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Guidebook on Pedestrian and Bicycle Volume Data Collection

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Abstract:

NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection is directed to practitioners involved in collecting non-motorized count data. The Guidebook (1) describes methods and technologies for counting pedestrians and bicyclists, (2) offers guidance on developing a non-motorized count program, (3) gives suggestions on selecting appropriate counting methods and technologies, and (4) provides examples of how organizations have used non-motorized count data to better fulfill their missions. The research behind the Guidebook can be found on the TRB website as NCHRP Web-Only Document 205: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection (NWOD 205). NWOD 205 includes the results of the testing and evaluation of a range of automated count technologies that capture pedestrian and bicycle volume data.

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NCHRP

REPORT 797

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Guidebook on Pedestrian and Bicycle Volume Data Collection

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NCHRP REPORT 797

Guidebook on Pedestrian and Bicycle Volume Data Collection

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WASHINGTON, D.C.

2014

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Crawford F. Jencks

Staff Officer

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NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection is directed to practitioners involved in collecting non-motorized count data. The Guidebook (1) describes methods and technologies for counting pedestrians and bicyclists, (2) offers guidance on developing a non-motorized count program, (3) gives suggestions on selecting appropriate counting methods and technologies, and (4) provides examples of how organizations have used non-motorized count data to better fulfill their missions. The research behind the Guidebook can be found on the TRB website as *NCHRP Web-Only Document 205: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection* (NWOD 205). NWOD 205 includes the results of the testing and evaluation of a range of automated count technologies that capture pedestrian and bicycle volume data.

The lack of pedestrian and bicycle volume data is a barrier to transportation agency efforts to plan more effective facilities and to improve safety for pedestrians and bicyclists. Transportation agencies have well-established procedures for collecting, summarizing, and disseminating motor vehicle traffic volumes, but these procedures do not generally provide pedestrian and bicycle volume data. Most pedestrian and bicycle volume data collection is done for specific project locations after preliminary selection of candidate project locations has been made. The lack of systemwide pedestrian and bicycle volume data limits the ability of transportation agencies to provide or improve pedestrian and bicycle facilities where the need is greatest and is an impediment to developing better predictive methods for pedestrian and bicycle crashes.

Many potential sources of pedestrian and bicycle volume data are not being used. The feasibility of using these sources, including addressing privacy and security issues and extrapolating to estimate 24-hour counts and annual counts, needed to be investigated. Once investigated, guidance for practitioners on the use of existing, new, and innovative methods and technologies could be developed.

Under NCHRP Project 07-19, “Methods and Technologies for Collecting Pedestrian and Bicycle Volume Data,” a research team led by Kittelson & Associates, Inc., assessed new data sources and new technologies for obtaining pedestrian and bicycle volume data for use in systemwide needs assessments, project development, and safety management. The team tested and evaluated a range of automated count technologies focusing on different count settings (i.e., ranges of temperature, varying weather conditions, mixed traffic conditions, mixed travel directions, and different facility types) to determine their accuracy and reliability in the different contexts.

Research results have been documented in two publications. This Guidebook is geared to the application of results by practitioners. NWOD 205, which can be found on the TRB website, is recommended reading for those interested in the details of the research that led to the Guidebook.

AUTHOR ACKNOWLEDGMENTS

This guidebook was developed under NCHRP Project 07-19. Paul Ryus of Kittelson & Associates, Inc. (KAI) was the Principal Investigator. Co-investigators were Erin Ferguson and Kelly M. Laustsen of KAI; Robert J. Schneider of University of Wisconsin-Milwaukee; Frank R. Proulx of Safe Transportation Research & Education Center (SafeTREC), University of California, Berkeley; Tony Hull of Toole Design Group (TDG); and Luis Miranda-Moreno of McGill University.

Additional members of the research team were Andrew Ooms of KAI; Jessica Horning, formerly with KAI; and RJ Eldridge, Jennifer Toole, Katie Mencarini, Ciara Schlichting, and Jim Elliott of TDG. Jackie Olsommer and Dorret Oosterhoff of KAI provided administrative assistance. Tony Dang, Karen Chu, Noor Al-Samarrai, Brandon Lee, Sana Ahmed, Saad Patel, and Nellie Nafissi of SafeTREC spent many hours developing manual counts from video footage.

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- *University of Minnesota*: Greg Lindsey, Steve Hankey, and Peter Hankla

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Jamie Parks, now with the City of Oakland, California, got the project started while at KAI and provided review comments throughout the course of the project. Dr. Greg Lindsey of the University of Minnesota shared data and advice with the research team.



CONTENTS

ix	Quick Start Guide
ix	How to Use This Guide
x	Introduction to Non-Motorized Counting
xi	Potential Applications for Non-Motorized Counts
xii	Planning and Implementing a Data Collection Program
xiv	Adjusting Count Data
xvi	Sensor Technologies
xvii	Case Studies
xvii	Other Resources
1	Chapter 1 Introduction
1	1.1 About This Guidebook
2	1.2 Guidebook Scope
5	1.3 Non-Motorized Counting Concepts
10	Chapter 2 Non-Motorized Count Data Applications
10	2.1 Measuring Facility Usage
12	2.2 Evaluating Before-and-After Volumes
14	2.3 Monitoring Travel Patterns
15	2.4 Safety Analysis
17	2.5 Project Prioritization
19	2.6 Multimodal Model Development
21	Chapter 3 Data Collection Planning and Implementation
21	3.1 Chapter Organization
22	3.2 Planning the Count Program
42	3.3 Implementing the Count Program
57	Chapter 4 Adjusting Count Data
57	4.1 Chapter Overview
57	4.2 Sources of Counter Inaccuracy
59	4.3 Measured Counter Accuracy
61	4.4 Counter Correction Factors
66	4.5 Expansion Factors
70	4.6 Example Application of Factor Adjustment Methods
75	Chapter 5 Sensor Technology Toolbox
76	5.1 Manual In-Field Counts
78	5.2 Manual Counts from Video
80	5.3 Automated Counts from Video
81	5.4 Pneumatic Tubes
84	5.5 Inductive Loop Detectors
87	5.6 Passive Infrared

