	Inductive loops (quadropole) used for detection, and counting also	About 15 bike lane locations around the city (see PORTAL)	2011 and later, but mostly 2012	15	Bike lanes in roads around the city (one direction)		
Wilsonville, OR	Metro (MPO)	EcoCombo (infrared + Zelt inductive loops), bike and pedestrian differentiated	Tonquin Trail in Graham Oaks Nature Park	Incorrect loop installation. Reinstalled May 2013.	1	Path		Recreational
Portland Metro area, OR	Metro (MPO)	TRAFx™ counters - pedestrian only trails	Pedestrian trails in nature parks around the region Mostly permanent, but sometimes moved.		28	Paths		Recreational

5.0 FACTORING METHODS

The most common way to express motor vehicle traffic counts is to estimate the annual average daily traffic (AADT). This value represents the annual average 24 hour two-way count on a facility. Because it is impractical to count everywhere on a continuous basis, most counts are short duration. Since traffic has temporal and seasonal variation methods have been developed to estimate AADT from the short duration counts. This chapter provides a review of factoring methods and identifies existing approaches to factoring (i.e. the adjustments and statistical analysis that must be introduced in order to estimate AADT values from short duration counts). This chapter also identifies differences among bicycle, pedestrian, and motorized vehicles factoring and sampling approaches. Existing Oregon bicycle and pedestrian data are used to demonstrate how to develop factors and calculate bicycle and pedestrian AADT (annual average daily traffic) estimation. Recommendations to minimize AADT estimation errors end this chapter.

5.1 VARIABILITY OF NON-MOTORIZED TRAFFIC

Pedestrian and bicycle counts vary dramatically over time – in most cases significantly more than motorized vehicle counts. For example, **Error! Reference source not found.** compares data from a major commute freeway (Interstate 84 half mile east of Interstate 5) and the most important (by volume) commute bicycle facility in Oregon (Hawthorne Bridge with over a million and a half counted bicycles per year). The monthly volume variability is significantly higher for the bicycles, especially when warmer and colder months are compared.

Table 5.1: Percent AADT by Month and Vehicle Type

Month of Year	Bicycles, Hawthorne Bridge	Motor vehicles I-84
January	72%	96%
February	85%	99%
March	78%	100%
April	107%	102%
May	126%	102%
June	96%	103%
July	115%	103%
August	135%	101%
September	137%	100%
October	112%	101%
November	82%	96%
December	55%	96%

For motorized counts, employing both day of the week and monthly seasonal factors is usually sufficiently accurate to estimate AADT volumes using short-term counts. However, the estimation of bicycle or pedestrian AADT volumes from short-term counts is less accurate, because pedestrian and bicycle counts vary dramatically over time as shown in **Error! Reference source not found.**. Hence, more sophisticated methods or longer short-term count durations may be needed to accurately estimate non-motorized AADT from less than annual counting locations.

5.2 MOTOR VEHICLE FACTORING METHODS

For motor vehicles, there are well established factoring methods and practices. Section 3 of the Traffic Monitoring Guide (TMG) provides guidelines for data collection and monitoring of motor vehicle traffic *(FHWA 2013)*.

The TMG framework for counting and data collection consists of a set of permanent continuous counting sites and a complementary short duration count program, usually collected in durations of one day to one month. The primary interests for collecting motor vehicle data are to determine average annual daily traffic (AADT) volumes and to meet the data reporting demands of the Highway Performance Monitoring System (HPMS) which allocates federal funds *(FHWA 2013).*

The AADT is an estimate of the average daily traffic that occurs over the year over a section of a facility. Due to the temporal (seasonal, weekly, daily) variation in traffic demand, the 24-hour count of any one day will likely overestimate or underestimate the actual annual average, i.e. estimates have always an associated error. Thus, to reduce AADT estimation errors all short-term traffic counts are corrected by day of the week (DOW) and monthly adjustment factors. The permanent count sites are needed for establishing temporal trends and estimating adjustment factors for short duration counts. Accordingly, the TMG recommends developing factor groups for motor vehicles that include vehicle type, day of week, seasonal adjustment, axle correction, and growth factors from long term continuous sites in order to estimate traffic volumes from short-term counts at other locations.

5.2.1 Motor Vehicle Factoring Methods from Continuous Counts

There are two primary procedures for calculating AADT from permanent, 365 days - 24 hour counting stations, also referred to as automated traffic recorders (ATR); one is a simple sum of all daily volumes for one year divided by 365 days and the other is an average of averages *(FHWA 2013)*. The AADT calculation for averages of averages from continuous counts comes from the AASHTO Guidelines for Traffic Data Programs, prepared in 1992 *(AASHTO 1992)* One outcome of the method to calculate the average of averages is estimates for day of week (DOW) and monthly seasonal factors. The procedure for the AASHTO method of determining AADT using continuous counts are as follows:

1. Calculate the average for each DOW for each month to derive each monthly average DOW.

2. Average each monthly average DOW across all months to derive the annual average DOW.

3. The AADT is the mean of all of the annual average DOW.

The AASHTO formula for determining AADT is:

$$\boldsymbol{AADT = \frac{1}{7}\sum_{i=1}^{7}\left[\frac{1}{12}\sum_{j=1}^{12}\left(\frac{1}{n}\sum_{k=1}^{n} VOL_{ijk}\right)\right]} \qquad \textbf{(1)}$$

where:

VOL= daily traffic for day k, of day of the week *i*, and month *j*
i = day of the week
j = month of the year
k = index to identify the occurrence of a day of week *i* in month *j*
n = the number of occurrences of day *i* of the week during month *j*.

It is preferred to use at least one year of continuous data for determining AADT and corresponding factors. Multi-year data are better for to account for growth trend impacts. Estimates are then used to extrapolate estimated AADT values from short-term counts at similar or nearby locations *(AASHTO 1992)*. Multi-year data produce better factors to estimate AADT.

ODOT's Transportation Systems Monitoring Unit uses similar methods to AASHTO for determining AADT *(Crownover 2013)*. The procedure for the ODOT method of determining AADT using continuous counts are:

1. Calculate the average for each DOW for each month to derive each monthly average DOW

2. Average the monthly average DOW for each month to derive the annual average day of the month

3. The AADT is the mean of all of the annual average days of the month

The formula for the ODOT method of determining AADT is given as:

$$\boldsymbol{AADT = \frac{1}{12}\sum_{j=1}^{12}\left[\frac{1}{7}\sum_{i=1}^{7}\left(\frac{1}{n}\sum_{k=1}^{n} VOL_{ijk}\right)\right]} \qquad \textbf{(2)}$$

where:

VOL= daily traffic for day *k*, of day of the week *i*, and month *j*
i = day of the week
j = month of the year
k = index to identify the occurrence of the day of week *i* in month *j*
n = the number of occurrences of day *i* of the week during month *j*

Essentially, the AASHTO procedure of determining the AADT is to average the volumes for each DOW in each month, then average each DOW across all months. Lastly, take the average of the seven annual averages of the DOW. The ODOT procedure switches the last two steps of the AASHTO procedure by averaging all the average DOW for each month to develop an average day of the month and then average all twelve of the monthly averages to determine the AADT. The AADT using the AASHTO or ODOT procedure yields the same results.

5.2.2 AADT Estimation from Short Duration Counts

For short duration count locations, AADT must be estimated. Because the short duration count only captures the traffic in one particular season, month, week, day, or hour, this short-term count must be adjusted. To estimate AADT using short-term counts, axle counts are converted to AADT using the following equation from the TMG:

$$\boldsymbol{AADT_{est\,hi} = VOL_{hi} * M_h * D_h * A_i * G_h} \tag{3}$$

where:

$AADT_{est\ hi}$ = the estimated annual average daily travel at location i of factor group h
VOl_{hi} = the 24-hour axle volume at location i of factor group h
M_h = the applicable seasonal (monthly) factor for factor group h
D_h = the applicable day-of-week factor for factor group h (if needed)
A_i = the applicable axle-correction factor for location i (if needed)
G_h = the applicable growth factor for factor group h (if needed)

No specific method is given for determining seasonal, DOW, growth, or axle correction factors. However, the TMG does recommend the AASHTO method for determining monthly factors for motor vehicles *(FHWA 2013)*. The monthly factor for each long term ATR is the ratio of the AADT to MADT. Once it has been verified that the ATR station has been running reliably, then the AADT should be determined using AASHTO formula *(AASHTO 1992)*.

5.2.3 Quality Control for Using Motor Vehicle Counts

Quality control is also an important part of counting programs. When data records are missing or suspect due to machine malfunction or atypical traffic periods, the above procedures must be adapted or modified. There are different methods for validating permanent and short-term count data. Methods may vary depending on each unique situation and missing data. If long term, historical data exists, missing count data may be estimated using historical data. If other count sites are nearby or have similar patterns, this data can also be used to make adjustments and estimations. If directional data is collected and only one data collection device fails, then the data from the other direction can help determine estimates for missing data *(AASHTO 1992)*.

5.3 NON-MOTORIZED TRAFFIC FACTORING

One of the major differences between motor vehicle and non-motorized traffic is the influence of weather and seasons on travel behavior. While weather can influence motor vehicle traffic, non-motorized traffic is more sensitive to changes in weather. Bicyclists and pedestrians are more exposed to the weather elements than motor vehicle drivers. In inclement weather, bicyclists and pedestrians may decide to use another mode of transportation.

Many studies have found that weather conditions do have a significant impact on bicycling and pedestrian traffic volumes. In particular, studies evaluating weather effects in Oregon found that temperature and rainfall have significant effects on bicycle volumes *(Ahmed et al. 2011; Rose et al. 2011).* These studies found that weather conditions (temperature) have non-linear impacts on bicycling volumes. Furthermore, the sensitivity of people in Oregon (Portland) and Australia (Brisbane) to weather conditions is quite different. This finding strongly suggests that AADT adjustment factors must reflect local weather and population characteristics.

Weather effects are inherently incorporated into bicycle and pedestrian traffic volumes; when the weather is comfortable, bicycle and pedestrian volumes will tend to increase; if the weather is unpleasant, volumes will decrease. When evaluating the bicycle and pedestrian AADT and adjustment factors using the methods described in this chapter, seasonal variations in weather are most apparent when observing average monthly traffic. When analyzing bicycle and pedestrian volumes, there are two useful methods for incorporating the effects of weather on AADT estimations; one is to develop seasonal or monthly factors, the other is to explain unusual or outlying traffic counts by reviewing historical weather data.

5.3.1 Weather Factoring

In the City of Vancouver, Canada a recent study analyzed a number of variables that could potentially affect bicycle ridership and decrease error *(El Esawey et al. 2013)*. Among the variables tested were new approaches to factoring methods based on harmonic mean and monthly AADT, weekend versus weekday volumes, road class, and weather variables. The study found a strong correlation between total precipitation and bicycle volumes. Total snow and snow on the ground were also correlated with bicycle traffic volumes. It was found that precipitation adjustment factors improved bicycle AADT estimations and decreased error by three to eight percent.

When factoring for weather conditions it was recommended to simplify weather into general categories. It was found that creating adjustment factors from more than one weather variable can lead to an excessive number of variables and large data sets. This study simplified rain into wet and dry weather. “Wet weather” was rain over 5mm and “dry weather” was anything below 5mm. It is not clear what are the relevant or most appropriate weather categories or thresholds. This method does not discuss how to set categories or thresholds (e.g. rainfall below or above 5mm).

5.3.2 Seasonal Factoring

Monthly factors are often used to assess seasonal changes in bicycle and traffic volume over a course of the year. Depending on the climate, it might be advantageous to develop seasonal factors that more closely represent actual seasonal changes in order to develop more accurate AADT estimates. One method of factoring was developed in Vermont and addresses seasonal and day of the week adjustments *(Dowds and Sullivan 2011)*. Using one year of data, adjustment factors were developed for each day of the week in each seasonal aggregation period, either by month or season. By using cluster analysis to identify more accurate seasonal periods, unique cluster seasons were developed. This method takes into consideration weather variables such as temperature, rainfall and snowfall and clusters segments of the year into similar yearly weather patterns. In this Vermont example, 6 different seasonal cluster breaks were identified. See Table 5.2. Adjustment factors were then calculated for each DOW and each aggregation period. This produced 84 adjustment factors for monthly aggregation; a value for each day of the week for all 12 months. This was also applied to the adjustment factors for cluster aggregation, producing 42 adjustment factors; a value for each of the 7 days of the week for each of the 6 cluster seasons.

Table 5.2. Example of the Seasonal Adjustment Factors For Tuesdays *(Dowds and Sullivan 2011)*

			Monthly Aggregation		Cluster-Seasonal Aggregation		
Weeks of the Year	**Month**	**Cluster-Season**	**Adjustment Factor**	**Standard Deviation**	**Adjustment Factor**	**Standard Deviation**	**Difference in Adjustment Factors**
1 – 4	Jan	1	1.2	0.11	1.11	0.33	0.09
5 – 8	Feb		1.21	0.09			0.1
9 – 12	Mar		0.89	0.3			-0.22
13	Apr	2	0.89	0.3	1.01	0.34	-0.12
14-17	May		1	0.34			-0.01
18-21	Jun	3	0.83	0.1	0.86	0.12	-0.03
22	Jul	4	0.83	0.1	0.84	0.15	-0.01
23-26	Aug		0.78	0.11			-0.05
27-31	Sep		0.85	0.16			0.01
32-35	Oct		0.81	0.17			-0.02
36-39	Nov		0.78	0.07			-0.05
40-43	Dec	5	0.77	0.09	0.81	0.11	-0.04
44	Jan	6	0.77	0.09	99	0.13	-0.21
45-47	Feb		0.95	0.1			-0.03
48	Mar	1	0.95	0.1	1.11	0.33	-0.15
49-52	Apr		1.04	0.35			-0.07

An annual factor was developed from a ratio between the average pedestrian volume for each day of the week in aggregation period (DOW_p) and the Average Annual Daily Bicycle and Pedestrian Volume (AADT_{bp}), shown in Equations 10, 11 and 12. This method is somewhat cumbersome and it is not clear from this methodology how many clusters are necessary or optimal.

$$\mathbf{DOW}_{p} = \frac{1}{nD}\sum_{d=1}^{nD} C_{d} \qquad (10)$$

$$AADT_{bp} = \frac{1}{7}\sum_{i}^{7}\left[\frac{1}{nP}\sum_{p=1}^{nP}\mathbf{DOW}_{p}\right] \qquad (11)$$

$$AF_{psd} = \frac{AADT_{bp}}{\mathbf{DOW}_{p}} \qquad (12)$$

Where:

d=DOW
s=site
p=aggregation period
C_d = count for a given day of the week
nD=number of counts collected on that day of the week of that aggregation period (i.e. 4 Mondays in January)
nP= Number of aggregation periods
AF= Adjustment Factor

5.3.3 National Bicycle and Pedestrian Documentation Project

One of the most common counts performed for bicycle and pedestrian traffic monitoring are the short two-hour counts done in support of the National Bicycle and Pedestrian Documentation Project (NBPDP) *(Alta Planning and Design and ITE 2013)*. The NBPDP has developed a methodology for adjusting counts based on data submitted from across the country. Factors have been developed for counting bicyclists and/or pedestrians on multi-use paths and pedestrians in high density pedestrian and entertainment areas. In order to use these factors, counts should be conducted at least two times during the same time period and week (they recommend that weekday counts be done Tuesday through Thursday, excluding holidays, and weekend counts can be done on either day). The factors are for combined bicyclists and pedestrians; the numbers can be broken down by using a weighted average based on counts of bicyclists and pedestrians at each specific location. The steps for determining AADT using the NBPDP method are:

1. For each site (on a multi-use path or high density pedestrian area), conduct at least two, preferably three, counts during the same time period and week (i.e. 2PM-4PM on consecutive weekdays during the same week or in consecutive weeks).

2. Develop an average weekday or weekend count volume for bicyclists and/or pedestrians.

3. Choose any one hour period from either of those days.

4. Apply an adjustment factor by multiplying the one hour count value by 1.05 (the five percent inflation is to account for people who use the facility between 11PM and 6AM, about five percent of the daily total). This step can be skipped if there is certainty that the facility gets virtually no use between 11 pm and 6 am.