89	5.7 Active Infrared
91	5.8 Piezoelectric Strips
92	5.9 Radio Beams
95	5.10 Thermal
96	5.11 Laser Scanners
96	5.12 Pressure and Acoustic Pads
98	5.13 Magnetometers
98	5.14 Fiberoptic Pressure Sensors
100	Chapter 6 References
103	Appendix A Case Studies
117	Appendix B Manual Pedestrian and Bicyclist Counts: Example Data Collector Instructions
121	Appendix C Count Protocol Used for NCHRP Project 07-19
138	Appendix D Day-of-Year Factoring Approach



Quick Start Guide

Guidebook Organization

- Chapter 1: Introduction
- Chapter 2: Non-Motorized Count Data Applications
- Chapter 3: Data Collection Planning and Implementation
- Chapter 4: Adjusting Count Data
- Chapter 5: Sensor Technology Toolbox
- Chapter 6: References
- Appendix A: Case Studies
- Appendix B: Manual Pedestrian and Bicycle Counts: Example Data Collector Instructions
- Appendix C: Count Protocol Used for NCHRP Project 07-19
- Appendix D: Day-of-Year Factoring Approach

How to Use This Guide

This *Guidebook on Pedestrian and Bicycle Volume Data Collection* is a resource for those who are, or would like to be, involved in collecting non-motorized count data. The guidebook

- Describes methods and technologies for counting pedestrians and bicyclists,
- Offers guidance on developing a non-motorized count program,
- Gives suggestions on selecting appropriate counting methods and technologies, and
- Provides examples of how organizations have used non-motorized count data to better fulfill their missions.

This guidebook also describes correction factors to improve the accuracy of counts produced by automated counters, factors for expanding short-term counts to longer-term volume estimates, and factors for adjusting counts to reflect environmental conditions at the time of the count, such as rain. Related topics, such as trip sampling techniques (e.g., surveys, wireless device detection, and global positioning system [GPS] data), pedestrian and bicycle presence detection, and pedestrian and bicycle trip generation estimation, are outside the guidebook's scope.

This Quick Start section provides the highlights from each guidebook chapter, to help readers quickly find the most important information in the guidebook and to lead them to the material of greatest interest to them.

Chapter 1 Topics

- Guidebook objectives
- Guidebook organization
- Guidebook development
- Topics covered in the guidebook
- Related topics *not* covered in the guidebook
- Relationship of the guidebook to the FHWA *Traffic Monitoring Guide*
- Important differences between motorized and non-motorized counting
- Components of a non-motorized volume counter

Introduction to Non-Motorized Counting

Chapter 1, Introduction, describes how the guidebook is organized and summarizes the research that led to its development (Section 1.1), discusses what is and is not covered in the guidebook (Section 1.2), and gives an overview on non-motorized counting concepts (Section 1.3).

While methods and technologies for motorized vehicle counting are well established, there has been little national guidance available on pedestrian and bicycle counting, primarily consisting of the National Bicycle and Pedestrian Documentation Program (NBPD), which began in 2004, and the FHWA's *Traffic Monitoring Guide* (TMG), which added a chapter on non-motorized counting in 2013. This guidebook is intended to help fill this gap.

There are some important differences between motorized and non-motorized traffic counting. In particular

- **Pedestrian and bicycle volumes are more variable than motor vehicle volumes.** While both motorized and non-motorized volumes vary over time (e.g., by time of day, by season of year), non-motorized volumes on a given day are much more sensitive to the weather that day than are motorized volumes. In addition, hourly pedestrian and bicycle volumes at most locations tend to be relatively low compared to the volumes observed at typical motorized vehicle count sites; these lower volumes also contribute to higher day-to-day variability.
- **Pedestrian and bicycle trips tend to be shorter than automobile trips and are often made for different purposes.** As a result, pedestrian and bicycle volumes tend to be more sensitive to adjacent land uses (automobiles may be just passing through an area, rather than beginning or ending a trip there, and peak periods for pedestrian and bicycle trips may not necessarily coincide with the peak periods for automobile traffic).
- **Motor vehicles tend to be easier to detect than pedestrians and bicycles.** Pedestrians and bicyclists are smaller than motor vehicles, often travel together in close groups, and may travel outside designated walkways and bikeways. In contrast, motor vehicles are large, metal objects that move in lanes and travel with relatively sizable gaps between each vehicle (FHWA 2013).
- **Experience with pedestrian and bicycle counting technology is more limited than for motor vehicles.** The technologies commonly used to count motor vehicles are well established, counting errors associated with particular technologies are understood, and methods for addressing errors are fairly well developed (FHWA 2013). In contrast, some of the counting technologies used for non-motorized counting are different than those commonly used for motorized vehicle counting, and new technologies are emerging.

Chapter 2 Topics

- Measuring the usage of a pedestrian or bicycle facility
- Measuring the change in pedestrian or bicycling activity following the development or improvement of a facility
- Monitoring non-motorized travel patterns
- Using non-motorized count data to evaluate risk or exposure as part of safety analyses
- Applying count data when prioritizing transportation projects
- Using count data in developing and validating multimodal travel demand models

The greater variability present in non-motorized volumes means that factoring techniques used to estimate long-term (e.g., annual) motorized volumes based on short-term (i.e., 24-hour or less) counts are not necessarily appropriate for non-motorized counting. Many sources in the literature (e.g., Danish Road Directorate 2004, Niska et al. 2012, Nordback et al. 2013) show that the error in estimating average annual bicycle traffic from 2-hour, 12-hour, or even 1-week counts can be up to 40%.

Potential Applications for Non-Motorized Counts

Chapter 2, Non-Motorized Count Data Applications, provides real-world examples of the many ways that non-motorized count data can be applied to improve the way transportation organizations perform their work. This project's practitioner survey found that the most common ways that pedestrian and bicycle count data were being used were

- Tracking changes in pedestrian and bicycle activity over time,
- Evaluating the effects of new infrastructure on pedestrian and bicycle activity,
- Prioritizing pedestrian and bicycle projects,
- Modeling transportation networks and estimating annual volumes, and
- Conducting risk or exposure analyses.

Chapter 2 describes and provides examples of applying non-motorized count data in the following ways:

- Measuring facility usage at the city and state levels;
- Evaluating before-and-after volumes after a new facility is opened, as performed by a metropolitan planning organization (MPO) and a city;
- Monitoring travel patterns at automated count sites, for use in developing factors to expand short-term bicycle and pedestrian counts at other locations, as conducted by a county and an MPO;
- Counting non-motorized volumes to quantify exposure and develop crash rates and to identify the before-and-after safety effects of upgrading a facility;
- Identifying high-priority locations for pedestrian and bicycle facility improvements; and
- Developing and calibrating multimodal travel demand models.

Non-motorized count data will likely continue to grow in importance as states and regions integrate non-motorized performance measures into their performance management programs, including performance reporting occurring due to MAP-21 transportation funding requirements.

Chapter 3 Topics

- Planning a non-motorized volume counting program
- Implementing the count program

Planning and Implementing
a Data Collection Program

Chapter 3, **Data Collection Planning and Implementation**, describes the steps involved in starting and expanding a non-motorized count program:

<u>Planning the Count Program</u>	<u>Implementing the Count Program</u>
Specify the data collection purpose	Obtain necessary permissions
Identify data collection resources	Procure counting devices*
Select count locations and determine the count timeframe	Inventory and prepare devices*
Consider available counting methods and technologies	Train staff
	Install and validate devices*
	Calibrate devices*
	Maintain devices*
	Manage count data
	Clean and correct count data
	Apply count data

*Steps that only apply to counts using automated counting techniques.

Planning the Program

The following steps are involved when starting to plan a non-motorized count program:

- **Specify the data collection purpose.** It is important to define at the start *why* data will be collected and *how* the data will be used, as this information drives subsequent decisions about where, when, and how to collect data. Both current and potential future uses of data should be considered.
- **Identify data collection resources.** Available resources will help define the initial scale of the program. Many successful programs have started with a small number of count sites and later expanded after the value of performing counts had been demonstrated. Even organizations with no dedicated counting budget can start a program by organizing volunteers, creating partnerships with other agencies, and/or taking advantage of existing data collected by others.
- **Select general count locations and determine the count timeframe.** Pedestrian and bicycle data collection programs can benefit from combining two approaches: (1) gathering short-duration counts (typically less than one day to several days, but potentially up to several months) at many locations; and (2) gathering continuous counts over multiple years at a small sample of locations. Count sites can be selected in a number of ways, but the data collection purpose should always be a consideration when selecting sites. In addition to identifying the geographic scope of their count program, organizations need to think about *how long* and *how often* counts will occur.
- **Consider available counting methods and technologies.** There are a number of available technologies for counting pedestrians and bicycles, and many count programs use several of these. According to this project’s practitioner survey, the most common technologies are

manual counts (i.e., the human eye), passive infrared, active infrared, radio beam, pneumatic tubes, inductive loops, piezoelectric sensor, radio beam, and automated video. Matching a specific technology to a specific site requires considering

- The site’s physical characteristics (e.g., facility width, background objects, ease of mounting or installing a counter, and intersection versus mid-block location);
- The site’s user characteristics (e.g., pedestrians only versus bicycles and pedestrians, tendency of users to travel in groups, and anticipated peak user volumes);
- Whether only counts are required, or also user behavior or demographic data (e.g., helmet use and gender); and
- Need for obtaining permits or other forms of permission.

Implementing the Program

The following steps are involved when implementing the counting program:

- **Obtaining permission.** If the organization conducting the counts is not the same as the organization owning the right-of-way (e.g., a public works department or a DOT) or objects within or next to the right-of-way that will be used to mount equipment (e.g., a utility pole or a building face), it will likely be necessary to obtain permission to install a counter. Tracking down whom to ask and then obtaining permission can take some time, which should be planned for in the implementation schedule.
- **Procuring counting devices.** Choosing good equipment and a good vendor is important when using automated technology as part of a count program. The sensor technology itself is supported by other equipment (e.g., mounting devices and data loggers) that are also essential for the success of a counting product, and the vendor’s customer service record is important to consider. Section 3.3.2 provides suggested questions to ask vendors when considering purchasing equipment. It often takes 1 to 2 months to obtain equipment after placing an order, which should be planned for in the schedule.
- **Inventorying and preparing devices.** An inventory documents whether all the expected equipment has been delivered. In addition, an inventory is useful for identifying additional tools or supporting equipment that may be necessary to obtain in advance of field installation (e.g., wrenches, screws, fastening devices, and batteries). In these security-conscious times, it is also a good idea to place contact information on the equipment. Section 3.3.3 provides an equipment preparation checklist.
- **Training staff.** Staff training is important for both automated and manual counting, although the kind of training involved is very different for the two types of counting. With automated counting, training involves how to monitor and adjust the equipment, while manual counting requires training staff or volunteers on how to perform a count. Section 3.3.4 provides an equipment monitoring checklist for automated counts and a description of key elements for manual counter training.
- **Installing and validating equipment.** Equipment installation can be one of the most challenging steps in the data collection process. Count managers should budget significant time for installation to ensure that it is done correctly. To help practitioners successfully install equipment, Section 3.3.5 provides the following checklists of activities to perform before, during, and after installation: advance preparation, on-site arrival, counter installation, post-installation, and follow-up. An important step in the equipment installation process is validation: determining whether or not a device is working properly and taking inventory of existing and planned facilities at the count location. Validation involves testing the device both on the installation day and several days after installation.

- **Calibrating devices.** The sensors used in some counting technologies (e.g., inductive loops and pneumatic tubes) can be adjusted to make the sensor more or less sensitive, and thereby less prone to non-detections (undercounting) or false-positive detections (overcounting). The initial test period during installation can suggest whether or not a sensitivity adjustment is needed. Validation counts should also be performed at least once a year to monitor a device's accuracy, and the device recalibrated as needed.
- **Maintaining devices.** Counting equipment must be regularly maintained to ensure accurate, consistent counts. In particular, staff should visit permanent count sites at least every 3 months to check that devices are still present, pointed in the correct direction, and in working condition. Staff should check for the accumulation of dirt, mud, water, or other materials that could affect the sensor or other equipment components.
- **Managing count data.** Various systems are available for managing data after data have been downloaded from the counter, including in-house spreadsheets and databases, vendor-supplied software, in-house software, and cloud-based repositories. When possible, organizations should consider building on the expertise and data management systems they may have already developed for their motorized count data. In addition to saving time and effort by using an existing framework, integrating pedestrian and bicycle counts into a motorized count database can help an organization create a fully multimodal traffic monitoring system.
- **Cleaning and correcting count data.** *Cleaning* count data refers to identifying and addressing problems with the data (e.g., no recorded counts for a period of time or unusually high counts with no obvious explanation). *Correcting* count data refers to adjusting the raw count results to address the under- or overcounting inherent to a particular technology.
- **Applying count data.** Once the count data have been collected, adjusted, cleaned, and stored, they are ready to be used in all of the ways described in Chapter 2.

Adjusting Count Data

Chapter 4, Adjusting Count Data, focuses on two types of factors that can be applied to count data when developing volume estimates:

- **Correction factors** are developed from validation counts and account for systematic inaccuracies in counter technology. These factors are used to adjust raw counts to more closely represent the ground truth.
- **Expansion factors** are applied specifically to short-duration counts to estimate volumes over longer periods of time.

Chapter 4 Topics

- Sources of automated counter errors
- Measured accuracy and precision of automated sensor technologies
- Correction factors for automated counters, used to adjust raw counts to more closely represent the ground truth
- Expansion factors, applied to short-duration counts to estimate volumes over longer periods of time
- Example application of applying correction and expansion factors

The primary sources of errors that require correction are

- **Occlusion.** Some counter technologies count users who cross an invisible screenline. When two or more people cross the line simultaneously, an undercount occurs because the device only detects the person nearest the sensor.
- **Environmental conditions.** Depending on the particular counting technology, precipitation, temperature, or lighting conditions may create undercounts (i.e., a person is not detected who should have been) or overcounts (e.g., when snowflakes are counted as persons).
- **Bypass errors.** In some cases, it may not be technologically possible for a counter's detection zone to cover the full facility width; in other cases, it may be possible for users to bypass the detection zone (e.g., bicyclists riding on the sidewalk, when the counter is in the bike lane). In these cases, a counter could be perfectly accurate at detecting persons passing through its detection zone and yet not produce a perfectly accurate count of the number of persons using the facility.
- **Mixed-traffic effects.** When bicycle counters are located close to, or in, the motor vehicle travel lanes, some motor vehicles may be counted as bicycles, or bicycles may be missed if a motor vehicle passes the counter at the same time.

Section 4.3 provides statistics on the accuracy and consistency of various automated counting technologies tested under NCHRP Project 07-19. In this guidebook, *accuracy* refers to the magnitude of the difference between the count produced by the technology and the actual ("ground truth") count (gathered manually from video data or another means of obtaining a precise estimate of the actual count). This difference typically depends on user volumes, movement patterns, traffic mix, and environmental characteristics. *Consistency* reflects the remaining variability in the count data after being corrected for expected under- or overcounting, given specific conditions. This variability typically depends on the counting technology itself, how a specific vendor uses the technology in a particular product, and the quality of the installation.

Section 4.4 provides correction factors for adjusting the raw counts produced by a counter to more accurately reflect the true volumes. Because the accuracy of a given counting technology can vary substantially between different vendors' implementations of the technology, and because site-specific conditions can also affect a counter's accuracy, it is recommended that local correction factors be developed whenever possible. These factors can be applied to (1) a permanent count site, to account for both technological and site-specific sources of errors, or (2) a device used for short-term counts used at many sites, to account for the device's technological sources of error. Section 4.4.2 describes how to develop local correction factors.