5. Factors broken down by hour, weekday/weekend, multi-use path /pedestrian area, and season, adjust hourly counts to average daily counts

$$\boldsymbol{Daily\ Volume} = \frac{\boldsymbol{Adjusted\ Weekday\ Hourly\ Count}}{\boldsymbol{Factor\ from}\ \textbf{Table 2}}$$

6. Calculate average weekly volumes. Using Table 2, adjust counts based on the day your count was taken. If multiple counts were done, take the average of those factors.

$$\boldsymbol{Average\ Weekly\ Volume} = \frac{\boldsymbol{Daily\ Users}}{\boldsymbol{Factor\ from}\ \textbf{Table 3}}$$

7. Convert to monthly volumes. Multiply the average weekly volume by the average number of weeks in a month (4.33)

$$\boldsymbol{Average\ Monthly\ Volume} = \boldsymbol{Average\ Weekly\ Volume} * \mathbf{4.33}$$

8. Convert to annual totals. Using Table 3, obtain a factor based on the month the counts were conducted and the general climate zone.

$$\boldsymbol{Annual\ Volume} = \frac{\boldsymbol{Average\ Monthly\ Volume}}{\boldsymbol{Factor\ from}\ \textbf{Table 4}}$$

9. Calculate average monthly and daily figures.

$$\boldsymbol{Average\ Monthly\ Volume} = \frac{\boldsymbol{Annual\ Volume}}{\mathbf{12}}$$

$$\boldsymbol{Average\ Daily\ Volume} = \frac{\boldsymbol{Annual\ Volume}}{\mathbf{365}}$$

Table 5.3. NBPDP Hourly Adjustment Factors

	APR-SEP				**OCT-MAR**			
	6am - 9pm				**6am - 9pm**			
	---- PATH------		----PED District----		---- PATH----		----PED District---	
	weekday	**weekend**	**weekday**	**weekend**	**weekday**	**weekend**	**weekday**	**weekend**
Hour			X					
6:00	2%	1%	1%	1%	2%	0%	1%	0%
7:00	4%	3%	2%	1%	4%	2%	2%	1%
8:00	7%	6%	4%	3%	6%	6%	3%	2%
9:00	9%	9%	5%	3%	7%	10%	5%	4%
10:00	9%	9%	6%	5%	9%	10%	6%	5%
11:00	9%	11%	7%	6%	9%	11%	8%	8%
12:00	8%	10%	9%	7%	9%	11%	9%	10%
13:00	7%	9%	9%	7%	9%	10%	10%	13%
14:00	7%	8%	8%	9%	9%	10%	9%	11%
15:00	7%	8%	8%	9%	8%	10%	8%	8%
16:00	7%	7%	7%	9%	8%	8%	7%	7%
17:00	7%	6%	7%	8%	7%	5%	6%	6%
18:00	7%	5%	7%	8%	6%	3%	7%	6%
19:00	5%	4%	7%	8%	4%	2%	7%	6%
20:00	4%	3%	7%	8%	2%	1%	6%	6%
21:00	2%	2%	6%	8%	2%	1%	5%	5%

Table 5.4. NBPDP Daily Adjustment Factors (Holidays use Weekend Rates)

Day of the Week	Adjustment Factor
SUN	18%
MON	14%
TUES	13%
WED	12%
THURS	12%
FRI	14%
SAT	18%

Table 5.5. NBPDP Monthly Adjustment Factors

CLIMATE REGION	Long Winter Short Summer	Moderate Climate	Very Hot Summer Mild Winter
JAN	3%	7%	10%
FEB	3%	7%	12%
MAR	7%	8%	10%
APR	11%	8%	9%
MAY	11%	8%	8%
JUN	12%	8%	8%
JUL	13%	12%	7%
AUG	14%	16%	7%
SEP	11%	8%	6%
OCT	6%	6%	7%
NOV	6%	6%	8%
DEC	3%	6%	8%

Although the NBPDP method for counting bicycle and pedestrian traffic is the most established and comprehensive data collection method in the United States, it relies heavily on short-term manual counts. Studies have also shown that the NBPDP bicycle and pedestrian AADT estimates can have substantial error and a high degree of variance *(Milligan et al. 2013; K. Nordback et al. 2013)*.

5.4 BICYCLE SPECIFIC FACTORING METHODS

There are distinctions between how road networks are used by motor vehicles and how they are used by bicyclists. If there is no provision for a bicycle lane, bicyclists will travel in the motor vehicle lane. However, if a road network is perceived to be dangerous, cyclists may use sidewalks or other non-motorized routes. This can create challenges for collecting accurate bicycle traffic data using existing technologies already implemented for counting motor vehicles. In addition, bicycle traffic volumes do not necessarily align with locations of high motor vehicle traffic. For example, a major arterial with high volumes of motor vehicles will likely have low bicycle volumes. Conversely, a residential street with low motor vehicle volumes may be used as a major bicycle route and have high bicycle traffic volumes. Additionally, separate or off-road facilities that are designated for non-motorized traffic and are often shared with pedestrians are popular with bicyclists.

Most research related to bicycle data collection distinguishes between three main categories and subcategories of bicycle facilities:

1. On-street/roadway
   a. Bicycle lane
   b. Cycle track
   c. Bicycle boulevard, neighborhood greenway
   d. Bicycle route
2. Shared path, separated
   a. Shared bicycle and pedestrian path
   b. Exclusive bicycle path
5. No on-road bicycle facilities

Each of these facility types has different advantages and disadvantages for collecting non-motorized data. Counting equipment type and placement can be determined based on these or similar categories of facilities *(FHWA 2013; Turner et al. 2012)*. Another dimension that impacts equipment placement is trip purpose. There are two main categories of bicycle trips which result in distinct temporal and spatial patterns:

1. 1. Commute
2. 2. Non-commute
   a. Utilitarian
   b. Recreational
3. Mixed patterns

These trip types are often used to establish factor groups. For example, a separated bicycle path in a scenic area will tend to be used for recreational purposes on weekends, holidays, and in good weather while an urban bicycle lane will tend to be used by commuters during weekdays. These assumptions are not always true and need to be observed by plotting average hourly volumes and average weekly volumes.

Figure 5.1**Error! Reference source not found.** and Figure 5.2 illustrate typical non-commute or recreational hourly and weekly travel patterns. Non-commute traffic tends to be distributed over the course of the day without a clear peak and weekend counts are higher than weekday counts

(FHWA 2013). Later in this section, Figure 5.7 and Figure 5.8 show a strong commuter patterns for the Hawthorne Bridge in Portland. Mixed patterns will have a mix of commuter and non-commute traffic volume patterns.

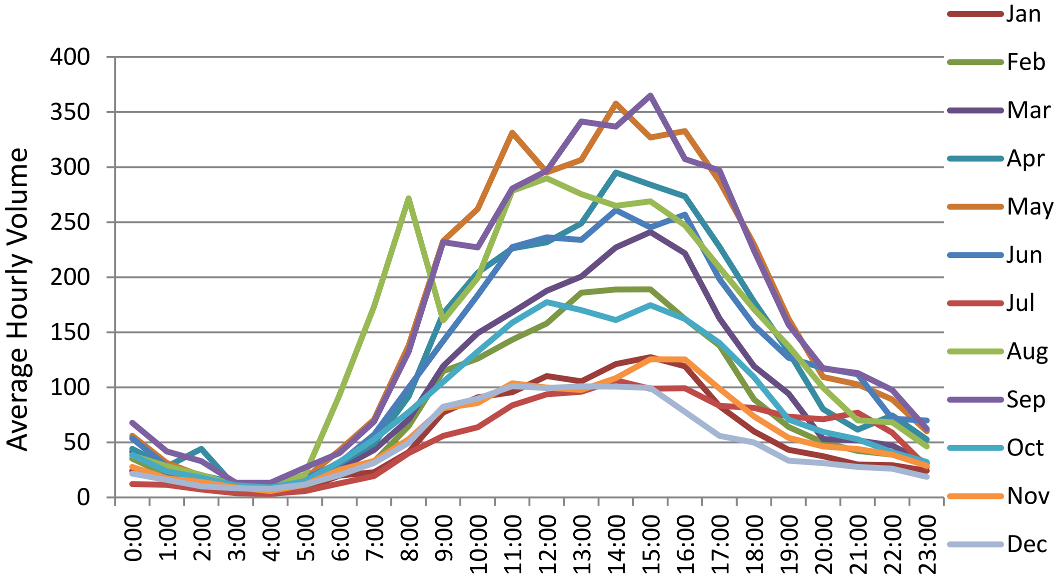


Figure 5.1: Typical Recreational Hourly Patterns

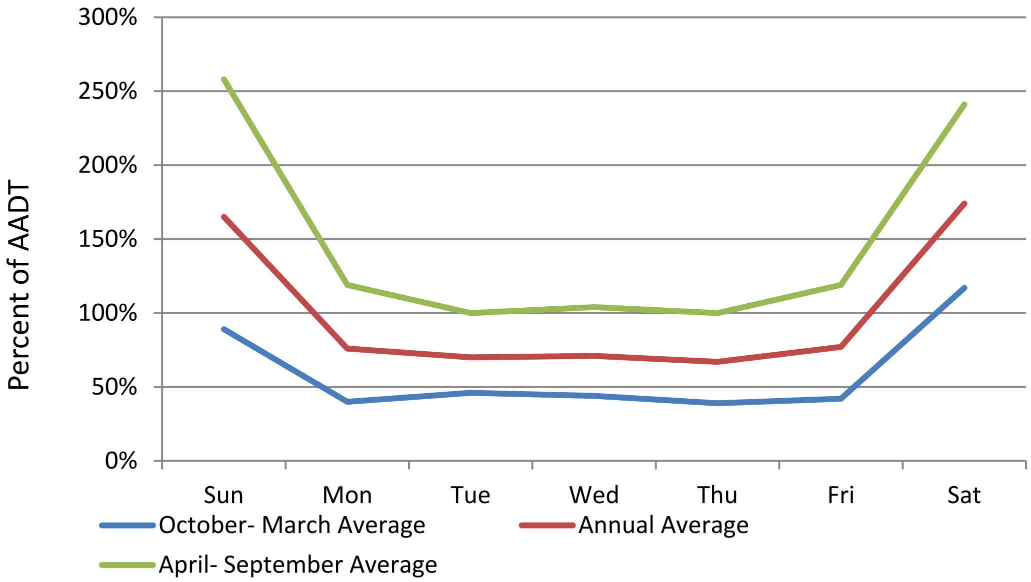


Figure 5.2. Typical Recreational Weekday Patterns

5.4.1 Colorado Department of Transportation Bicycle Data

Colorado Department of Transportation (CDOT) has been a leader in developing a state-wide data collection method for bicycle traffic. CDOT's Strategic Plan for Non- Motorized Traffic Monitoring, implemented in 2012, has established short-term factor groups for different bicycle trip purposes similar to the factor groups in the preceding section *(Turner et al. 2012)*:

1. Commuter and school based trips
2. Recreation/utilitarian
3. Mixed trip purposes

CDOT also determines bicycle trip purpose by analyzing each permanent counting station data separately. Three plots are generated for each counting station, similar to the plots shown in Figures 1, 2, 3, and 4:

1. Average time-of-day patterns by season and weekday/weekend
2. Average time-of-week patterns by season and all months combined
3. Average time-of-year patterns by weekday/weekend and all days combined

These plots are used to designate the bike facilities into their respective bicycle factor groups. The factor groups are used to group together sites that are similar. These groups of sites will then be used to together to develop AADT factors. No specific factoring equations were known to be established at CDOT the time of this literature review. However, research is currently being developed on appropriate factoring methods.

5.4.2 Central Lane Metropolitan Planning Organization

The Central Lane Metropolitan Planning Organization (CLMPO) began a Regional Bicycle Count Program (RBCP) in fall 2012. In preparation for their RBCP, bicycle data was collected near the University of Oregon in Eugene for a preliminary study. Counts were collected during summer months on both midweek days and weekends in 2012. The following is a study that uses the Eugene bicycle counts to compare NBPDP factors and locally derived factors.

Local Bicycle AADT factors were developed and compared to NBPDP factors as part of a Portland State University Master's Thesis *(Roll 2013)*. Using counts from automated pneumatic tube counters in Lane County, Oregon collected by CLMPO, Roll derived two sets, or scenarios, of time-of-day expansion factors based on different factor groupings. These were then compared to the NBPDP time-of-day expansion factors.

Scenario 1 uses 24 hour duration counts collected during summer months in 2012 from 20 locations in Eugene and four facility factor groups:

- Multi-use regional path
- Bicycle lane
- Bicycle boulevard
- No bicycle facilities

Time-of-day factors were developed for two peak periods; the AM peak factor for 7AM to 9AM and the PM peak factor for 4PM to 6PM. The data used was only collected on either a Tuesday or a Thursday. To develop a factor for a 2 hour count from the 24 hour counts, Roll applied the following procedure:

1. Calculate the average percentage of the traffic observed for each hour or factor period
2. Multiply the short-term count and the factor together to get approximate 24 hour total
3. The factoring calculation is:

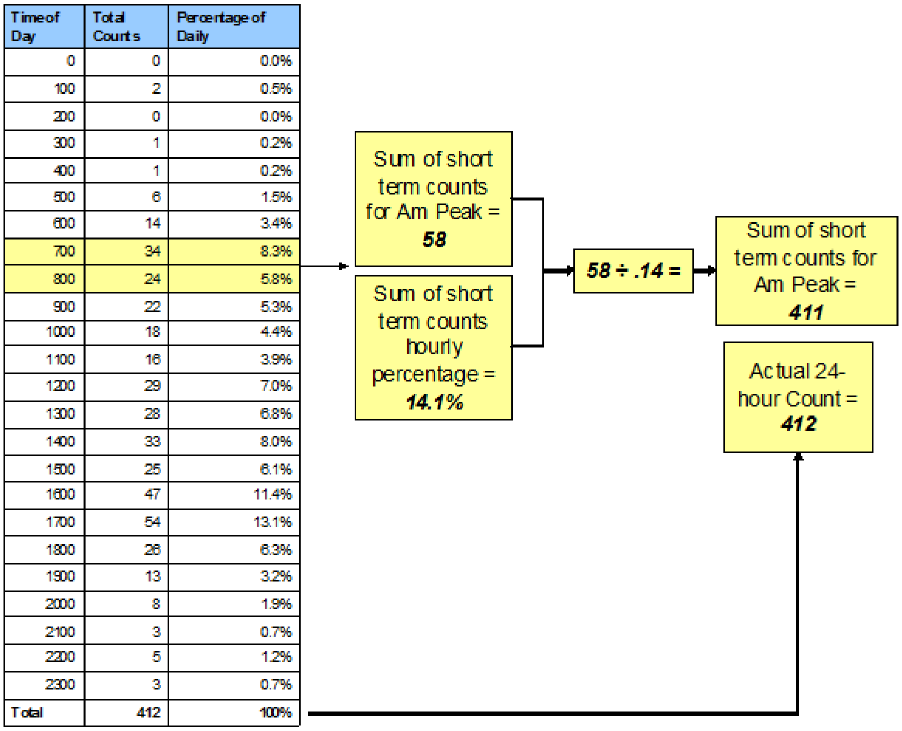
$$\boldsymbol{Daily\ Traffic = \sum sample\ /\ PeakPct} \tag{6}$$

where:

Sample = two hour counts

PeakPct = the assumed percentage of total daily volumes.

Figure 5.3 illustrates the process for estimating the daily volume using Scenario 1 two hour counts.



Time of Day	Total Counts	Percentage of Daily
0	0	0.0%
100	2	0.5%
200	0	0.0%
300	1	0.2%
400	1	0.2%
500	6	1.5%
600	14	3.4%
700	34	8.3%
800	24	5.8%
900	22	5.3%
1000	18	4.4%
1100	16	3.9%
1200	29	7.0%
1300	28	6.8%
1400	33	8.0%
1500	25	6.1%
1600	47	11.4%
1700	54	13.1%
1800	26	6.3%
1900	13	3.2%
2000	8	1.9%
2100	3	0.7%
2200	5	1.2%
2300	3	0.7%
Total	412	100%

Figure 5.3: Calculating 24 Count Estimation from Hourly Percentage *(Roll 2013)*

Next, the Eugene counts from the summer months were used to develop bicycle AADT using the NBPDP method, as described in Section 1.2.1. The factors were then tested using the counts collected during fall months of 2012. The actual AADT and the derived AADT from Scenario 1 and the NBPBP were then used to calculate the error for both methods.

The results from this study found that both the Scenario 1 method for determining daily volumes and the method derived by the NBPDP overestimated observed counts. Scenario 1 factors overestimate daily counts by 6 to 17 percent. NBPDP factors overestimated daily counts by 32 to 57 percent. For counts less than 100 bicyclists per day the error was even greater. The average absolute difference using Scenario 1 for locations with less than 100 bicyclists was 56 percent compared to 13 percent for locations with 100 daily bicyclists or greater.

Scenario 2 uses 123 daily counts in Eugene, including daily counts from the 32 locations tested in Scenario 1.   Scenario 2 also uses the same factors derived in Scenario 1 but adds another factor grouping by splitting the multi-use regional path factor group into:

1. Path-commute
2. Path- recreation

In addition, Scenario 2 uses a different factoring procedure; using R statistical software, an iterative process was developed to determine error associated with each possible peak period factor. Error was decreased using Scenario 2 but required more data and was more complicated to calculate and may not be a realistic method for agencies.

Roll suggests that when developing a bicycle counting program, using the NBPDP is a good starting point, but that it is also very limited. A better approach for agencies is to install a sufficient number of permanent counters and develop local factors for short-term data collection to minimize error.

5.5 PEDESTRIAN SPECIFIC FACTORING METHODS

Pedestrian traffic is challenging to monitor. Pedestrians are not confined to fixed travel patterns and therefore accurate volumes are difficult to collect *(FHWA 2013)*. Methodologies for counting pedestrians are also less developed. Pedestrian travel patterns are different than those of motor vehicles or bicycles. Like bicyclists, pedestrians are affected by weather but they are also more sensitive to spatial factors such as land use, road and transit networks *(Schneider et al. 2009; Miranda-Moreno and Lahti 2013)* Most of the research found regarding pedestrian activity is related to weather and land use patterns.

5.5.1 Estimating Pedestrian Intersection Volumes in Alameda County

This research developed factors for estimating intersection pedestrian volumes in Alameda County, which is part of the San Francisco Bay Metropolitan Region *(Schneider et al. 2009)*. Fifty intersections were chosen for the study based on differences in population density, median income, and proximity to commercial properties. See Table 5.6. Manual counts were collected from 9AM to 11AM, 12PM to 2PM and 3PM to 5PM on the midweek days of Tuesday, Wednesday and Thursday. Four automated infrared counters were rotated between 12 intersection locations on a monthly basis. A fifth counter remained in one place. This data was collected for 13 weeks. Using the collected counts:

1. Weekly pedestrian counts were sorted by hour of the week for each counter location
2. Counts for each hour were averaged to generate a weekly pedestrian volume at each location
3. The weekly pedestrian volumes from all the locations were then averaged to create a composite weekly pedestrian volume profile
4. The composite weekly pedestrian profile was used to extrapolate the two-hour pedestrian counts

This procedure is different from AASHTO and ODOT in that it produces factors for every week of the year. Error was not discussed in this study. However, this study developed factors based on land use and weather to decrease error in pedestrian estimates.

5.5.2 Expanding Short-Term Pedestrian Intersection Counts Using NBPDP and Local Count Methods

Another study from Winnipeg, Manitoba, Canada compared the NBPDP factoring method to local factors computed for motor vehicles as a way to estimate pedestrian intersection traffic *(Milligan et al. 2013)*. The research investigated three expansion methods:

1. The base case, which expands a short-term count without applying temporal information and makes the assumption that volumes do not fluctuate by time of day, DOW, or season.