Expansion factors are used to estimate pedestrian or bicycle volumes under conditions different than actually counted and include the following types of adjustments:

- **Temporal adjustments.** Temporal adjustments are used to estimate volumes at a different time, or for a longer time period, than was counted. A common application is to expand a short-term count to an estimate of annual volume.
- **Environmental adjustments.** Environmental adjustments are used to estimate what the counted volume would have been under different conditions than occurred during the count. For example, a count taken during rainy, hot, or windy conditions could be adjusted to estimate the volume that would have been seen on a good weather day.
- **Land use and facility type adjustments.** These adjustments can be used to account for differences in volumes attributable to differences in the surroundings of a count site, compared to a continuously counted control site.

Expansion factors are typically applied to short-term count sites sharing an activity profile (e.g., commuter versus recreational route or shopping district versus residential area) similar to that of the continuously counted site(s) used to develop the expansion factor.

Section 4.6 provides a simplified, hypothetical exercise of working with raw data to arrive at an estimate of annual volumes.

Sensor Technologies

Chapter 5, Sensor Technology Toolbox, summarizes 14 existing and emerging sensor technologies available for non-motorized counting. Each technology or method (in the case of manual counting) is presented in its own subsection, along with the following information:

- **Description** of how the counting technology or method detects pedestrians or bicyclists;
- **Typical applications** for the technology;
- General **installation considerations** for the technology (The manufacturer's installation recommendations should take precedence over these general considerations);
- Relative **level of effort and cost**, drawing from the literature, vendor-provided information, and the research team's experience;
- **Strengths and limitations** of the technology or method, drawing from the literature and the research team's experience;
- **Accuracy**, drawing from the NCHRP Project 07-19 testing when possible, and supplementing from the available literature; and
- Description of current **usage**, drawing from the NCHRP Project 07-19 practitioner surveys and interviews.

Chapter 5 Topics

Chapter 5 summarizes typical applications, installation considerations, relative level of effort and cost, strengths and limitations, accuracy, and usage of 14 existing and emerging counting technologies and methods:

- Manual in-field counting
- Manual counts from video
- Automated counts from video
- Pneumatic tubes
- Inductive loop detectors
- Passive infrared
- Active infrared
- Piezoelectric strips
- Radio beams
- Thermal
- Laser scanners
- Pressure and acoustic pads
- Magnetometers
- Fiberoptic pressure sensors

Case Studies

Appendix A provides ten real-world case studies that highlight particular aspects of non-motorized counting:

1. Using continuous count patterns to compare short pedestrian counts;
2. Using continuous count data to achieve multiple purposes;
3. Using pedestrian volume patterns to provide data for a community-wide demand model;
4. Using pedestrian volume patterns to provide exposure data for a safety analysis;
5. Using volunteers to collect annual pedestrian and bicycle counts;
6. Using counts to document trail use, involving coordination among three organizations;
7. Using a systematic process to select permanent count sites;
8. Using automated counters to identify common bicycle volume patterns;
9. Using counts to map pedestrian and bicycle volumes throughout a community; and
10. Using counts to classify bicycle traffic patterns in five North American cities.

Other Resources

Appendix B provides sample data collector instructions for performing manual pedestrian and bicycle counts. **Appendix C** provides the count protocol used by NCHRP Project 07-19 for generating ground truth manual counts from video, used in determining the accuracy of various automated counting devices. **Appendix D** describes an approach for expanding short-term counts based on day-of-the-year factors, rather than the traditional day-of-week and month-of-year approach.

Introduction

Chapter 1 Topics

- Guidebook objectives
- Guidebook organization
- Guidebook development
- Topics covered in the guidebook
- Related topics *not* covered in the guidebook
- Relationship of the guidebook to the FHWA *Traffic Monitoring Guide*
- Important differences between motorized and non-motorized counting
- Components of a non-motorized volume counter

1.1 About This Guidebook

This *Guidebook on Pedestrian and Bicycle Volume Data Collection* is a resource for practitioners who are, or would like to be, involved in collecting non-motorized count data. The guidebook describes methods and technologies for counting pedestrians and bicyclists, with a focus on automated technologies. The guidebook also provides guidance on developing a data collection program, selecting appropriate counting technologies, and using the data to help fulfill an organization's mission.

1.1.1 Guidebook Objectives

This guidebook is designed to help practitioners

- Understand the value of collecting pedestrian and bicycle volume data;
- Develop a pedestrian and bicycle data collection plan, including identifying count locations, determining count frequencies and durations, and establishing data management and sharing standards;

Sidebars

Sidebars such as this are provided throughout the guidebook to provide more detail on particular topics and to provide examples of real-world applications.

- Identify and recommend data collection methods that will meet their project needs, while considering the organization's available resources; and
- Correct raw count data to account for systematic over- or undercounting resulting from the use of a particular counting technology.

1.1.2 Guidebook Organization

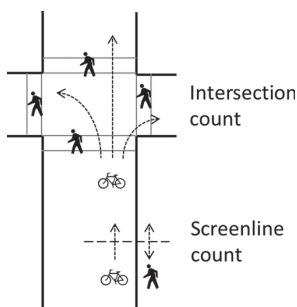
This guidebook contains five main chapters. It is not necessary to read the entire guidebook cover to cover to make use of it. In particular, Chapters 4 and 5 provide reference information that applies to various counting technologies; readers only need to look at the portions of these chapters that apply to the specific technologies they are using or considering using.