2. The NBPDP method

3. Vehicle factors which used temporal factors from a local vehicle traffic pattern group based on continuous vehicle traffic monitoring on highways around Winnipeg.

Table 5.6. Pedestrian Land Use Factors for Alameda County, CA

Land Use Category	Definition	Manual Count Time when Land Use Adjustment is Applied	Example Land Use Adjustment Factor
Employment Center	>= 2000 jobs with 1/4 mi.	Weekdays 12-2 PM	0.795
Residential Area	<= 500 jobs with 1/4 mi.^{2}and no commercial properties within 1/10 mi.	Weekdays 12-2 PM	1.39
Neighborhood Commercial Area	>= 10 commercial retail properties within 1/10 mi.	Saturday 12-2 PM	0.722
Neighborhood Commercial Area	>= 10 commercial retell properties within 1/10 mi.	Saturday 3-5 PM	0.714
Near Multi-use Trail	>= 0.5 centerline miles of multi-use trails within 1/4 mi.	Weekdays3-5 PM	0.649
Near Multi-use Trail	>= 0.5 centerline miles of multi-use trails within 1/4 mi.	Weekdays 3-5 PM	0.767

Weekly and monthly pedestrian volumes estimated with motor vehicle factors had a greater error than NBPDP pedestrian volume estimations. However, when estimating the pedestrian AADT, the vehicle factors performed much better than the NBPDP factors. When comparing annual pedestrian crossing estimates to the base case, the average error was approximately 40 percent. For NBPDP, pedestrian estimated AADT error was 30 percent. Both the base case and NBPDP overestimated pedestrian traffic volumes. In contrast, local vehicle factors used for estimating pedestrian volumes underestimated with a 10 percent error. This study concludes that local motor vehicle factors may provide better pedestrian AADT estimates than using the NBPDP pedestrian factoring method.

5.6 MINIMIZING AADT ESTIMATION ERRORS

Higher AADT estimation accuracy without higher data collection costs can be obtained if data collection days are scheduled so that unfavorable data collection days are avoided. Sometimes this is not possible or feasible to schedule only on favorable days for all counting locations. Sometimes there is high variability due to seasonal, weather, or other factors. In these cases it is possible to employ more advance procedures to reduce AADT estimation errors without extending the duration of the counts.

Figliozzi et al. (2014) developed a methodology to reduce AADT estimation variability. This methodology takes advantage of the AASHTO DOW/monthly factors but also develops a correcting function that can be applied to any day of the year. The proposed methodology is suitable for any type of traffic with high volume variability and can be successfully applied to bicycle counts. Unlike previous work already cited in this report this method does not rely on the predefinition of weather categories, clusters, or thresholds. The methodology utilizes a correcting function that accounts for the characteristics of the day of the count (and previous days, if there are lagged variables) and includes not only weather variables (e.g. rain, temperature) but also activity or usage based variables (e.g. holiday or school day). The correction function was shown to significantly improve the accuracy of the AADT estimation *(Figliozzi et al. 2014)*.

5.7 SAMPLE DATA ANALYSIS

5.7.1 Factors Using Bicycle Data

This section exemplifies the calculation of AADT factors utilizing Oregon data. Pneumatic tube bicycle counters have been operated by the City of Portland on the Hawthorne Bridge for several years. There is one set of tubes on the south sidewalk and another on the north sidewalk and only count cyclists. The tubes are also able to detect the direction of travel. The system records bicycle counts in 15-minute increments. The public bicycle count display Totem is located on the west side of the bridge in downtown Portland. The Totem records counts from both paths on the bridge to give the total bicycle volume in near real time. It also displays the yearly accumulated bicycle volumes. The website will also prepare graphs and reports and data can be download in yearly, daily, hourly, and 15 minute increments which can easily be downloaded from the website in a comma seperated or Excel format for further analysis.

Figure 5.4. Vicinity map of Hawthorne Bridge from Eco Counter Website and Hawthorne Totem Counter

Daily and hourly Hawthorne Totem 2012 count data were used for AADT factor estimation and analysis. Note that approximately three weeks of data are missing between July 10 and August 5 because of equipment damage. Therefore, the daily averages in those months were calculated using only the available data; July averages are based on the 10 days worth of data that were availible and August averages were also based on the 25 days worth of available data. This bicycle volume data were converted into average annual daily and monthly factors. Plots of hourly and day of week volumes were created in order to graphically display patterns (showing a commute or non-commute pattern) as well as seasonal patterns.

AADT tables for the weekdays and weekends were also developed in order to compare the differences in the AADT calculations, as suggested in the AASHTO Guidelines for Traffic Data Programs *(AASHTO 1992)*.These values are displayed in

Table 5.7 and Table 5.8. The tables show clear differences in bicycle volumes in annual, weekday and weekends (weekends have a have a much lower AADT than the weekdays). The average annual bicycle traffic (AADT) is 4,440, the annual average weekday bicycle traffic (AAWDT) is 5,118 and the annual average weekend bicycle traffic (AAWEDT) is 2,744. The weekday average volumes are almost double weekend average volumes.

Table 5.7. Hawthorne Bridge 2012 Bicycle Weekday AADT Including Daily, DOW, and DOM Averages

Daily Averages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	DOW Average
Mon	3,341	4,435	4,070	5,955	5,623	4,863	6,270	6,561	6,253	5,770	4,378	2,870	5,032
Tue	4,124	4,505	3,946	5,512	6,568	4,212	6,395	6,853	7,653	6,180	5,121	2,741	5,317
Wed	3,978	4,415	4,206	4,754	6,612	5,445	4,549	7,007	7,489	6,203	4,882	3,342	5,240
Thu	4,290	4,888	3,844	4,676	5,843	4,810	5,866	6,688	7,451	6,763	4,286	3,423	5,236
Fri	3,915	4,084	4,137	4,839	5,981	4,558	5,431	6,025	6,683	4,812	3,778	2,912	4,763
Monthly Average	3,930	4,465	4,041	5,147	6,125	4,777	5,702	6,627	7,106	5,946	4,489	3,058	5,118 AAWDT

Table 5.8. Hawthorne Bridge 2012 Bicycle Weekend AADT Including Daily, DOW, and DOM Averages

Daily Averages	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	DOW Average
Sum	1,160	1,933	1,861	3,180	3,484	3,107	3,512	5,225	3,662	1,936	1,160	1,052	2,606
Sat	1,698	1,971	2,112	4,152	4,112	2,854	4,537	3,979	4,120	2,112	1,655	1,288	2,882
Monthly Average	1,429	1,952	1,986	3,666	3,798	2,981	4,024	4,602	3,891	2,024	1,407	1,170	2,744 AAWET

Figure 5.5 shows the average daily volumes per month in 2012 on the Hawthorne Bridge for both directions of travel. The lowest volumes were in December and the highest volumes were in August and September. There is an unexpected decrease in the volumes in June, which may be attributed to unfavorable weather conditions in June 2012. According to National Oceanic and Atmospheric Administration (NOAA) website, precipitation in Portland in June 2012 was above normal for the 4th consecutive month *(NOAA 2013)* as shown in Figure 5.6. June had 4.82 inches of rain, which is the 10th wettest June on record. Also, average high temperatures were 2.5 degrees below normal.

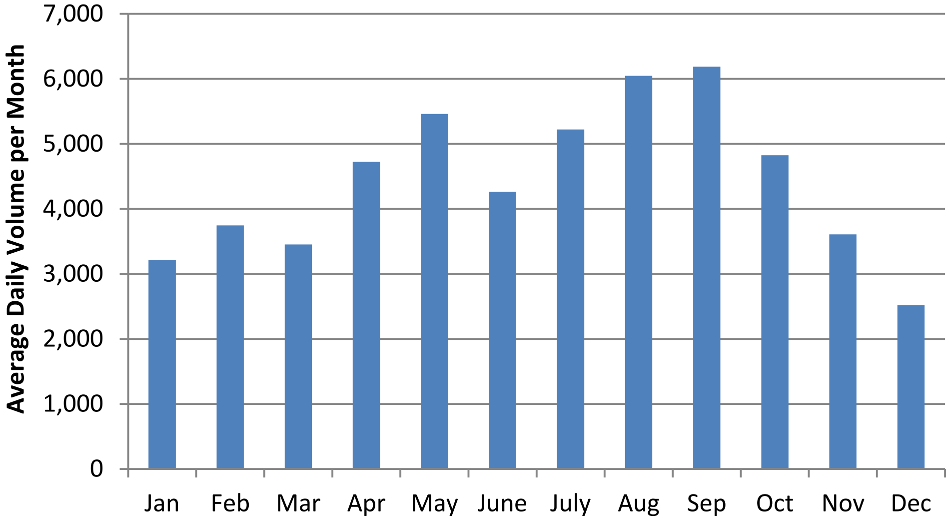


Figure 5.5. Hawthorne Bridge 2012, Average Daily Bicycle Volumes per Month

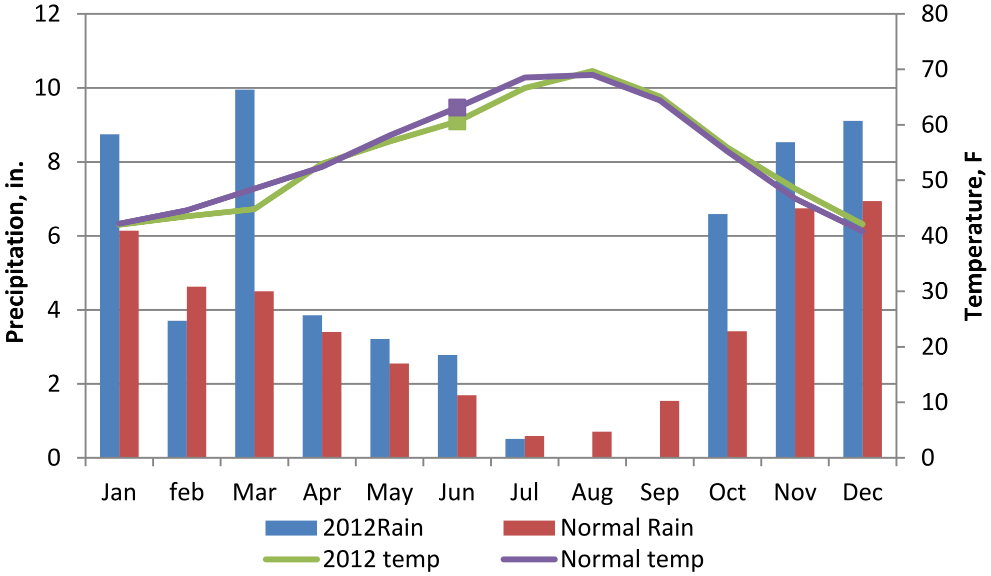


Figure 5.6. Portland Weather in 2012 versus Normal Portland Weather Conditions

Figure 5.7 illustrates the average hourly bicycle traffic per month on the Hawthorne Bridge which illustrates strong commuter bicycle traffic patterns with maximum daily volumes at 8AM to 9AM and 5PM to 6PM. Figure 5.8 also shows strong commuter patterns with higher volumes on weekdays, especially midweek, compared to weekends. Note that the average counts for Wednesdays through Saturdays in July are only based on one day of counts.

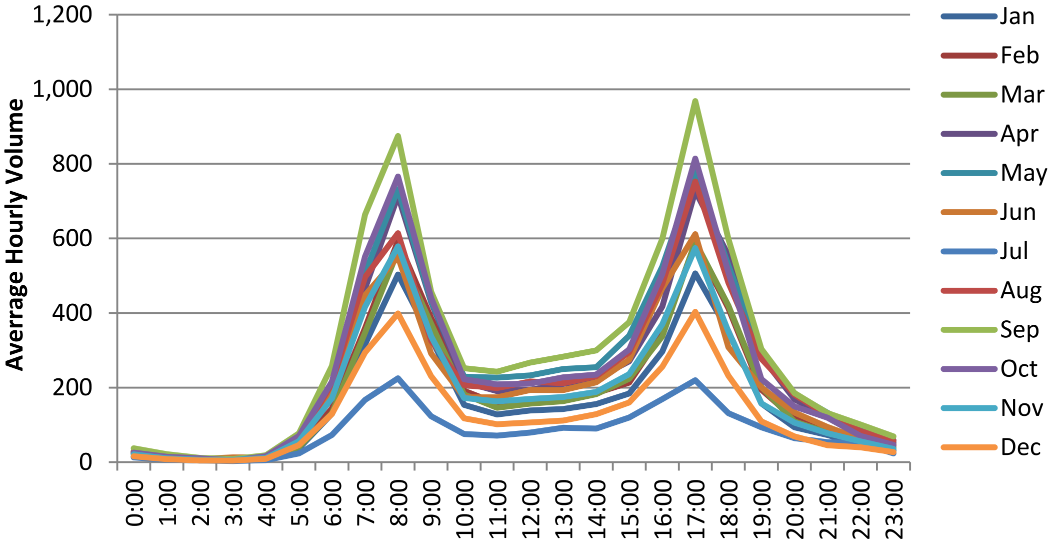


Figure 5.7. Hawthorne Bridge 2012, Average Hourly Bicycle Volume

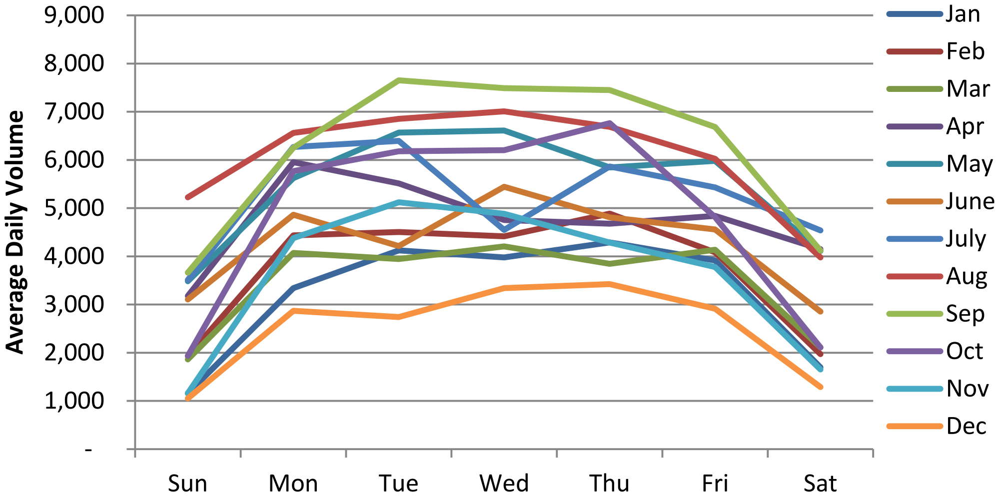


Figure 5.8. Hawthorne Bridge 2012, Average Daily Bicycle Volume

As described in the literature review, factors can be created by dividing the AADT by the average daily volumes for each day, week and month:

$$\boldsymbol{Daily\ Factors} = \frac{\boldsymbol{AADT}}{\boldsymbol{Average\, Volume\ for\ DOW_i\ for\ Month_j}}$$

$$\boldsymbol{DOW\ Factors} = \frac{\boldsymbol{AADT}}{\boldsymbol{Average\, Volume\ for\ DOW_i}}$$

$$\boldsymbol{Monthly\ Factors} = \frac{\boldsymbol{AADT}}{\boldsymbol{Average\, Volume\ for\ Month_j}}$$

Table 5.9. Hawthorne Bridge 2012 Bicycle AADT Factors

Daily Factors	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**DOW Factors**
Sun	3.8	2.3	2.4	1.4	1.3	1.4	1.3	0.8	1.2	2.3	3.8	4.2	1.7
Mon	1.3	1.0	1.1	0.7	0.8	0.9	0.7	0.7	0.7	0.8	1.0	1.5	0.9
Tue	1.1	1.0	1.1	0.8	0.7	1.1	0.7	0.6	0.6	0.7	0.9	1.6	0.8
Wed	1.1	1.0	1.1	0.9	0.7	0.8	1.0	0.6	0.6	0.7	0.9	1.3	0.8
Thu	1.0	0.9	1.2	0.9	0.8	0.9	0.8	0.7	0.6	0.7	1.0	1.3	0.8
Fri	1.1	1.1	1.1	0.9	0.7	1.0	0.8	0.7	0.7	0.9	1.2	1.5	0.9
Sat	2.6	2.3	2.1	1.1	1.1	1.6	1.0	1.1	1.1	2.1	2.7	3.4	1.5
Monthly Factors	1.4	1.2	1.3	0.9	0.8	1.0	0.9	0.7	0.7	0.9	1.2	1.8	1.0

5.7.2 Factors Using Pedestrian Data

This section exemplifies the calculation of AADT factors utilizing pedestrian data from the intersection of Highway 99W and SE Hall Boulevard in Tigard, Oregon; 99W or Pacific Highway is an ODOT facility with seven traffic lanes traveling southwest and northeast; SW Hall Boulevard has four vehicle lanes and travels north and south.

Figure 5.9: 99W and SW Hall Boulevard Intersection

The traffic signals at the intersection are operated by a 2070 controllers running the latest version of Voyage software. Voyage software is capable of logging a variety of intersection performance measures, including pedestrian push button actuations. Pedestrian phases are only served when it is actuated by pushing the button; therefore each actuation indicates the presence of at least one pedestrian. Push button actuation does not record the number of times the button has been pushed after the first actuation. However, pedestrians may push more than one button at each corner and the same pedestrian may cross more than one leg of the intersection. In addition, there may be more than one pedestrian at each crossing. However, even if pedestrian actuations do not record the actual number of pedestrians passing through an intersection the number of actuations can be a good proxy to measure the level of pedestrian activity when combined with video data collection (from the pilot study).

The data used in this example is the sum of all actuations at all corners. Pedestrian actuation counts were available from October 2010 through March 2013. Counts from 2012 were used for this evaluation. Herein we will refer to average annual daily (pedestrian) phases or AADP. Pedestrian AADP is 529 which is an average of 22 actuations per hour for all four corners. See Table 5.10. Table 5.11 and

Table 5.12 show weekday and weekend actuations. Weekend actuation AADP (476) is less than weekday AADP (550) which signals that there is more commute-related activity than recreational walking.

Table 5.10. 99W and SW Hall Boulevard 2012 Pedestrian Actuation AADP Including Daily, DOW, and DOM Averages

Daily Averages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DOW Average
Sun	417	507	483	349	398	665	448	731	442	366	318	319	453
Mon	582	704	656	461	454	710	506	852	480	475	435	428	562
Tue	528	701	527	427	458	768	480	686	517	460	450	360	530
Wed	637	754	536	423	460	754	467	709	475	458	451	472	549
Thu	700	775	480	408	458	653	502	668	503	454	427	430	538
Fri	634	675	650	461	479	667	520	847	512	471	447	471	569
Sat	558	581	582	448	431	581	435	708	449	414	391	398	498
Monthly Average	579	671	559	425	448	685	480	743	483	443	417	411	529 AADP

Table 5.11. 99W and SW Hall Boulevard 2012 Pedestrian Actuation AADP. Including Daily, DOW, and DOM Averages

DOW Averages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DOW Average
Mon	582	704	656	461	454	710	506	852	480	475	435	428	562
Tue	528	701	527	427	458	768	480	686	517	460	450	360	530
Wed	637	754	536	423	460	754	467	709	475	458	451	472	549
Thu	700	775	480	408	458	653	502	668	503	454	427	430	538
Fri	634	675	650	461	479	667	520	847	512	471	447	471	569
DOM Average	616	722	570	436	462	710	495	752	498	464	442	432	550 AAWDT

Table 5.12. 99W and SW Hall Boulevard 2012 Pedestrian Actuation AADP. Including Daily, DOW, and DOM Averages

Weekend Averages	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DOW Average
Sun	417	507	483	349	398	665	448	731	442	366	318	319	453
Sat	558	581	582	448	431	581	435	708	449	414	391	398	498
DOM Average	487	544	533	398	414	623	442	720	445	390	354	359	476 AAWEDT

Figure 5.10 illustrates the monthly pattern for pedestrians. Pedestrian actuations are higher in January, February, and March than expected and the month of August has the highest counts.

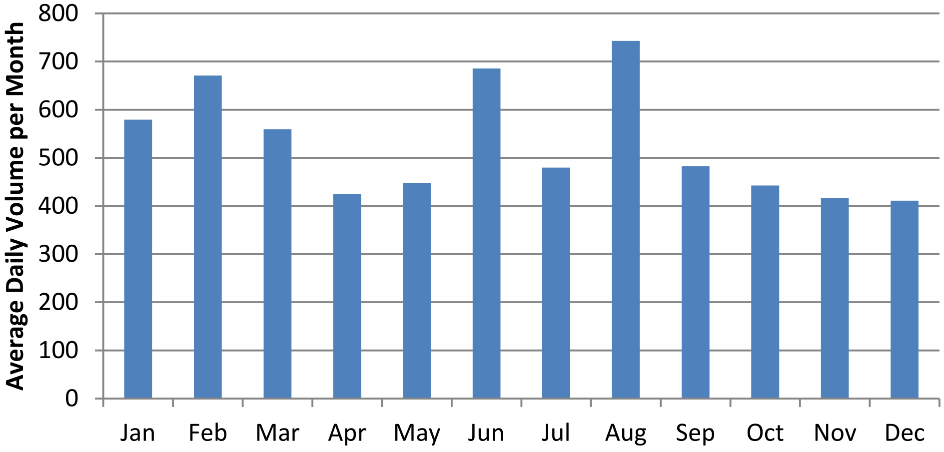


Figure 5.10. 99W and SW Hall Boulevard 2012 Average Daily Pedestrian Actuation Volumes per Month

Hourly average pedestrian actuations at this intersection are very consistent throughout the year See Figure 5.11 . Peak actuations are at noon and decrease gradually during the afternoon. There are no other peak hours. This pattern reflects recreational and/ or utilitarian use.

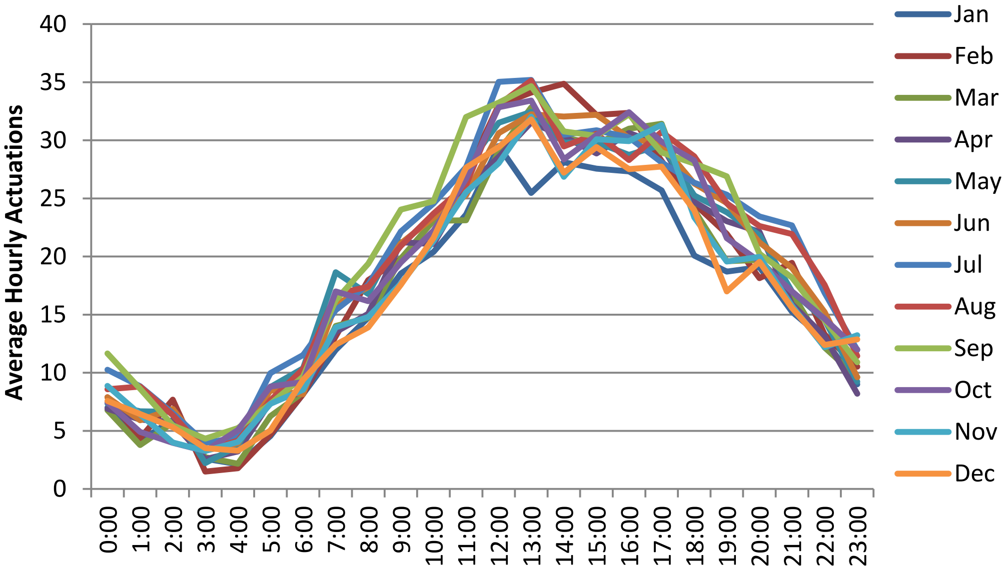


Figure 5.11. 99W and SW Hall Boulevard Average Hourly Pedestrian Actuation

Figure 5.12 displays the average DOW pedestrian actuations. This shows slightly higher volumes on Mondays and Fridays with slightly higher counts midweek as opposed to the weekend, which is also reflected in Table 5.11 and

Table 5.12.

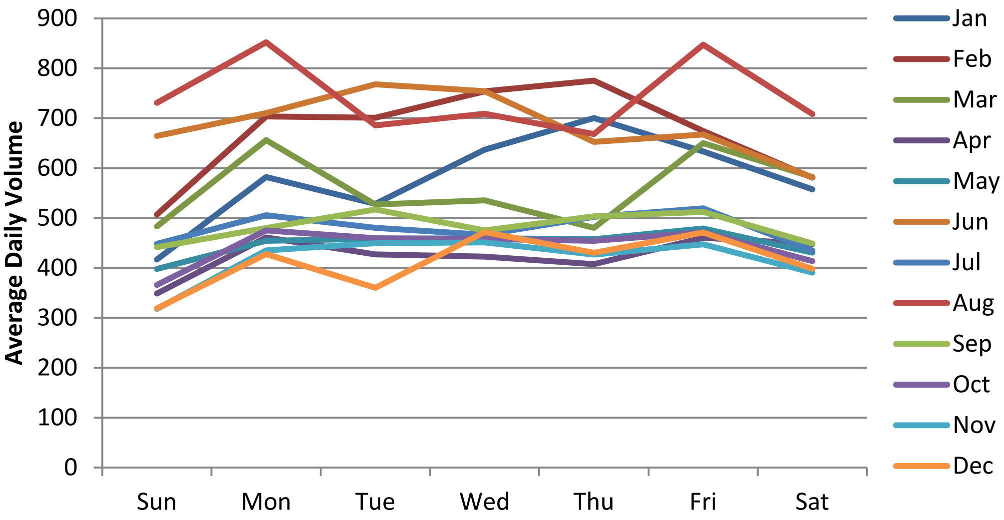


Figure 5.12. 99W and SW Hall Boulevard 2012 Average DOW Pedestrian Actuation

Pedestrian actuation factors have also been developed. See Table 5.13. The best days that represent AADP are Tuesdays, Wednesdays and Thursdays. The months that best represent actuation AADP are March, July and September as illustrated in Figure 5.12 and Table 5.13.

Table 5.13. 99W and Hall Boulevard 2012 Pedestrian Actuation AADP Factors

DOW Factors	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	DOW Factors
Sun	1.3	1.0	1.1	1.5	1.3	0.8	1.2	0.7	1.2	1.4	1.7	1.7	1.2
Mon	0.9	0.8	0.8	1.1	1.2	0.7	1.0	0.6	1.1	1.1	1.2	1.2	0.9
Tue	1.0	0.8	1.0	1.2	1.2	0.7	1.1	0.8	1.0	1.2	1.2	1.5	1.0
Wed	0.8	0.7	1.0	1.3	1.2	0.7	1.1	0.7	1.1	1.2	1.2	1.1	1.0
Thu	0.8	0.7	1.1	1.3	1.2	0.8	1.1	0.8	1.1	1.2	1.2	1.2	1.0
Fri	0.8	0.8	0.8	1.1	1.1	0.8	1.0	0.6	1.0	1.1	1.2	1.1	0.9
Sat	0.9	0.9	0.9	1.2	1.2	0.9	1.2	0.7	1.2	1.3	1.4	1.3	1.1
DOM Factors	0.9	0.8	0.9	1.2	1.2	0.8	1.1	0.7	1.1	1.2	1.3	1.3	1.0

Using continuous pedestrian actuation counts from the 2070 controller at SW Hall Boulevard and 99W, pedestrian volumes were evaluated for 2012. The pedestrian actuation AADP was 529. Weekday pedestrian actuation AADP was 550 and weekend was 476, which is an indication of commuter activity. In contrast, hourly and day of week plots show possible recreational/ utilitarian patterns. This path could be considered a recreation/ utilitarian factor group. Note that this data represents the number of times that the pedestrian signal was actuated, not the volume of pedestrians.

5.7.2.1 Converting AADP to AADT

To account for the fact that phase actuations are being counted, not actual pedestrians, an additional adjustment factor can be used. As calculated in the pilot study (see accompanying report), this adjustment factor is the ratio of the actual pedestrian volume to the number of pedestrian phases recorded by the 2070 controller. For the 24-hour study, the average ratio of pedestrians to actuations for all crosswalks was 1.24 (AADP must by multiplied by 1.24).

5.8 SUMMARY

The state of practice for estimating motorized vehicle volumes come from guidelines from the TMG and AASHTO. Motor vehicle data collection systems and procedures are well developed and robust. The most comprehensive bicycle and pedestrian data collection effort in the U.S. is the NBPDP and is based on annual short-term manual counts. The NBPDP methodology is expedient and does not require extensive data records, but because the NBPDP factors generalize data from all States and do not consider local factors the NBPDP bicycle and pedestrian AADT estimates may have gross errors.

A number of studies have developed bicycle and pedestrian AADT factoring methods similar to motor vehicle factoring. Studies comparing NBPDP to other AADT estimation methods found that NBPDP factors have higher error rates than the bicycle and pedestrian factors based on motor vehicle AADT methods. General recommendations for developing factors and AADT estimation methods for bicycles and pedestrians include:

- Use short-term factors that are at least one week in duration.
- Collect short-term counts during months that have the least variation in counts.
- Install at least five permanent counters per factor group.
- Weather and or seasonal factors must be developed in order to decrease errors in bicycle and pedestrian AADT estimations.
- Whenever possible apply advanced factoring methods that increase AADT estimation accuracy without increasing count durations or costs.

Next section presents a summary of recommendation for non-motorized data collection.

6.0 RECOMMENDATIONS

This chapter contains a summary of recommendations for developing a statewide bicycle and pedestrian data collection system for ODOT.

Before beginning a bicycle and pedestrian data collection system, it should be determined what metrics are desired, useful, and necessary. For motor vehicles, the Highway Performance Monitoring system (HPMS) requires vehicle counts along all road segments. These counts are mandated and used for developing AADT and vehicle miles traveled (VMT) metrics. In order to determine the AADT and VMT, the Traffic Monitoring Guide (TMG) provides a framework for motor vehicle data collection which consists of a set of permanent continuous counting sites and a complementary short duration count program, usually collected in durations of one day to one month, for all road segments. The short duration counts are extrapolated into AADT using factors that are developed from the continuous counts.

The motorized counting methods can also be mirrored for pedestrian and bicycle data collection though there are two important differences: a) non-motorized trips are typically shorter which results in potentially many more "road segments" to have the same level of accuracy and coverage obtained for motorized vehicles and b) non-motorized counting systems are incipient. ODOT at this time has no statewide system to count pedestrians or bicycles. Hence, the recommendations contained in this document tend to emphasize cost-effectiveness.

While this report provides recommendations with a statewide perspective, it should also be noted that the process of system design, sampling, site selection, and factoring should respect regional differences. These recommendations are based on the work completed in this research project including a literature review, a summary of data collection technologies, factoring methods utilizing Oregon data, a summary of known data collection efforts in Oregon, and a pilot study evaluating existing ODOT infrastructure/technologies for pedestrian and bicycle data collection.

6.1 STAFF RESOURCES

The implementation of a bicycle and pedestrian data collection system will require new staff or re-allocation of duties and resources. Resources are needed to develop and implement a counting system, validate the accuracy of the data collection equipment, and to collect and analyze the data. Training staff and contractors to correctly install and use new equipment will also be necessary to ensure quality data and evaluation. Time and cost estimates for the concrete implementation of a statewide bicycle and data collection system still need to be developed.

6.2 COORDINATION ACROSS JURISDICTIONS

It would be in the best interest of ODOT to develop relationships and coordinate data collection systems with other Oregon government agencies. As summarized earlier in this section, some local agencies have been collecting valuable bicycle and pedestrian volume data for over 10 years. Collaborating with other jurisdictions to simplify data collection methods and to share equipment, data collection protocols, and data will minimize overlap of counts and data and potentially save money and resources for all stakeholders. Guidelines for initiating statewide coordination of bicycle and pedestrian data collection need to be developed.

6.3 REGIONAL VARIATIONS

A major challenge will be how to design a comprehensive data collection system that takes into account regional differences across the state. Regional differences include factors such as climate, geography and population densities. These differences are important because predominant trip purpose, climate, geography and population density may all have major effects on bicycle and pedestrian traffic patterns and volumes. (Figure 6.1) Hence, each region may have different AADT factors. For example, in Region 1 a priority may include bicycle and pedestrian commuters in urban and suburban locations while Regions 4 and 5 may be more interested in data pertaining to bicycle touring on ODOT roads and pedestrian congestion at parks and wilderness areas, as well as traffic at tourist destinations.

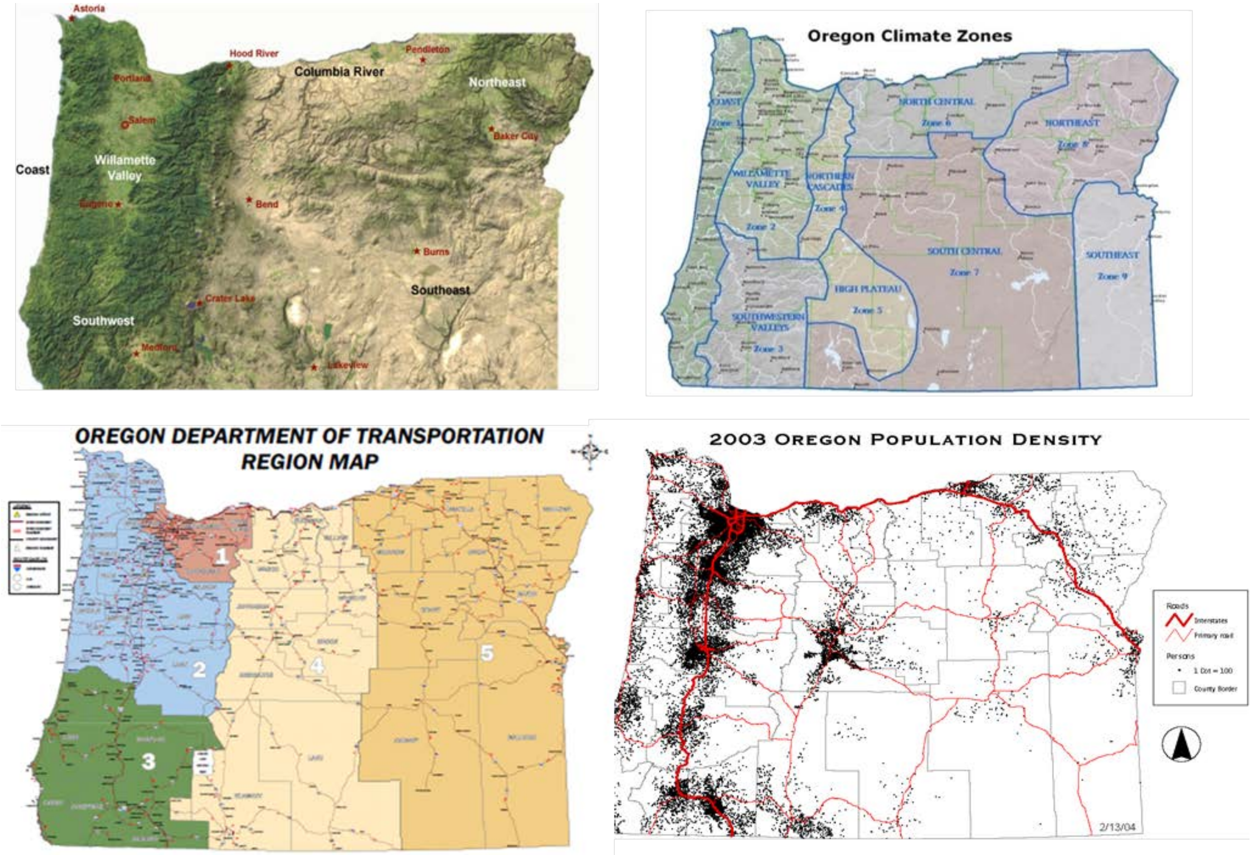


Figure 6.1. ODOT Regions with Topography, Climate, Population Density

6.4 SITE SELECTION

In order have an effective data collection system that best represents bicycle and pedestrian traffic, a method for determining locations for permanent, continuous counting and short-term counting sites needs to be developed. Budgetary constraints are key factors that will inform what is the feasible number of permanent counting sites at the state level or the rate of deployment (or phasing) of counting stations in the coming years. As described previously in this section, an overwhelming majority of non-motorized counters are currently located in the City of Portland or the Willamette Valley region.