The guidebook's chapters are organized as follows:

1. **Introduction:** This chapter provides an overview of the guidebook's purpose and describes related topics outside the guidebook's scope. This chapter also introduces the components of a counting system. Finally, the chapter provides a brief summary of the research behind this guidebook.
2. **Non-Motorized Count Data Applications:** This chapter describes and illustrates potential uses of pedestrian and bicycle data.
3. **Data Collection Planning and Implementation:** This chapter is the heart of the guidebook—it provides guidance on the various steps of the process involved with starting, implementing, maintaining, and expanding a non-motorized volume data collection program.
4. **Adjusting Count Data:** This chapter provides adjustment factors for correcting raw count data to account for systematic over- or undercounting associated with the use of a particular counting technology.
5. **Sensor Technology Toolbox:** This chapter provides a toolbox of the existing and emerging sensor technologies available for non-motorized counting, including information on each technology's strengths and limitations, accuracy, costs, and availability and usage in the United States as of the time of writing.

1.1.3 Guidebook Development and Research Objective

This guidebook is a product of NCHRP Project 07-19, "Methods and Technologies for Pedestrian and Bicycle Volume Data Collection." The objective of this research was to assess existing, new, and innovative technologies and methods and to provide guidance for transportation practitioners on how to best collect pedestrian and bicycle volume data. This assessment was to consider, among other factors, the feasibility, availability, quality, reliability, cost, and compatibility of various counting technologies. A summary of the research activities conducted as part of this project can be found in the project's final report (Ryus et al. 2014).



1.2 Guidebook Scope

1.2.1 Topics Covered in the Guidebook

This guidebook focuses on methods and technologies for collecting non-motorized volume data. It addresses both manual and automated methods, although it emphasizes automated methods, as these have been covered less comprehensively in the literature to date. A mature non-motorized counting program typically employs a mix of manual and automated counts.

The guidebook addresses both intersection and screenline counts, but focuses on screenline counts, as most of the automated counting technologies on the market are used for such counts.

Screenline counts are counts of the number of pedestrians or bicyclists crossing an imaginary line. Intersection counts include counts of pedestrians crossing each roadway leg or counts of bicyclists turning left, turning right, or going straight. Intersection counts have a number of uses, but the technologies available at present to collect these counts are limited to (1) manual counts in the field, (2) manual counts from video, and (3) automated counts from video. (The same technologies are also used for collecting motorized vehicle counts at intersections.)

As previously mentioned, the guidebook also discusses how to develop a non-motorized count program and how to adjust raw counts to account for systematic errors associated with a particular counting technology.

1.2.2 Related Topics

This guidebook covers methods for counting the actual number of pedestrians or bicyclists passing a given point or screenline or crossing an intersection. Three topics related to non-motorized volume counting *not* covered in this guidebook are trip sampling techniques, presence detection, and trip generation estimation.

Trip Sampling Techniques

As the name suggests, sampling techniques count a sample of the total volume passing a location or traveling between two points. These techniques are better suited for evaluating origin–destination travel patterns, investigating traveler route choice decisions, and estimating overall mode split, than they are for estimating volumes at a given location. Examples of sampling techniques include the following.

Bluetooth and WiFi Detection

Electronic devices with actively engaged Bluetooth and/or WiFi communication capabilities regularly transmit “here I am”–type messages. Included in these messages is a unique identifier (Media Access Control, or MAC, address) associated with the device’s Bluetooth or WiFi transmitter. Bluetooth or WiFi readers can detect and record these MAC addresses; by comparing the times and locations when a particular MAC address was recorded by different readers, a possible route and travel time can be estimated. It is not possible to differentiate between modes (e.g., motor vehicles, bicyclists, pedestrians) by this means; therefore, its application to pedestrian and bicycle studies is limited to isolated non-motorized environments, such as trails, malls, and stadiums (Liebig and Wagoum 2012). Estimating total pedestrian or bicycle volumes from these data samples is problematic even in these isolated locations, due to the need for location-specific adjustment factors, such as

- Percentage of users with Bluetooth-enabled devices,
- Percentage of Bluetooth-enabled devices turned on, and
- Percentage of users with multiple Bluetooth devices (e.g., phone and earpiece).

GPS Data Collection

Multiple efforts have used standalone GPS units or smartphone applications that use a phone’s GPS functionality to collect non-motorized trip data (Hood et al. 2011). These applications have been used primarily to evaluate route choice, but have also been used to compare demand at different locations. The sample data collected through this method can be used to establish minimum volumes at a location, but cannot be adjusted to estimate total pedestrian or bicycle volumes. Sample bias is also an issue with these technologies, as those being counted have to opt-in to the program and—with smartphone apps—have to own a smartphone and remember to use the app on each trip.

Radio Frequency ID (RFID) Tags

RFID tags are commonly used in the logistics industry for tracking individual packages and containers. The tags can be read at a distance of 5 to 10 meters, depending on the antenna power and particular radio frequency used (Andersen 2011). As with GPS-based methods, sample bias is an issue with this technology, as people have to “opt-in” to the program by placing tags on their bicycles. Unlike GPS-based methods, a bicycle’s position is known only at specific locations where an RFID reader has been placed. Fredericia, Denmark, uses these tags as part of a program to encourage residents and commuters to bike more often, with each “check-in” at a location counting as an entry to a prize drawing (www.cykelscore.dk).