As discussed in Chapter 2 of this report, most methods for data collection site selection use qualitative criteria based on local knowledge of bicycle and pedestrian activity. Chapter 4 of the TMG States "– Although it may be tempting to select the most heavily used locations for permanent monitoring, one should focus primarily on selecting those locations that are most representative of prevailing non-motorized traffic patterns (while still having moderate non-motorized traffic levels)." While this might be a sufficient guideline for the initial implementation of a non-motorized data collection system, this site selection method might produce biased estimates of overall bicycle ridership and neglect bicycle volumes at some locations *(FHWA 2013)*. San Diego County, CA has the most extensive regional bike counting network in the U.S. Their regional bicycle network consists of 40 corridors. The San Diego goal was to develop a bicycle and pedestrian counting network that represented a variety of volumes, land uses, and demographics; 170 recommended counting sites were proposed. A list of detailed criteria based on demographic and land use factors were used to prioritize bicycle and pedestrian counting sites in the network; out of the 170 recommended sites only 35 sites were chosen *(Ryan 2013)*.

6.5 ADJUSTMENT FACTORS

Adjustment factors are used to extrapolate short term counts into annual estimates (AADT factors) or to account for equipment biases or limitations. The determination of each type of adjustment factor requires a non-trivial amount of field data collection and posterior data analysis. Note that errors obtained by using adjustment factors can be high when there is not enough continuous count data available or there are periodic equipment failures from lack of calibration or maintenance.

Adjustment factors can be regional or site specific depending on the type of facility being modeled. This is a new line of research and there is still a very tenuous understanding of the best practices related to bicycle and pedestrian adjustment factors. However, it is clear that staff time for data collection, data analysis, and equipment calibration/maintenance grows with number of counting stations and the geographic scope of the counting program.

A number of factors may need to be developed that capture variations in travel. Types of adjustment factors are used to compute bicycle and pedestrian AADT include:

- Weather (discussed in section 5.3.1)
- Seasonal and Average Annual Daily Traffic variation (discussed in section 5.3.2)
- Location or equipment error (discussed in section 0)

6.6 LOCATION OR EQUIPMENT ERROR

Each counting location/equipment has its own unique potential for error. Equipment may be faulty. There may be limits on equipment installation locations at the site which may compromise ideal counting ability. For example, there may not be a fixed object with the appropriate height or angle for attaching data collection equipment. Motor vehicle traffic may compromise inductive loop or tube counts. Moving objects, such as trees moving in the wind, may compromise the accuracy of infrared equipment. Conducting manual or video evaluation at automated data collection sites is recommended at each site in order to determine counting error. These errors may be used to develop adjustment factors for equipment error.

6.7 DATA FORMAT

It is critical that data be reported in a consistent format so that it is easy to share, store, and analyze data. The TMG includes a recommended record format. It is also recommended to determine a method for dissemination of the data to other government agencies and to the public. As discussed in Chapter 2 it was common to have data in a comma delimited (.csv) or a spreadsheet format. In the near future it is likely that online mapping or portals will be developed to share or disseminate volume/count data. It will be more efficient to agree on one or a few formats for data storage. For example, a different method of data collection and storage is used the Hawthorne Bridge bicycle counts, for the I-205 path bicycle counts, and for the 2070 controller bike loop counts.

6.8 PERMANENT COUNTING EQUIPMENT

In order to make the best use of existing equipment and to develop the most extensive system of cost-effective counters, it is recommended that ODOT take advantage of their system of 2070 controllers (and future controller deployments/upgrades). Intersections properly equipped with 2070 controllers, the appropriate software, bicycle loop detectors, and pedestrian phase push buttons can be used for collecting continuous bicycle volumes and pedestrian phase actuations; bicycle detection can be done using loops, infrared or micro-radar devices.

Permanent counting equipment should be deployed at locations with significant traffic and where it is possible to develop factors that can be applied to other short-term counting stations in the region/area. The deployment of permanent counting stations can be carried out in phases; initially it is recommended to perform short-term validation and counting (if necessary with temporary data collection equipment) before deciding on the location of any permanent counting site.

6.8.1 Traffic Controllers

Intersections are suitable places to count pedestrians and bicycles in many urban, suburban, and rural locations. There are two main types of intersection signal controller units used by ODOT. The most common is the older Type 170 controller which has 44 inputs and is usually inadequate for adding bicycle and pedestrian data collection capabilities. The 170 controller using W4IKS™ firmware is capable of recording detections from 12 inputs; these 12 inputs are traditionally used for counting motor vehicles. On the other hand, 2070 controllers with Voyage™ firmware are capable of recording detections from 32 inputs (some of the additional inputs can be used for bicycle and pedestrian data collection).

Region 1 is in the process of replacing or updating many of its traffic controllers. All ODOT 2070 update locations should be considered and evaluated as potential permanent counting stations for bicycle and pedestrian data. It is also recommended that suitable counting locations with 2070 controllers operate the latest version of the Voyage software and provide automated logging and remote data retrieval capabilities. Specific recommendations for counting bicycles and pedestrians using 2070 controllers are provided in the following two subsections.

6.8.2 Bicycle Inductive Loops

The pilot study revealed that loop counting accuracy is greatly reduced when the loops are located near the path of motorized vehicles. Suggested methods for bicycle loop detection improvements include:

- **Improved placement of bicycle loops for counting and detecting bicycles.**

  The pilot study results indicate that bicycle counting loops should be located as far as possible from the path of motorized vehicles. In particular, special attention should be directed to place bicycle inductive loops on the bicycle travel path and away from the turning path of motorized vehicles (right or left turns or driveways).

- **New methods for testing bicycle inductive loops.**

  Currently, ODOT tests inductive loops for both motor vehicles and bicycles by checking the electrical current in the loops; the pilot study showed that actual bicycles may not be detected this way.

  It is recommended that a new bicycle loop test is developed to help technicians better adjust the sensitivity of bicycle loops. It is recommended that a standard “test bicycle” is developed to set the sensitivity of the bicycle counting loops.

- **Test additional inductive loop configurations.**

  The diamond shape loop configuration currently used for bicycles at ODOT (Figure 6.2) may be more sensitive at the corners of the diamond near the outer edges of the bike lane. If the location of the most sensitive area of the loop is close to the motor vehicle lanes, bicycles may not be detected and motor vehicles may be falsely detected. Other jurisdictions, such as the City of Portland, report better accuracy with other loop configurations. ODOT is in the process of testing other bicycle loop configurations.

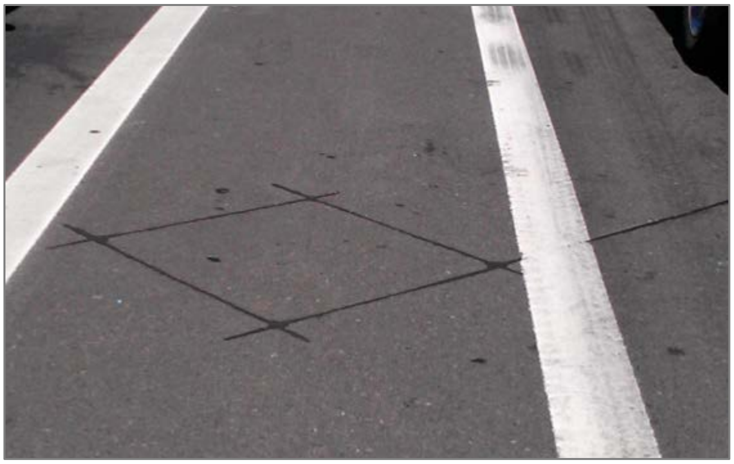


Figure 6.2: ODOT Diamond Bicycle Loop, 99W and Hall Boulevard, Tigard

- **Wire bicycle inductive loops separately.**

  At the intersection of 99W and Hall Boulevard, each Hall approach has two bicycle loops: one close to the stop bar and another approximately 50 feet behind the stop bar. These loops are binned together (one common input into the controller for two loops) which produces a data file that reduces bicycle count accuracy. Wiring the loops separately is necessary to improve count accuracy and detect defective loops easily.

- **Evaluate the behavior of cyclists at each location.**

  In the pilot study it was observed that almost half of the bicycles rode on the sidewalk. It is recommended that to estimate correction factors for sidewalk usage, 24 hours of video footage should be analyzed.

- **Loop counting should be validated individually using a valid sample size**

  It is recommended that for validation and to estimate correction factors, at least 30 cyclists should be observed per loop (if bicycle volumes are low, it may be more cost-effective to have staff ride over the loops with a standard test bicycle); more than 30 observations are recommended for permanent sites. The counts logged in the 2070 controller should be compared to number of bicycles ridden over the loop in the same time interval. Accuracy adjustment factors can then be computed.

6.8.3 Pedestrian Phase Actuations

Pedestrian traffic volumes are the most challenging traffic data to collect. Although actual pedestrian volumes are not recorded by 2070 controllers, it is recommended that ODOT utilize pedestrian phase counts from 2070 controllers to estimate pedestrian volumes. Compared to other data collection technology, the 2070 controllers that log phase data require no additional equipment expenditures besides pedestrian push buttons and 2070 traffic controllers with voyage software to log granted pedestrian phases. Phase actuation counting cannot be used when pedestrian phases are on recall which is common in high-pedestrian use areas.

Pedestrian phase activity does provide useful metrics such as how often and at what times of the day pedestrians utilize ODOT crosswalks. With the data collected for the pilot study, it was shown that it is possible to utilize phase data and pedestrian group adjustment factors to estimate pedestrian AADT. This method of pedestrian AADT estimation is promising; however, this method should be validated in more intersections and different settings (land use, regions, etc.).

Combined with other ODOT information, such as crash data, bicycle and pedestrian facility inventory, pedestrian phase actuations can better inform ODOT on safety issues involving pedestrians, locations for pedestrian facility improvements, or warrant changes in traffic signal settings.

6.8.4 Existing Pneumatic Tube Counters

During the pilot study pneumatic tube counters, TimeMark™ Gammas, used by ODOT for motorized counts were tested for bicycle counting purposes. At the pilot study site the pneumatic tube counters were installed by experienced ODOT technicians following vendor recommendation; different tube layouts were tested. Only 7.5 percent of the bicycles were detected. Unless further research and/or experiments show that there are alternatives to improve their accuracy it is recommended that ODOT does not use existing pneumatic tube counters that are intended for motor vehicles to collect bicycle traffic volumes. Instead, pneumatic tube counters specifically designed for continuous bicycle data collection are recommended.

6.8.5 Other Methods for Bicycle and Pedestrian Data Collection

At locations without a signalized intersection (e.g. a midblock locations or multi-use trails) other equipment may need to be purchased and installed. For bicycles, infrared detection devices, pneumatic tubes and inductive loops can be used. For pedestrians, infrared pedestrian counters are recommended. For collecting both bicycle and pedestrians, technologies are available that distinguish bicycles from pedestrians by counting all cyclists and pedestrians with infrared equipment and simultaneously collecting bicycle pneumatic tube or inductive loop counts. Given the cost of this type of equipment/setup these locations should be carefully planned and evaluated.

6.8.6 Mid-block, Paths or Trail Locations

For multiuse paths or trails in the jurisdiction of ODOT, it is recommended to use counting technologies that use a combination of infrared, pneumatic tubes or inductive loops to count trail traffic. One of these counters has recently been installed on the newly restored portion of the Historic Columbia River Highway Trail and it is recommended that the accuracy of the deployed equipment is carefully analyzed in future research efforts. On gravel or unpaved trails, other types of counters may be more appropriate, such as a pressure pad. Refer to Section 3 of this report or the Traffic Monitoring Guide for other options.

6.9 TEMPORARY COUNTING EQUIPMENT

To develop a cost-effective pedestrian and bicycle data collection system it will be necessary to acquire a set of bicycle and pedestrian counters intended for short-term counts. Possible equipment choices are described in Section 3.0 of this report and additional guidance is part of the forthcoming NCHRP 7-19 project report.

Some issues to consider when deciding on the number and type of counters to purchase include:

- How many sets of equipment for collecting short-term bicycle and pedestrian counts simultaneously are necessary? The number of sets will be a function of the number of permanent counting stations, the level of accuracy, and the coverage desired. A higher number of permanent counting stations tend to reduce the frequency or total number of short-term counts.

- Initially, each potential bicycle and pedestrian data collection site should record one to two weeks' worth of continuous data. After traffic patterns have been studied and classified (e.g. commuter, mixed, etc.) it may be possible to reduce the duration of short-term counts to a day.

- Depending on equipment and site, most locations will need more than one counter per site. A typical midblock on-street location would require up to two bicycle tube counters and up to two infrared counters for pedestrians. Paths will only require one bicycle and pedestrian counter or two if directional factors are important.

For example, if 30 sites are chosen for initial site sampling, then at 2 weeks per site, that would equal 60 weeks' worth of data collection. If the available counting time is three months (best summer months), or about 14 weeks, then it is necessary to simultaneously count at 5 sites.

$$\boldsymbol{60\ weeks/14\ weeks = 4.28\ count\ sites\ \approx\ 5\ sites*}$$

* It is always better to round up since this is a very rough approximation; it is necessary to provide additional time for transporting/setting up equipment and additional time for staff contingences or scheduling constraints.

When using pneumatic tube counters for bicycles, one counter may be needed for each side of the road:

$$\boldsymbol{5\ count\ sites * 2\ bike\ lanes = 10\ pnumatic\ tube\ counters}$$

To decrease the cost of deploying these counters, ODOT could consider partnering with local agencies though this may result in higher coordination costs and lack of control; the tradeoffs should be carefully evaluated.

For most traffic counting technology, vehicle (or pedestrian) counts are collected either individually with the exact time that the vehicle crosses the equipment or the counts are aggregated by the counter in time intervals such as 15 minutes or hourly. For data collection and equipment validation it is recommended that counts are individual (at the minute or second level) or that time intervals do not exceed 15 minutes.

It is recommended that ODOT requires equipment data output formats that are compatible with the current or future traffic data format used to warehouse pedestrian, bicycle, or motorized traffic data. If the data obtained from the 2070s or any other equipment is not compatible, routines or data conversion scripts must be developed to post-process the data and produce a compatible format.

6.10 DEVELOPING A CONTINUOUS COUNTING SYSTEM

A traffic counting system consists of a set of permanent continuous counting sites and a complementary set of short duration count program that produces short-term counts. Short-term counts are extrapolated into average annual daily traffic (AADT) using factors that are developed utilizing data from the continuous counting sites. This section recommends some steps necessary to develop a cost-effective system of continuous counting sites.

Local agencies that currently collect continuous data for bicycles and pedestrians use qualitative site selection criteria and choose sites based on local knowledge regarding sites with high bicycle and pedestrian volumes within their jurisdictions. Examples include counting in areas with known high traffic volumes like the Hawthorne Bridge in Portland or on multi-use paths in Minneapolis.

Existing permanent counting locations may not be sufficient for ODOT non-motorized counting purposes. When choosing permanent counting sites for a region it is important to consider macro factors such as climate, geography, population, as well as a mix of rural and urban locations. The actual location of the site will also depend on local knowledge within a region regarding locations with high traffic or locations that require counts for specific projects (e.g. safety improvements).

The following subsection proposes steps to develop a balanced system of continuous counting locations. Although the following steps are applied for both bicycle and pedestrian data collection systems, bicycle and pedestrian traffic patterns can be greatly different at a specific site or region. Hence, the actual data collection sites may not always coincide or overlap (which may increase data collection costs for non-motorized traffic).

6.10.1 Recommendations for Selecting Permanent Count Sites

It is recommended that developing and operating an appropriate set of permanent counters is an iterative process as described below.

1. Sample a set of potential permanent count sites. Ideally, there should be enough sites to cover variations in land use, weather, geography, and trip purpose patterns across the state.

    a. The final number of sites to be evaluated will be determined by desired accuracy and coverage considerations. It is recommended that ideally no less than 30 sites are selected for initial evaluation.

    b. At least one to two weeks of data should be collected (ideally a month of data at each site)

c. Data collection costs may be reduced if suitable intersections with 2070 controllers are available or if existing data collection sites are included (e.g. from other jurisdictions/agencies)

2. Collect traffic counts and construct average hourly and average daily graphs (if at least two weeks of data are collected).

3. Group sites with similar patterns, these sites will be used to produce AADT factors for that type of traffic pattern. Some locations will not have a traffic pattern that will fit into a group but many will.

   Are there enough sites to cover variations in land use, weather, geography, and trip purpose patterns across the state?

   a. If the answer to the previous question is YES, continue with step 4)

   b. If the answer to the previous question is NO, go back to 1 and select additional potential sites.

6. Determine the number of feasible permanent sites.

7. Utilizing the results of steps 3) and 4) allocate the number of sites determined in step 4 taking into account that:

   - To develop more accurate AADT estimations utilizing short-term counts it is recommended that there are several permanent counting sites for each traffic pattern.

   - More permanent sites increase accuracy but also costs; further research specific to Oregon is needed to evaluate the number of permanent counting stations needed. As a reference the literature indicate that for each factor group, three to seven permanent count sites should be chosen *(Nordback et al. 2013)*.

   - It may desirable to have a distribution of permanent sites that cover different regions and weather/traffic patterns.

     It may be necessary to:

     a. Establish a set of priorities or clear criteria to prioritize locations

     b. Stage the deployment of permanent counting sites based on the priorities established

8. Install permanent counters in the selected locations.

   Continue conducting short-term counts until permanent sites can be established

9. Review and revise the plan to deploy new permanent counting stations annually or as often as necessary when new planning needs/goals arise.

It is very likely that ODOT will not have enough resources to start with the recommended number of permanent data collection sites for either bicycle or pedestrian modes. The development of criteria to guide the allocation of resources among modes or regions may be a challenging process that includes considerations that are not just technical. Guidelines to select the initial set of potential sites are described in the following subsection.

6.10.2 Initial Steps

The following steps are recommended to select the first set of potential permanent counting locations.

1. Inventory existing count locations

The first task in developing a permanent counting system is to inventory existing count sites. This inventory should include sites operated by ODOT as well as local governments, agencies, MPO's, or business districts *(FHWA 2013)*.

An inventory of counting sites should include:

- Count location, preferably the coordinates or intersection
- Whether bicycles and/or pedestrians are being counted
- Whether they are continuous or short-term count sites
- The technology used for collecting data
- How long the counter has been in operation or when was it in operation
- If the data collection equipment has been verified for accuracy and what accuracy adjustment factor, if any, has been computed
- Road and/or bicycle and pedestrian facility class
- Into what local jurisdictions it falls
- Land use information, including if the site is urban, suburban or rural
- Map or ideally combine the existing locations into a GIS file

As shown in Chapter 4, the existing sites are mostly located in urban areas in the Willamette Valley. These sites should be complemented by new sites. Guidelines to create a list of potential new sites are described in the following subsection.

2. Develop a list of new potential permanent counting sites

Once information on existing count sites is organized and mapped, develop a list of new potential counting sites. From the list of potential sample sites, locations can be chosen and scheduled for initial site sampling. The following information will be helpful to develop a list of potential new permanent counting sites.

- Data gaps in significant bicycle/pedestrian corridors or geographic areas (GIS maps are recommended)
- Inventory of 2070 controllers and future 2070 controller upgrades
    - Existing bicycle loop detectors and pedestrian phase actuation information
    - Existing infrastructure for installing equipment (access to electricity, data collection/processing technology, remote login and data transmission)
    - Land use along ODOT facilities, including if the site is urban, suburban or rural
- Other potential data sources that would improve site selection, such as crash data on bicycles and pedestrians, sidewalk infrastructure, school locations, local demographic information that may reveal a propensity for higher bicycle and pedestrian activity
- High volume trail networks and tourist/scenic routes
- Non-ODOT high volume facilities that cross ODOT facilities, unique local conditions not represented by other permanent count sites.
- Distribution of sites to represent each region and weather patterns, land uses and population densities as well as an adequate mix of urban, suburban, and rural locations.

Using the above criteria, choose new sites for evaluation.

3. Sample potential counting sites

Schedule counts using the list of sampling sites; the duration of time to sample these sites will be dependent on the amount of equipment available and desired accuracy. Sites with less than 100 non-motorized users per day in the peak season may not be appropriate for permanent count stations, especially if other sites with higher volumes are available.

4. Collect Preliminary Data

Once the counting equipment is installed and verified following appropriate QA/QC procedures, then the data collection can begin. A two week count period will garner the data necessary to discover daily and weekly travel patterns at each site; high traffic variations may take place during one week due to weather factors for example. The two-week data is necessary to determine if traffic patterns are predominantly commuter, recreational, or mixed. A study from Sweden also recommends two-week counts *(Niska et al. 2012)*.

5. Group sites

Once the initial two-week data is collected, it is possible to group sites with similar patterns. To detect patterns it is recommended to utilize hourly and daily graphs per direction of traffic or counting device. It is possible to classify patterns into these categories:

1. Commute
2. Recreational
3. Mixed
4. Other

Figure 5.1and Figure 5.2 in Chapter 3 illustrate typical non-commute hourly and weekly travel patterns. Recreational traffic tends to be distributed over the course of the day and with weekend counts that are higher than weekday counts. This pattern is also called “non-commute” in some publications. In typical commuter patterns the average hourly volumes tend to peak during morning commute times between 6AM and 9AM and again during evening peak hours at about 4PM to 6PM. Commuter traffic volumes are lower on weekends; higher volumes take place during the midweek. Mixed patterns are a mix of commute or non-commute patterns. These may be the most common patterns for bicycle and pedestrian traffic. There may be also unique travel patterns associated to a specific location or land use that cannot be put into a typical group and should not be added to a factor group. An example of this traffic could be a counting station near (or at) a sport facility where the traffic pattern heavily depends on the home team schedule.

6.11 DEVELOPING A SHORT-TERM COUNTING SYSTEM

Site selection is the process of choosing a specified number of traffic data collection sites that can best represent the overall traffic patterns in a chosen area.

For motor vehicles on ODOT facilities, data collection sites comply with the HPMS, which require volume estimates on all road segments. As discussed previously, the TMG provides a framework for motor vehicle data collection which consists of a set of permanent continuous counting sites and a complementary short duration count program, usually collected in durations of one day to one month, for all road segments. The short duration counts are extrapolated into AADT using factors that are developed from the continuous counts. The system of data collection sites for motor vehicles is fully developed whereas there is no system of permanent and short-term counters for bicycles and pedestrians. Additionally, there is no established method to determine an appropriate system of bicycle and pedestrian data collection sites. The following are recommendations to start a short-term counting program.

6.11.1 Select count locations for short-term sampling

Once permanent counting sites have been established, develop a list of short-term sampling sites. Bicycles and pedestrians may not have the same list of short-term count sites, although it is more economical to combine as many sites as possible.

The purpose of developing a short-term counting network for bicycles and pedestrians is to increase the reach of counts and construct a more extensive overview of bicycle and pedestrian traffic patterns and changes. Local jurisdiction counting efforts may not produce enough data in locations where pedestrians and cyclists are using or crossing ODOT facilities. A data collection system for ODOT will be unique compared to other data collection efforts in the state. Temporary count sites can be located at intersections but counts may more easily be conducted on road segments or on off-street path locations depending on the counting technology used. This list of sites should be relatively large in relation to the number of permanent counting sites.

6.11.2 Schedule counts

Once a list of count sites is assembled, design a schedule of short-term counts. The best months for collecting bicycle counts are April to October. Prepare a schedule of counts based on:

- Selected count durations
- Months in a year established to administer short-term counts
- Counting equipment that is available for collecting short-term counts
- Account for extra time to move equipment and counting crews. Allow for unexpected delays and/or equipment failures.

Higher AADT accuracy without higher counting costs can be obtained if data collection days are scheduled so that unfavorable data collection days are avoided and/or more advanced AADT estimation methods are applied *(Figliozzi et al. 2014)*.

6.11.3 Set up temporary counting equipment

Once a schedule has been established, begin the counting regimen. Set up appropriate temporary data collection equipment at the chosen sites. Once temporary counting equipment has been installed, make sure that the equipment is functioning properly, according to the recommendations.

1. Collect short-term data

   Once short-term data collection equipment has been verified for accuracy, begin the short-term count. If possible visually check equipment during the data collection period and verify that no vandalism or theft has occurred.

2. Plot data, look for patterns, and determine factor group

   Once data collection has been completed, evaluate the short-term data by graphing the hourly and/or daily patterns to determine its factor group.

3. Extrapolate short-term counts to get AADT

When at least one year of data has been collected at permanent counting stations of the same group factor, estimate AADT from short-term counts by applying the appropriate factors.

If bicycle/pedestrian traffic patterns at a short-term counting site do not fit into any of the developed or existing factor groups, AADT should not be estimated. Instead, it is recommended that:

- The count is repeated, if possible with a longer duration count. The unusual patterns may be the result of data variability and the new count may produce a well-known pattern. The unusual pattern is easier to discard if there are previous counts that fit the new data.

- If a new count does not solve the lack of pattern fit problem, the site should be included in the list of future permanent counting stations especially if the traffic volumes warrant the additional cost or for the following year.

4. Repeat short-term count program

   While some programs count each location annually, this is not as necessary if permanent count stations represent temporal changes at the site.

   Each year, schedule a list of new short-term sites. It is recommended that candidate permanent counting sites must also first have a short-term count. Each site should be tested on a rotation of perhaps three to five years as is usually done for motorized vehicle counts.

6.12 ASSEMBLE AND PROCESS DATA

Another important step in the development of a counting program is data management, storage, and processing. The development of a long-term data warehouse or other appropriate database is crucial to safeguard the data integrity and reduce data access costs.

1. Upload Data to Appropriate Data Warehouse

   The data collected from the continuous sites will need to be uploaded to the data warehouse. Depending on the format of the data records, some additional processing might be required.

2. Apply Factoring to Short Term Counts

   ODOT’s Transportation Systems Monitoring Unit uses similar methods to AASHTO for determining AADT *(Crownover 2013)* for motor vehicles. It is recommended that ODOT use the same procedures for developing bicycle and pedestrian AADT factors (see Chapter 3) or adaptation of the AASHTO method for 2070 data.

6.12.1 Quality Assurance and Quality Control

Installing counters and collecting data two weeks to one year only to find that the equipment was not functioning correctly is a waste of time and effort. Hence, verifying counting equipment accuracy is essential. A systematic process of quality assurance/quality control process (QA/QC) must be followed to avoid common and preventable data collection errors.

Employing video to determine counting equipment accuracy is a reliable yet expensive method. Although it would be optimal to test QA/QC using the most thorough methods, it is not realistic to evaluate all temporary sites and counts with video validation. Therefore, two levels of QA/QC are been recommended for equipment verification.

6.12.2 Short-term equipment QA/QC

For short-term count sites, it is usually enough to check that the equipment is working properly and to verify that no obvious errors are occurring. Counting 30 pedestrians/bicyclists is recommended. In locations where volumes are low, counting crew members can ride a bicycle or walk over the counting device.

6.12.3 Continuous equipment QA/QC

Already operating permanent counting sites should be periodically inspected.

For new permanent counting installations, video verification of counting equipment involves the set-up of video equipment at the new counting equipment site. The video is directed at the area(s) of detection to observe pedestrians/ bicycles crossing detection area. Counting equipment data collection and video are collected during the same time period. Video and counting equipment data collection time clocks are then synced. It is recommended that a minimum of 100 bicycle or pedestrians be collected in order to have enough data to determine accuracy. In locations where volumes are low, counting crew members can ride a bicycle or walk over the counting device.

For new sites, video analysis should include travel direction, crosswalk utilization, and behavioral data such as helmet use, traffic patterns, traffic compliance, and any anomalies that may be commonly observed. For example, in the pilot study, through analyzing the video, it was found that approximately 50 percent of cyclists use the sidewalk; in this case adjustment factors should be developed to better estimate counts.

6.13 LEVERAGING NEW DATA SOURCES

In the past ten years there has been an important surge in bicycle and pedestrian research and data collection efforts. Researchers and practitioners have not only leveraged knowledge and technologies from the motorized travel realm but also adopted new technologies that can provide a wealth of data. The most promising technology for cyclists is the use of smartphone applications to collect cyclist route and demographic data. Smartphone route data can be employed to complement existing counts and increase data coverage in a cost-effective way. Researchers in Montreal have found that smartphone counts are highly correlated to AADT estimates *(Jackson et al, 2014).* In addition, smartphone route and count data can be used to better locate both permanent and temporary counting sites. An ongoing ODOT research project is developing a smartphone application to collect cyclists’ route and demographic data in Oregon.

7.0 REFERENCES

AASHTO. *AASHTO Guidelines for Traffic Data Programs*. American Association of State Highway Transportation Officials, (AASHTO), Washington D.C., 1992.

Ahmed, F., G. Rose, M. Figliozzi, and C. Jakob. Commuter Cyclist's Sensitivity to Changes in Weather: Insight from Two Cities with Different Climatic Conditions. Presented at the 90th Annual Meeting of the Transportation Research Board, Washington D.C., 2011.

Alta Planning and Design. *National Bicycle and Pedestrian Documentation Project. Automatic Count Technologies*. 2009. http://bikepeddocumentation.org/index.php/download_file/-/view/22. Accessed February 26, 2014.

Alta Planning and Design and ITE. *National Bicycle and Pedestrian Documentation Project*. 2013. http://bikepeddocumentation.org/. Accessed June 16, 2013.

Auckland Regional Transport Authority. *Regional Cycle Monitoring Plan, Provisional Guidelines, 2006-2008*. ARTA, Auckland, 2006.

Bell, A. Technology Innovations: Infrared Bicyclist & Pedestrian Counter. *Journal of the Association of Pedestrian and Bicycle Professional*. Cedarburg, 2006, pp.4–5.

Berkow, M. The National Bicycle and Pedestrian Documentation Project. Presented at the Bike and Pedestrian Program Information Exchange & Technology Transfer Summit Meeting. Oregon Transportation Research and Education Consortium. Portland, OR, 2011.

Blue, S. *Counting Pedestrians and Bicyclists in Vermont; Towards a State-Wide Estimate of Non-Motorized Traffic Volumes*. State of Vermont. 2011.

Caltrans. *The Advanced Transportation Controller Model 2070. An Overview of the Model 2070 Signal Controller Student Guide*. Caltrans. 2002.

CountingCars.com. *CountingCars*. http://www.countingcars.com/. Accessed February 24, 2014

Crownover, D. e-mail response to author. May 6, 2013.

Davies, R. Pedestrian and Cycling Counters –South East Queensland. Presented at the Walk21 Conference, Brisbane, 2008.

Department for Transport. Traffic Counts. 2012. http://www.dft.gov.uk/traffic-counts/cp.php . Accessed December 5, 2012

Dowds, J, and J. Sullivan. Applying a Vehicle-Miles of Travel Calculation Methodology to County-Wide Calculation of Bicycle and Pedestrian Miles of Travel. Submitted to the 2012 TRB Annual Meeting. University of Vermont, Burlington, 2011.

EcoCounter. General Specifications. 2013. http://www.eco-compteur.com/Solutions.html?wpid=15031. Accessed August 13, 2013.

El Esawey, M., C. Lim, T. Sayed, and A.I. Mosa. Development of Daily Adjustment Factors for Bicycle Traffic. *Journal of Transportation Engineering*. Vol. 139, No. 8, 2013, pp.859–871.

FHWA. *Traffic Monitoring Guide*. U.S.Department of Transportation. Federal Highway Administration, Washington, D.C., 2013.

Figliozzi, M., P. Johnson, C.Monsere, and K. Nordback. A Methodology to Characterize Ideal Short-Term Counting Conditions and Improve AADT Estimation Accuracy. Forthcoming 2014 *Journal of Transportation Engineering*. 2014.

Fischer, E.L., G.K. Rousseau, S. Turner, E.J. Blais, C.L. Engelhart, D.R. Henderson, J.A. Kaplan, et al. *Pedestrian and Bicyclist Safety and Mobility in Europe*. FHWA-PL-10-010. FHWA. U.S. Department of Transportation. Federal Highway Administration, Washington D.C., 2010.

Gibson, D. Making Signal Systems Work for Cyclists. *Public Roads*. Vol. 71, No. 6, 2008.

Goodridge, S.G. *Detection of Bicycles by Quadruple Loops at Demand-Actuated Traffic Signals*. Undated. http://www.humantransport.org/bicycledriving/library/signals/detection.htm. Accessed October 26, 2013.

Gravitas. *Manual Cycle Monitoring in the Auckland Region*. Auckland Regional Transport Authority. 2007.

Greene-Roesel, R., M.C. Diogenes, D.R. Ragland, and L.A. Lindau. Effectiveness of a Commercially Available Automated Pedestrian Counting Device in Urban Environments: Comparison with Manual Counts. In TRB 87th Annual Meeting Compendium of Papers DVD. Transportation Research Board, Washington D.C., 2008. Paper #08-0503.

Hyde-Wright, A., B. Graham, and K. Nordback. Counting Bicyclists with Pneumatic Tube Counters on Shared Roadways. *ITE Journal*, February 2014. pp. 33–37.

Jackson, S., L.F. Miranda-Moreno, C. Rothfels, & Y. Roy. Adaptation and Implementation of a System for Collecting and Analyzing Cyclist Route Data Using Smartphones. In TRB 93rd Annual Meeting Compendium of Papers DVD. Transportation Research Board, Washington D.C., 2014, Paper #14-4637.

Jones, M.G., S. Ryan, J. Donlon, L. Ledbetter, D.R. Ragland, and L.S. Arnold. *Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and its Relationship to Land Use*. Transportation, Safety, and Facility Type. California PATH Research Report. UCB-ITS-PRR-2010-12. University of California, 2010.

Kittelson & Associates. Methods and Technologies for Collecting Pedestrian and Bicycle Volume Data, Draft Literature Review for the NCHRP Project 7-19. Draft Report. The National Cooperative Highway Research Program, 2012.

Klein, L.A., M. K. Mills, and D. Gibson. *Traffic Detector Handbook: Third Edition--Volume 1*. FHWA-HRT-06-108. Federal Highway Administrative, U.S. Department of Transportation, Washington D.C., 2006.

Koh, P.P., Y.D. Wong, P. Chandrasekar, and S.T. Ho. Walking and Cycling for Sustainable Mobility in Singapore. Proceedings of Walk21 Conference, Vancouver. 2011.

Kothuri, S.M., T. Reynolds, C.M. Monsere, and P.J.V. Koonce. Preliminary Development of Methods to Automatically Gather Bicycle Counts and Pedestrian Delay at Signalized Intersections. In TRB 91st Annual Meeting Compendium of Papers. DVD. Transportation Research Board, Washington D.C., 2012. . Paper #12-2107

Lehman, R., D. Lee, I. Reid, N. Barker, J. Zhong, K. Kim, T. Vaclavek, and R. Garland. Cycling in New South Wales: What the Data Tell Us. Presented at Premier's Council for Active Living, Sydney. 2008.

Lieswyn, J., A. Wilke, and S. Taylor. Automatic Cycle Counting Programme Development in Hamilton. Presented at the Institution of Professional Engineers New Zealand (IPENZ) Transportation Conference. Hamilton City Council. Auckland, 2011.

Lindsey, G., J. Chen, and S. Hankey. Adjustment Factors for Estimating Miles Traveled by Nonmotorized Traffic. In TRB 92nd Annual Meeting Compendium of Papers. Transportation Research Board, Washington D.C., 2013. Paper # 13-4082.

Lindsey, G., K. Hoff, S. Hankey, and X. Wang. *Understanding the Use of Non-Motorized Transportation Facilities*. CTS 12-24. University of Minnesota, Minneapolis. 2012.