Bike Sharing Data

Bike sharing stations can record the identification number of a bike when it is checked in or out at a particular station. Some bike sharing programs also equip their bicycles with GPS devices. These data can be used to estimate origin–destination patterns and possible routes and travel times. Because the data are reflective of bike share users only, rather than the bicycling population as a whole, and because the bicycle’s location may only be known with certainty at the bike share stations, it is not a practical method for determining actual bicycle volumes at a given time and place.

Pedestrian Signal Actuation Buttons

At some traffic signals, pedestrians have to push a button to activate the WALK signal for the pedestrian crossing. The number of requests can be stored, and researchers have found that signal activation rates can be a reasonable proxy for determining relative rates of pedestrian demand (Day et al. 2011). However, these researchers also stated that observing these rates is not an effective method for collecting total pedestrian counts. At the time of writing, Portland, Oregon, counted and stored pedestrian button activations at 14 locations, with more locations planned, and was investigating the possibility of developing relationships between actuations and demand, based on-site characteristics (Kothuri et al. 2012b).

Surveys

Surveys can be used to collect such pedestrian- and bicyclist-related data as mode share and origin–destination patterns. Mode shares can then be extrapolated to determine total pedestrian volumes for a larger area, such as within a neighborhood or traffic analysis zone (TAZ). However, estimates made this way are not suitable for collecting count data, due to the relatively small sample size in contrast with a relatively large sample area with complex land use patterns.

Presence Detection

Some of the sensor technologies discussed in this guidebook can be used to detect pedestrians and bicycles. For example, they may be used to detect the presence of bicyclists or pedestrians at a traffic signal, so the traffic signal can adjust its timing to serve those users. They can also be used to detect the presence of a pedestrian or bicyclist in an unauthorized area, such as a tunnel. Because these applications focus on whether or not a pedestrian or bicyclist is present, rather than determining the number of people present, these applications are not a substitute for counting. However, at the time of writing, vendors that specialized in presence-detection applications were working on expanding their functionality to include counting applications.

Trip Generation

Transportation engineers have long used the Institute of Transportation Engineers’ *Trip Generation Manual* (ITE 2012) to estimate the number of motorized vehicle trips that would be generated by a particular land use. A recent NCHRP Project 08-78, “Estimating Bicycling and Walking for Planning and Project Development,” has developed a guidebook (published as *NCHRP*

Hyperlinks

In the PDF version of this guidebook, click on web addresses to go directly to that website or document. Website addresses are subject to change; if a link no longer works, use an Internet search engine to find the document or site.

Report 770) with guidance on estimating pedestrian and bicycle trip generation associated with particular types of trips and demand to use particular pedestrian and bicycle facilities (Kuzmyak et al. 2014). A fundamental difference between trip generation estimation and volume counting is that the former forecasts future demand, while volume counting measures current usage. However, improved and more widespread volume counting can aid the development of better trip generation estimates.

1.2.3 Relationship to the *Traffic Monitoring Guide*

The FHWA's *Traffic Monitoring Guide* (TMG) provides “up to date guidance to State highway agencies in the policies, standards, procedures, and equipment typically used in a traffic monitoring program” (FHWA 2014). The 2013 edition of the guide includes information on non-motorized traffic counting; Chapter 4 specifically addresses traffic monitoring for non-motorized traffic. This NCHRP research project and guidebook complement the FHWA guide by providing more recent data on the accuracy of various counting technologies and providing real-world examples of non-motorized traffic counting applications. The TMG is available at <http://www.fhwa.dot.gov/policyinformation/tmguide/>.