Manhard Consulting. *Non-Motorized Digital Data Collection on State Highways Pilot Project*. Humboldt County Association of Governments. Eureka. 2011.

Milligan, C., R. Poapst, and J. Montufar. Performance Measures and Input Uncertainty for Pedestrian Crossing Exposure Estimates. *Accident Analysis & Prevention*, Vol 50, 2013, pp.490–498.

Miranda-Moreno, L.F., and A.C. Lahti. Temporal Trends and the Effect of Weather on Pedestrian Volumes: A Case Study of Montreal, Canada. Transportation Research Part D: Transport and Environment. *Transportation Research Board*, Washington D.C., Vol. 22, 2013, pp.54–59.

Nabors, D., E. Goughnour, L. Thomas, W. DeSantis, M. Sawyer and K. Moriarty. *Bicycle Road Safety Audit Guidelines and Prompt Lists.* Publication FHWA-SA-12-018. Federal Highway Administration, U.S. Department of Transportation, 2012.

National Weather Service Forecast Office. *Local Climate Data from Portland Airport*. National Oceanic and Atmospheric Administration (NOAA). 2013. http://www.wrh.noaa.gov/pqr/pdxclimate/index.php. Accessed June 19, 2013.

Niska, A., A. Nilsson, M. Varedian, J. Eriksson, and L. Soderstrom. *Evaluating Pedestrian and Cycle Traffic. Development of a Harmonized Method for Monitoring the Municipal Proportaion of Pedestrian and Cycle Traffic Through Travel Surveys and Cycle Counts.* VTI: Linkoping, Sweden, 2012, p. 82.

Nordback, K., and B.N. Janson. Automated Bicycle Counts. In Transportation Research Record: *Journal of the Transportation Research Board,* No. 2190. Transportation Research Board, Washington D.C., 2010, pp.11–18.

Nordback, K.L. *Estimating Annual Average Daily Bicyclists and Analyzing Cyclist Safety at Urban Intersections*. Ph.D. diss. University of Colorado At Denver. 2012.

Nordback, K., W.E. Marshall, B.N. Janson, and E. Stolz. Estimating Annual Average Daily Bicyclists: Error and Accuracy. In Transportation Research Record: *Journal of the Transportation Research Board.* No. 2339, Transportation Research Board, National Research Council, Washington D.C., 2013, pp. 90-97.

Ozbay, K., B. Bartin, H.Yang, R. Walla, and R. Williams. *Automatic Pedestrian Counter*. Publication FHWA-NJ-2010-0012010. New Jersey Department of Transportation, Federal Highway Administration, U.S. Department of Transportation, 2010.

Portland Bureau of Transportation. *2011 Bicycle Counts Report*. Portland Bureau of Transportation. 2012.

Roll, J.F. *Bicycle Traffic Count Factoring: An Examination of National, State and Locally Derived Daily Extrapolation Factors*. Thesis, Portland State University. 2013.

Rose, G., F. Ahmed, M. Figliozzi, and C. Jakob. Quantifying and Comparing the Effects of Weather on Bicycle Demand in Melbourne (Australia) and Portland (USA). In TRB 90th Annual Meeting: January 23-27, 2011, Washington, DC: compendium of papers. Transportation Research Board, Washington D.C., 2011.

Ryan, S. Establishing an Automated Regional Non-Motorized Transportation Data Collection System to Support Active Transportation Performance Monitoring. In TRB 92nd Annual Meeting Compendium of Papers. Transportation Research Board, Washington D.C., 2013. Paper #13-0351.

Schneider, R.J. How To Do Your Own Pedestrian Count. Presentation at Pedestrians Count! 2012, Los Angeles, 2012.

Schneider, R.J., L.S. Arnold, and D.R. Ragland. Methodology for Counting Pedestrians at Intersections. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 2140 (1), Transportation Research Board, National Research Council, Washington D.C., 2009, pp. 1–12.

Schneider, R., R. Patton, J. Toole, and C. Raborn. *Pedestrian and Bicycle Data Collection in United States Communities: Quantifying Use, Surveying Users, and Documenting Facility*

Extent. Pedestrian and Bicycle information Center, Federal Highway Administration, Office of Natural and Human Environment, U.S. Department of Transportation, 2005.

Sensys Networks, Inc. *Sensor.* Sensys Networks, Inc. 2014a. http://www.sensysnetworks.com/products/sensor/. Accessed November 8, 2013.

Sensys Networks, Inc. *MicroRadar Sensor For Bicycle Detection and Counting*. Sensys Networks Inc . 2014b. http://www.sensysnetworks.com/products/microradar/. Accessed November 8, 2013.

Shladover, S.E., Z.W. Kim, M. Cao, A. Sharafsaleh, J. Li, and K. Leung. Bicycle Detection and Operational Concept at Signalized Intersections. *California PATH Program*, Institute of Transportation Studies, University of California, Berkeley. 2009.

Sloman, L., N. Cavill, A. Cope, L. Muller, and A. Kennedy. *Analysis and Synthesis of Evidence on the Effects of Investment in Six Cycling Demonstration Towns*. Department of Transport and Cycling England, London, 2009.

Somasundaram, G., V. Morellas, and N. Papanikolopoulos. *Deployment of Practical Methods for Counting Bicycle and Pedestrian Use of a Transportation Facility*. CTS 12-01, Center for Transportation Studies, University of Minnesota, Minneapolis, 2012.

SRF Consulting Group. *Bicycle and Pedestrian Detection*. Final Report. Federal Highway Administration, U.S. Department of Transportation, Minnesota Department of Transportation, St. Paul, MN, 2003.

Stolz, E. Bicycle and Pedestrian Counters, CDOTs New Bike & Ped Counting Program. *Colorado LTAP*, Summer Issue, June 2010, p.9.

Styer, M.V., and K. Leung. Bicycle Detection in California. Presentation to Caltrans, Los Angeles, CA, 2013.

Thiemann-Linden, J., and T. Mettenberger. Cycling Quality Management and Evaluation in Europe. *Publication Cycling Expertise*- Organization, Communication, Cooperation o-8/2012, Federal Ministry of Transport, Building and Urban Development, Berlin, 2012.

Turner, S., T. Qu, and P. Lasley. *Strategic Plan for Non-Motorized Traffic Monitoring*. Final Report. Texas Transportation Institute, Colorado Department of Transportation, 2012.

van Hengel, D., M. Tresidder, and M. Berkow. Memorandum #1 (subtask 2.1) - Bicycle and Pedestrian Travel Assessment Report Project. Oregon Department of Transportation, 2011a.

van Hengel, D., M. Tresidder, and M. Berkow. *Bicycle and Pedestrian Travel Assessment Report– Final Report*. Oregon Department of Transportation, 2011b.

APPENDIX A

LITERATURE REVIEWS

LITERATURE REVIEW: U.S. PROGRAMS

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Data Type	Collection Frequency	Site Selection	Methods	Notes
(FHWA 2013)	Reviews: • Inductance loops • Infrared Sensors • Magnetometers • Pneumatic Tubes • Pressure and Seismic Sensors • Video Image Processing	**B/P**	NA	• Compute, monthly, DOW, Hour-of-day factors to use in annualizing short duration counts	Select Specific Count Locations • Determine if bicycle and pedestrian traffic will be counted separately • Focus on choosing locations that are most representative of prevailing non-motorized traffic patterns • Choose a site that is chosen specifically for the specific monitoring equipment	Permanent Data program • Review Existing continuous counting program • Develop and inventory of available continuous count locations and equipment • Determine the traffic patterns to be monitored • Establish pattern/factor groups • Determine the appropriate number of continuous monitoring locations • Select specific count locations • Compute, monthly, DOW, Hour-of-day factors to use in annualizing short duration counts	• Very useful guidelines and explanation of data collection needs • Weak policy, but an existing structure for data collection • Great methodologies for determining counts. • Information on installation of devices
(Portland Bureau of Transportation 2012)	• Manual counts • Automated counts on or near bridges	**B**	NA	• Annual Manual counts • Two hour counts	• 156 Locations	• AADT Calculated by multiplying two hour count by 5	
(Nabors et al. 2012)	• Field reviews	**B**	NA	NA	NA	8 steps • Identify Projects • Select RSA Team • Conduct Start-Up meeting • Perform field Reviews • Analyze and report on findings • Present findings to owner • Prepare Formal Response • Incorporate findings	• FHWA report • RSA=Road Safety Audit • Weak policy, but an existing structure for data collection • Excellent guidelines for examination of qualitative factors related to bicycle safety
(R. J. Schneider 2012)	• Manual counts • Automated counts	**B/P**	• Excel	• Tuesday, Wednesday, and Thursday a) 4-6PM b) 5-7 PM NBPD c) 2-4 PM near schools • Saturday a) 9-11AM b) 12-2 PM c) 3-5 PM	Where to Count? • Neighborhoods with a range of incomes • Within a quarter mile of a school • Within half mile of light rail • Range of traffic volumes • About one quarter of intersections have: a) Median Islands b) Less than 4 lanes on mainline approaches c) No traffic signals	Conduct manual counts • Verify by conducting automated counts • Clean up automated counts • Correct for undercounting • Adjustment factors	• Los Angeles, CA • Berkeley, CA • Good information on manual counts • Collection of bicyclebicycle and pedestrian trend graphs from around the U.S.
(Somasundaram , Morellas, and	• Computer vision • Sony HD	**B/P**	• C++ using open source computer vision	• Various	• Chose various sites with different environments to see if equipment	• Object classification issues with video	• Argument for use of vision-based system for counting

Reference/ Authors	**Data Collection Technology**	**Bike &/or Ped**	**Data Type**	**Collection Frequency**	**Site Selection**	**Methods**	**Notes**
Papanikolopoulos 2012) Minnesota	Camera		libraries • OpenCV • VXL		performed better in different environments		bicyclebicycle and pedestrians
(Lindsey, Chen, and Hankey 2013) MNDOT	• Loop detectors • Active infrared	**B/P**	NA	• Continuous counts	• Off street trails with loop detectors and infrared counters	• volume adjustments to continuous counts	
(Turner, Qu, and Lasley 2012) CDOT	• No actual equipment types were discussed • Manual counts for quality control	**B/P**	TRADAS	• Before and after facility improvements, short-term counts • High non-motorized long term counts • Quality assurance process uses manual counts	• Site selection is informal and uses qualitative criteria and local knowledge for bicycling and walking patterns and travel. • “Special study” sites are places that are being considered for improvements. • High or growing use where facilities have already been established	• Establish business process for non-motorized traffic data • Maintain and extend local agency partnerships • Establish non-motorized factor groups • Short duration site selection • Enhance the quality assurance/ quality checking process	• The concept of establishing non-motorized factor groups: 1) Commuter and work/school based trips 2) Recreation/utilitarian trips 3) Mixed purpose trips (both commuter and recreation/ utilitarian
(K. L. Nordback 2012) CDOT	• Inductive loops (Canoga and EcoCounter) • Manual Counts	**B/P**	NA	• Continuous counts • Short term counts • Collision data	• The choice of city was based on available data, interest of the city staff, convenience and characteristics of the cities to be studied. • 12 locations in Boulder	• To develop a method to analyze bi cyclist safety in U.S. cities by quantifying bicycle use per roadway. Short term counts are annualized to calculate AADB	• Good summary of types of counters • Adjustment Factors • AADB • Cyclist Safety
(Kittelson & Associates 2012) NCHRP	• Various examples of equipment	**B/P**	NA	• Various examples of site selection	• Explanation of site selection	Proposal includes: • Summary of data collection technologies • Data Adjustment factors • Investigates approved methods • Develop Guide book	• Parallels our project • Provides summaries of other projects • Research Team: Paul Ryus, Jessica Horning, Erin Ferguson
(Blue 2011) Vermont	• Manual • Automatic	**B/P**	NA	• Regional Planning Commissions within the State all had different data collection frequency	NA	• There is no consistent data collection system in the state	• Summary of the disorganized bicycle and Pedestrian data collection systems among Regional Planning commission in the state of Vermont

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Data Type	Collection Frequency	Site Selection	Methods	Notes
(Hengel, Tresidder, and Berkow 2011a) ODOT	• Manual counts from different agencies • Surveys • Pneumatic tubes • Inductive loops • Infrared, passive and active • Pressure pads • Video counts	**B/P**	• No centralized location for non-motorized traffic data • Crash data • Traffic signal data • Traffic count data	• Before and after analysis • Overview of CDOT continuous and short term data collection • WSDOT • Caltrans	NA	• Review of existing programs including Colorado, Washington State, California, and Portland	• Related to our study. • Determines need for data collection method • Summarizes a literature review • Table 3 provides a summary of all types of counting equipment and methods
(Hengel, Tresidder, and Berkow 2011b) ODOT	• Recommends to develop a standard data collection methodology	**B/P**	• Recommends the development of a database framework for archiving and assessing data	NA	NA	• The report identified data that ODOT collects on bicycle and pedestrians and made recommendations to design a data collection system for bicycle and pedestrians	• The ODOT Evaluation by Alta • This is the pre-evaluation of our project
(Kothuri et al. 2012) PBOT	• Advance loops 9 in bicycle lanes. • transit priority logging feature in the traffic controller • logic 12 commands	**B/P**	• TransSuite® (ATMS) 28 software • 2070 controllers • data user service (PORTAL) • video cameras mounted at the intersection for traffic surveillance • Voyage controller software	• 6 Tuesdays between October 2010 and July 2011 continuous	• Existing infrastructure, equipment	• This paper summarizes preliminary efforts to develop a 5 long-term monitoring and collection system that leverages existing infrastructure to monitor bicycle and pedestrian activity. using existing hardware (loop detectors, signal controllers) and software at 8 intersections within the City of Portland, Oregon	• Uses existing bicycle loop detectors to count bicycles
(Berkow 2011)	• Survey • automated count	**B/P**	• manual counts	• Second week in September • Weekdays 7-9AM, 5-7PM (primary) Saturday, 12-2PM (primary)	• Chosen locations are used each year • Use of screen lines	• Screen line counts for the annual survey • No details given for automated counts but assume that they are consistent. • Automatic count data creates great maps on weather and bicycle traffic	• Presentation of the National Bicycle and Pedestrian Documentation Project • Good maps on seasonal variation from automated count data
(K. L. Nordback 2012) Boulder, CO	• Inductive loops double loop configuration • Manual counts for verification	**B**	• Global Traffic Technologies Canoga C900 and C800 series hardware card	• 1-2 hour intervals	• Multiuse paths • 6 stations at 6 locations • Chosen because they are collocated with another station	• Two manual counters were at each location • data from loop detectors were downloaded at the same locations as the manual counters and compared	• For accurate counts, loop detectors need to be calibrated.
(Ozbay et al. 2010)	• passive infrared counter by	**P**	NA	• Multiple 12-hour tests were	• Facilities and Users • Accident Occurrence		• Study of sensor technology • Sensor calibration

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Data Type	Collection Frequency	Site Selection	Methods	Notes
NJDOT U.S.DOT	EcoCounter and thermal sensor by TrafSys			conducted. • The tests at other sites were limited to 6 to 8 hours.	• Mounting structure • Energy supply • Traffic Pattern • Visibility • Safety • High volume and low volume sites		
(Stolz 2010) CDOT	• Eco Counter	**B/P**	• TRADAS by Chaparral	• From 2 hour counts • continuous	• Using existing bicycle • and pedestrian data collection locations	• Article in newsletter that explains installation of new EcoCounter™ units	• Betsy Jacobsen from CDOT
(Jones et al. 2010) California PATH Program San Diego County, CA	• active infrared counter manufactured by TrailMaster both bicycle and pedestrians • passive infrared counter manufactured by JAMAR • bicycle intercept surveys	**B/P**	• GIS	• 2007 and 2008 manual peak period counts • One-year, 24 hour automated counts from 8/2007 to 7/2008	Why San Diego County? • Regular bicycle • counts were available since 1985 • Extensive countywide GIS database with good historical information Count locations were based on: • historic count locations • Representative locations based on land use, demographics, and facility types. • 80 locations chosen	• In addition to peak-hour counts, the Seamless Travel Project collected automated year-long counts to establish trends in bicycling and walking. • Used a combination of passive infrared counters and active infrared counters. • Both count tools collect time-stamped data, contain their own power source, and allow data to be downloaded to a computer for analysis. • Active infrared counters allow bicyclists and pedestrians to be classified.	• There is a substantially higher demand for Class 1 bicycle paths • JAMAR Scanners are undercounting by approximately 15% to 21% • TrailMasters are undercounting all travelers by approximately 12% to 18% and undercounting pedestrians by approximately 25% to 48%, • Detailed discussion of count methods • Good tables and text on pros and cons of data collection equipment types.
(R. J. Schneider, Arnold, and Ragland 2009) Berkeley	• Survey; House Survey and Intercept • Continuous;	**P**	NA	• Tue., Wed., and Thurs. 4 pm to 6 pm and 5 pm to 7	• Most sites are in countywide Pedestrian & BicycleBicycle Plans • In neighborhoods with a range of incomes	• Method for estimating weekly pedestrian counts from two hour manual counts	• Demonstration of how pedestrian volumes can be integrated into transportation planning projects

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Data Type	Collection Frequency	Site Selection	Methods	Notes
Alameda County, CA	• Loops, infrared			pm 2 pm to 4 pm near schools • Saturday 9 am to 11 am 12 pm to 2 pm 3 pm to 5 pm • For 13 weeks	• 9 intersections within 0.5-miles (805 m) of a Bay Area Rapid Transit (BART) station • 20 intersections within 0.25-miles (402 m) of a elementary, middle, or high school • 33 intersections with sidewalks on both sides of all roadways within 0.25-miles (402 m) • 4 trail/roadway intersections • 6 central business district intersections ❖ Four in Oakland ❖ One in Hayward ❖ One in Fremont		
(Greene-Roesel et al. 2008) Berkeley, CA	• infrared beam counters • passive infrared counters • piezoelectric pads • laser scanners • computer vision technology.	**P**	NA	• 4 hour counts at three sites	• Berkeley, CA • The selection of sites was guided by two basic requirements: 1) Difference in pedestrian flows 2) Presence of a suitable place for installing the automated counter. • The three test sites were selected to represent varying pedestrian flows	• Manual counts • Video recordings were carefully analyzed	• Very useful! • Infrared was the most cost effective • Not good as distinguishing between pedestrians and bicyclebicycles and two persons walking together.
(Bell 2006)	• Infrared EcoCounter • Pyro-electric sensor and logger	**B/P**	• Date retrieved from handheld PDA	• Tested for one week in each of the three locations	• First tested in three different types of land use locations 1) Urban sidewalk 2) Suburban shared use path • Rural rail-trail	• Gives the pros and cons of an infrared bicyclebicycle and pedestrian counter system.	• Plan to install 4 to 6 permanent counter locations
(R. Schneider et al. 2005)	• Review of data collection methods in 29 different agencies	**B/P**	• Varies	• Varies	• Varies	"The purpose of this study is to share information about existing data collection efforts and provide the results to practitioners who want to collect pedestrian and bicycle data in their communities" • Discussion of how the case studies were	• Great information. • 29 data collection case studies with contact information for each. • Read entire document**.**

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Data Type	Collection Frequency	Site Selection	Methods	Notes
						solicited and written. - critically assesses the 29 case studies	
(R. Schneider et al. 2005) Albuquerque, NM	- Manual	**B/P**	- Data counts are transferred into a computer using a data entry program that MRCOG staff developed with Visual Basic (see Figure 2). This software compiles and stores the data in ASCII files. The data are subsequently geo-coded for use in GIS.	- Collect bicycle and pedestrian counts at all signalized intersections in Albuquerque (500+) on a three-year cycle. (Sixty-eight intersections have been counted as of February 2004). Data is recorded for the a.m. peak period, midday, and p.m. peak period.	- Part of existing traffic data collection	- Added the task of collecting pedestrian and bicycle counts to existing motor vehicle counting program because there was no additional funding for a new data collection program dedicated strictly to the bicycle and pedestrian modes. - Developed in-house software for compiling manually collected counts. - Displayed summary data in a Geographic Information System (GIS).	Cost of Data Collection - Because MRCOG incorporated the pedestrian and bicycle counts into program, there were no additional labor costs to gather the data. Some staff time was required to develop the approach and format for the counts, program software, and enter the count data. Funding for the counts was provided through the City of Albuquerque's intersection turning movement count program. - Albuquerque, New Mexico (population 450,000) is the largest city in the state.
(R. Schneider et al. 2005) Baltimore, MD	- Manual	**P**	*Data storage* Information from paper field data sheets is entered into a Lotus database by a staff member in the Traffic Engineering Department. The counts are summarized (see Data Analysis, below) and stored electronically on diskette and in paper form in binders in the Traffic Engineering Department. The City is planning to upload the electronic spreadsheets to a mainframe computer in the future.	- Record counts every 15 minutes and aggregate data by two-hour morning peak, two-hour mid-day peak, two-hour evening peak, and entire day	NA	NA	NA
(R. Schneider et al. 2005) Licking County, OH	- Passive infrared (TRAFx™)	**B/P**	- Data storage The TRAFx™ device includes a docking module and related	- continuous	- LCATS has identified 11 locations where infrared shared-use path counts will be repeated e	NA	- The Licking County Area Transportation Study (LCATS) is a Metropolitan Planning

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Data Type	Collection Frequency	Site Selection	Methods	Notes
			cables for connecting to a laptop computer. Using the included “TRAFx™ Reporter” computer program to manage the download, LCATS staff takes a laptop into the field, connect to the counter, and download the count data from the device. Raw data is entered directly into a spreadsheet for analysis.				Organization and cooperative transportation decision-making body that serves 648 square miles and over 125,000 residents in central Ohio. Five separate shared-use path systems exist currently Cost of Data Collection Effort • Each TRAFx™ infrared package costs $2,200, including three sensors, equipment to connect computer, user manual, and software. Other costs include the time required to download and analyze the data.
(SRF Consulting Group 2003)	• Passive Infrared/ Ultrasonic • Infrared • Microwave • Video • Magnetic	**B/P**	• Peek ADR 3000 • ASIM DT272 • Auto-scope Solo	• 2 Days, October 7 and 8, 2002	• One site included separated bicyclebicycle and pedestrian path underneath an overpass. • All methods were tested at this location	NA	• Great literature review. • Gives details about other studies and data collection projects around the world and in the U.S.. • Good technical details about different equipment

LITERATURE REVIEW: INTERNATIONAL METHODS AND RESEARCH

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Collection Frequency	Site Selection	Methods	Notes
(Department for Transport 2012) London, GB	• Shared motor and non-motor vehicle counts	**B/P**	• Continuous	NA	NA	• http://www.dft.gov.uk/traffic-counts/cp.php • http://assets.dft.gov.uk/statistics/releases/traffic-estimates-2010/traffic-estimates-2010-methodology.pdfs
(Thiemann-Linden and Mettenberger 2012)	• Household Surveys • Traffic counts • Parked bicycles	**B**	• Annually • Biannually	NA	• A variety of household surveys appointed on certain dates are used to access cyclists satisfaction	• Germany • Denmark • Netherlands • European Union Surveys
(Fischer, et al. 2010) FHWA	• Varies from country to country	**B/P**	• Varies • UK has both a manual and automated count system	NA	• Summaries of bicycle and pedestrian data collection programs in: • Germany • Sweden • Denmark • UK • Key Findings- These foreign hosts provide regular performance reports on pedestrian and bicycle safety and mobility	• A good base article to work off of. Gives some examples of data collection • http://www.international.fhwa.dot.gov/pubs/pl10010/ch07.cfm
(Lieswyn et al. 2011) Hamilton, NZ	• Automatic cycle counters, inductive loop counter.	**B/P**	• Two week durations • Sites were split into permanent and short term counting sites (10 week counts) • manual counts during peak periods	• Based on population, Determined that 6 to 9 automated counting sites was adequate	• Site selection • count durations • System Costs	• Details on implementing a bicycle count system • Hamilton has a population of 141,500, city area of 98 km^2 (38 mi^2) • Cycle ways, 101 km
(Koh et al. 2011) Singapore	• Desktop Video Extraction • field survey • interviews • Still photographic strips technique.	**B/P**	NA	NA	• RSP involves selecting paths with a good spread of pedestrian-cyclist interaction. • Pedestrians who have used the paths are intercepted and invited to rate the existing operating condition: o Not acceptable o Tolerable o Acceptable o Comfortable • Comments about sharing path with bicyclists is encouraged • Concurrently, the stretch of footway is video-	• Real-situation perception (RSP) technique. • Investigates shared paths

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Collection Frequency	Site Selection	Methods	Notes
					recorded from a vantage point (either on top of a nearby pedestrian overhead bridge or a lamppost) with distance markers (visible tapes placed at 5-10m intervals) for determining related factors such as pedestrian and cyclist volumes and walking/ cycling speeds.	
(Gravitas 2007) North Shore City, Australia	• Manual • School bicycle shed counts	**B**	• 6.30 and 9.00 am • 4.00 to 7.00 pm • M-F	"Decisions as to which sites were chosen for cycle counts were guided by each respective TA, "keeping in mind the planned developments for the Regional Cycle Network. In choosing their sites, TAs were strongly recommended to consider sites that could be retained over time as this will allow for the most accurate longitudinal assessment of change in cycle numbers"	• Detailed information on each counting site from manual counts such as percent change between 2007 and 2010, helmet use	
(Sloman et al. 2009) England	• Automatic cycle counters • Manual counts • Surveys • Parking counts • Interviews with local authorities	**B**	• Continuous • Before and After implementation	"Sustrans… was commissioned to develop and manage a programme of cycle activity measurement in the six towns. This required agreement with each town of a detailed monitoring plan, specifying the number and locations of automated cycle counters so as to give an overview of cycle activity across the whole town"	• 6 demonstration towns implemented a range of initiatives to encourage cycling. All towns were monitored before and after.	• Very little information on bicycle counting methods, it is an example of initiatives used in England to encourage cycling.
(Lehman et al. 2008) Australia	• New South Wales Cycling Geo-database	**B**	• Data collection methods vary	• Different stakeholders collected information differently	• A general overview of the types of cycling data that exists in New South Wales and plans to organize the data	• Base study to determine needs for new data collection system • Confusing but detailed. • Highlights existing inefficiencies and inconsistencies
(Davies 2008) Queensland, Australia	• Metro count MC5710 with MSI BL Piezo Sensor for cyclists • Normandy Pedestrian Cycle Link Automated Counter	**B/P**	• provided twenty-four (24) hour counts, with total counts at minimum fifteen (15) minute intervals	NA	An automated counter that: • provided separate directional counts of both pedestrians and cyclists • could be powered by both battery and mains/solar • could be installed on existing infrastructure • allowed remote access for data retrieval (GSM Modem or similar) • provided a data output file that was either simple to use (reformat/analyze) or complicated but was already in use by local governments and Main Roads • was not cost prohibitive for smaller projects (<$100,000)	• similar reasons to collect data in the U.S. to know how the network is performing, guide investment, demonstrate to community how well government programs are working

Reference/ Authors	Data Collection Technology	Bike &/or Ped	Collection Frequency	Site Selection	Methods	Notes
(Auckland Regional Transport Authority 2006) Auckland, New Zealand	• manual cycle counts • temporary automated cycle counters • permanent automated cycle counters • cordon / screenland counts • counts of parked cycles	**B**	• one day a year • Two week counts, one summer and one non summer holiday times • continuous	NA	• This plan proposes how ARTA and the TLAs across the region can – 1. align manual cycle count methodologies to one system, increasing regional comparability 2. deploy permanent cycle monitoring equipment, to collect annual trends in cycle use 3. use temporary automated cycle monitoring equipment to monitor specific infrastructure upgrades, as part of the development of the Regional Cycle Network 4. organize the collection and reporting of other related cycle monitoring data in a regionally consistent way.	• Detailed plan for types of counting and the deciding parties for types and locations of

APPENDIX B

ODOT TESTING PROCEDURE FOR VEHICLE DETECTORS AND FOR DEVICES THAT CLASSIFY BICYCLES AND MOTOR VEHICLES

The following procedure is intended to test the performance of detectors that have the capability to detect both bicycles and motor vehicles and to send the respective calls to different channels. These detectors are typically used in shared lane conditions where motorists and bicyclists share the same lane. Since bicyclists approach the intersection from a variety of positions within the lane, it is important that the detector have a broad range of detection and classification across much of the travel lane. It is also important that the detector not send false calls from vehicles in an adjacent lane.

The test area should be marked as shown in Figure 1. The detector will be tested in Lane 1. Lane 2 is set up as an "adjacent lane" that will test for false calls. The nine markings within Lane 1 may be shifted up to 1 foot off-center to minimize false calls from vehicles in lane 2, but they must remain 1 foot apart.

The performance of the detector will be assessed through the results of three tests. Test 1 consists of satisfactorily detecting and classifying bicycles that approach the intersection along one of the nine positions marked in Lane 1. Test 2 assesses the detector's ability to detect and classify a mid-sized sedan in Lane 1. Test 3 assesses the detector's ability to disregard adjacent vehicles in lane 2. The minimum and maximum thresholds to pass each test are shown in Tables 1, 2, and 3 below. All three tests must be passed with the detector located in the same position.

Test 1: Bike Detection (Sample size = 27, spread evenly over 9 lane positions)

	Acceptable Threshold	Test Results	Pass/Fail
Total of all detections	23 (minimum)	__	__
Detections misclassified as motor vehicle	5 (maximum)	__	__

Test 2: Motor Vehicle Detection in Lane 1 (Sample size = 15 sedans, centered in lane 1)

	Acceptable Threshold	Test Results	Pass/Fail
Total of all detections	13 (min)	__	__
Detections misclassified as bicycles	3 (max)	__	__

Test 3: False Calls from Adjacent Lane (Sample size = 15 sedans, centered in lane 2)

	Acceptable Threshold	Test Results	Pass/Fail
Total false calls	3 (max)	__	__

The test bicycle should be a steel or aluminum-framed bicycle weighing no less than 25 pounds with steel or aluminum rims. The test motor vehicle should be a traditional mid-sized sedan.

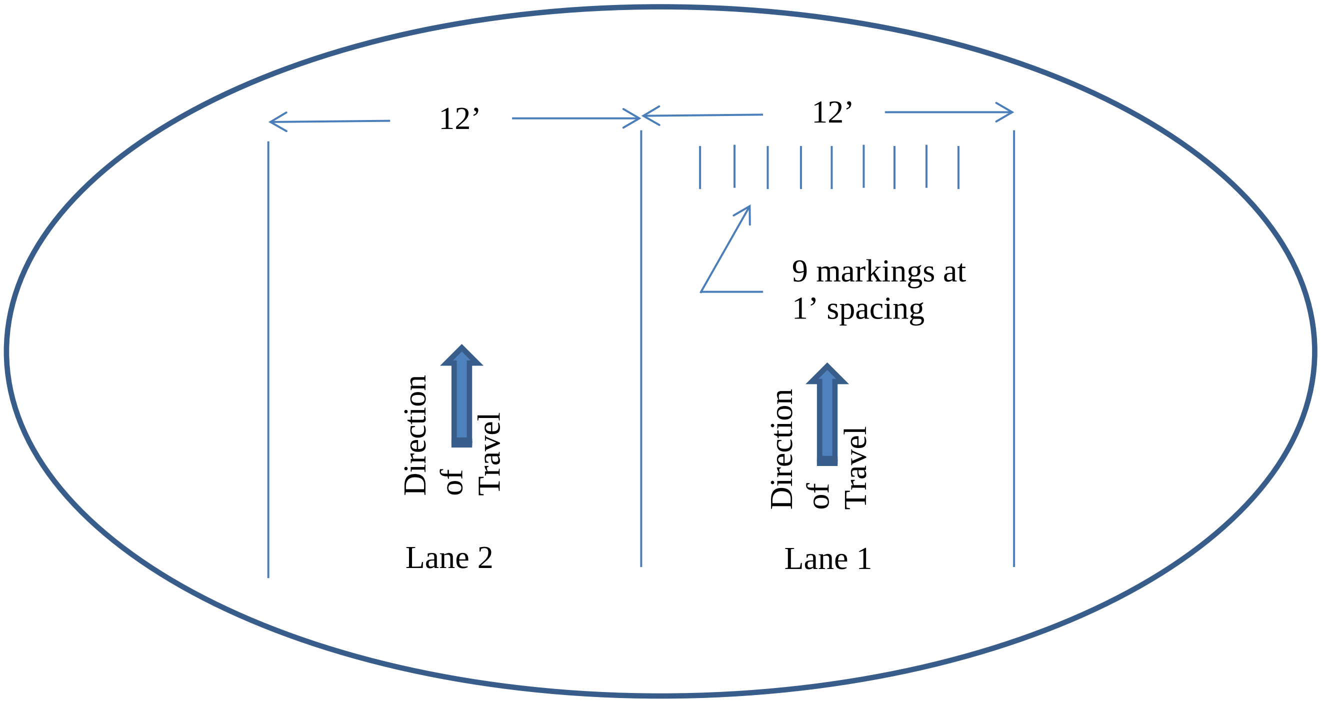
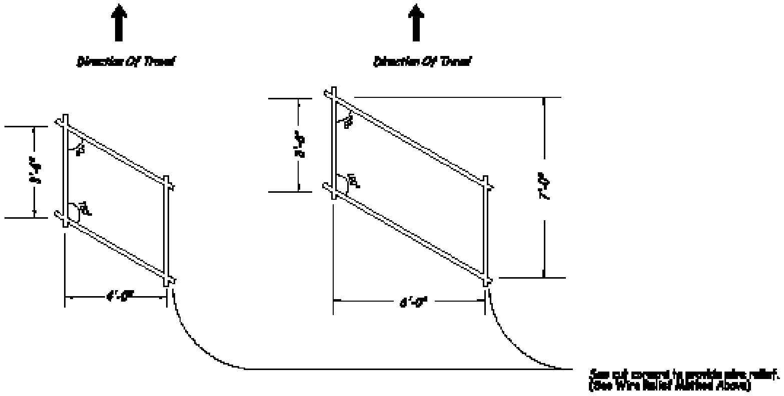
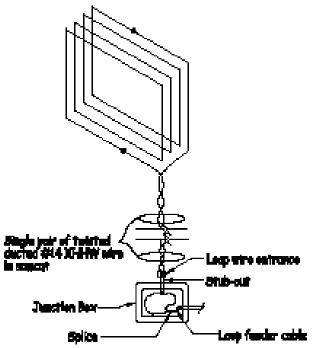


Figure 1: Test lane set-up.



PARALLELOGRAM TRAFFIC DETECTION LOOPS

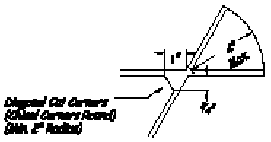


SINGLE LOOP

LOOP DETECTOR WINDING PATTERN

(Arrows Indicate Direction Of Loop Winding)

Loops Shall Be Of The Parallelogram Type With 4 Turns Of Ducted No. 14 XHHW Stranded Wire Centered In The Traffic Lane Or As Shown On Plans. Loop Wire Shall Be Twisted 4 To 6 Turns Per Foot Between Loop And Junction Box. All Loops Shall Be Individually Wired As Shown.



Make additional sawcut to provide wire relief at acute corners

WIRE RELIEF METHOD

NOTE:

1.) Loops are measured from the "stop line" or outside crosswalk line to the center of the loop.

2.) See TM 475 for details not shown.

OREGON DEPARTMENT OF TRANSPORTATION
TECHNICAL SERVICES
DETAILS

INDUCTIVE LOOPS
PARALLELOGRAM

DETAIL NO.
DET4433

DET4433

C:\Joe S\STANDARD DRAWINGS\Standard Details 06-11 Update\DET4433.dgn :: Default 6/1/2011 7:07:09 AM hwym26p

APPENDIX C

PILOT STUDY

(SEE SEPARATE DOCUMENT)