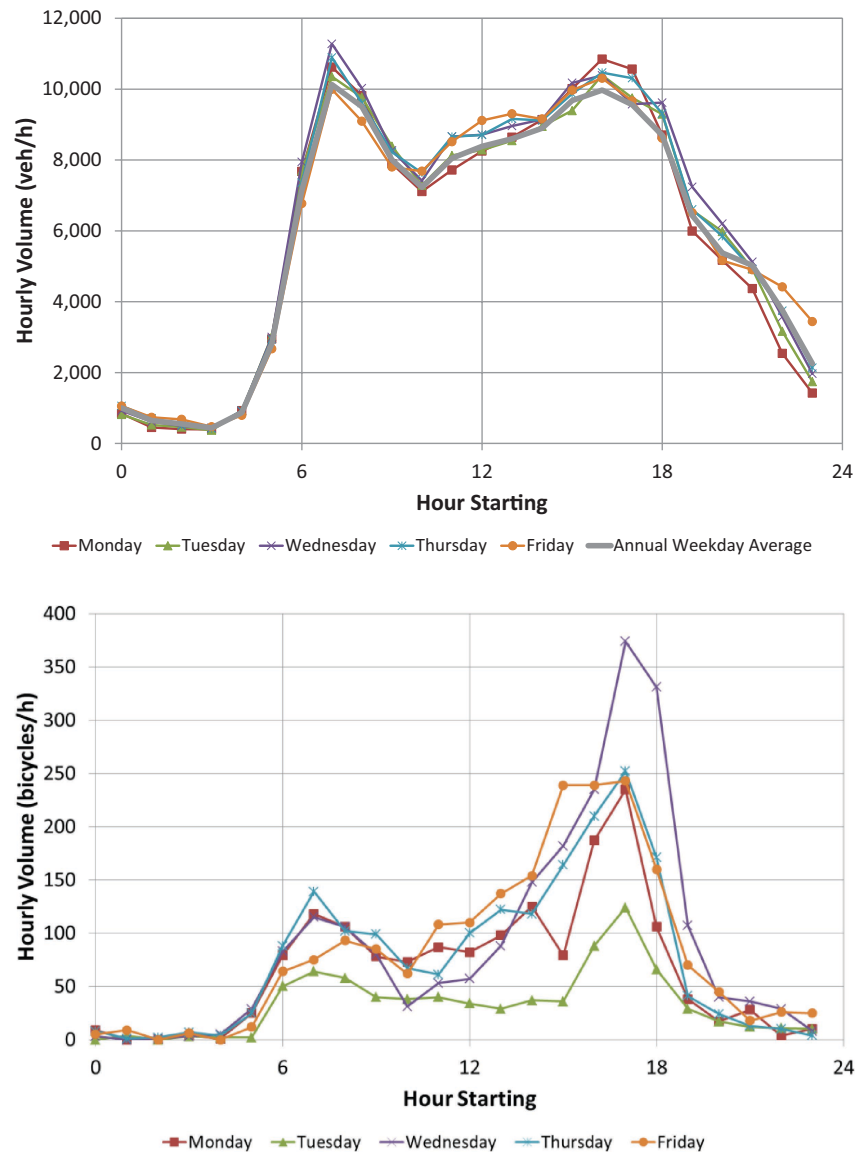
1.3 Non-Motorized Counting Concepts

1.3.1 Differences between Motorized and Non-Motorized Traffic Counting

Developing a non-motorized traffic count program presents unique challenges in comparison to motorized vehicle counting. Most transportation agencies have standard practices for collecting vehicular counts and have historical data available for assessing daily, seasonal, and annual trends. Agencies have a history of using “rules-of-thumb” to expand short-term motorized counts based on a roadway’s classification and character, as well as the time of day and year when the short-term count was taken. In contrast, there is limited U.S. guidance available on bicycle and pedestrian data collection—mostly developed since 2004 (e.g., the National Bicycle and Pedestrian Documentation Program [NBPD, Alta Planning + Design 2012], the *Traffic Monitoring Guide* [FHWA 2013])—and few agencies have developed a standard local practice.

Differences in Demand Variability

One key difference between non-motorized and motorized volume counting that must always be kept in mind is that non-motorized volumes are much more sensitive to environmental conditions—precipitation, temperature, darkness, etc.—than are motorized vehicle volumes. Figure 1-1 compares observed hourly bicycle volumes on a multi-use path in Minneapolis with observed hourly automobile volumes on a parallel freeway a couple of miles away, for 1 week in October 2013. Although the auto volumes are fairly similar, with the p.m. peak-hour volume



Sources: Auto: Minnesota DOT automatic traffic recorder #326 (I-394);
Bicycle: NCHRP Project 07-19 testing, Midtown Greenway.

Figure 1-1. Comparative variability of automobile (top) and bicycle (bottom) volumes, October 14–18, 2013.

varying only 5% from the lowest to the highest volume day, the bicycle volumes show 200% variability in the p.m. peak hour. According to Weather Underground’s archived weather data for Minneapolis, it rained about 1 inch on Tuesday, ½ inch on Monday and Thursday, 0.1 inch on Friday, and 0.01 inch on Wednesday.

Another critical difference is that hourly bicycle or pedestrian volumes at a given count site tend to be relatively low, compared to the volumes observed at typical motorized vehicle count sites; the lower volumes also contribute to higher day-to-day variability.

The greater variability present in non-motorized volumes means that factoring techniques used to estimate long-term (e.g., annual) motorized volumes based on short-term (i.e., 24-hour or less) counts are not necessarily appropriate for non-motorized counting. For example, a 12-hour motorized vehicle count could be converted to a daily count by dividing the counted

volume by the proportion of daily traffic occurring on average during the count period (based on previous 24-hour or longer counts), and the result could then be adjusted for monthly variations in traffic, as determined from data from a permanent counting station, to reach an estimate of average annual daily traffic (AADT). In comparison, a study of sites in Boulder, Colorado, found that estimates of average annual bicycle traffic (AABT) based on 12 hours of counts from a mid-week day had an average error of 40% from the true value (Nordback et al. 2013). Scandinavian research also confirms the difficulty of estimating AABT (Danish Road Directorate 2004) or year-to-year change in bicycle volumes (Niska et al. 2012), even when 1 week of count data was available. The longer timeframes required for accurate non-motorized volume estimates require greater usage of automated counting techniques.

Ease of Detection

Pedestrians and bicyclists are more challenging to detect than motor vehicles because they are smaller, move in less regular patterns, and are not confined to fixed lanes, as are vehicles. Pedestrians and bicyclists may travel outside designated walkways and bikeways, take unmarked shortcuts, or stop unexpectedly. In addition, pedestrians and bicyclists may travel in groups, which some types of counting technologies have difficulties distinguishing. In contrast, motor vehicles are large, metal objects that move with relatively sizable gaps between each vehicle, which make them easier to detect (FHWA 2013).

Experience with Counting Technology

Another key difference between motorized and non-motorized traffic counts relates to the level of experience with motor vehicle counts versus non-motorized counts. The technologies commonly used to count motor vehicles are well established, counting errors associated with particular technologies are understood, and methods for addressing errors are fairly well developed (FHWA 2013). In contrast, some of the counting technologies used for non-motorized counting are different from those commonly used for motorized vehicle counting, and new technologies are emerging. Even when counting technologies are similar (e.g., pneumatic tubes, inductive loops), the counting errors associated with these technologies can be different for non-motorized users than for motorized users. Therefore, one of the key objectives of this guidebook is to expand the available knowledge about the accuracy of non-motorized counting technologies.

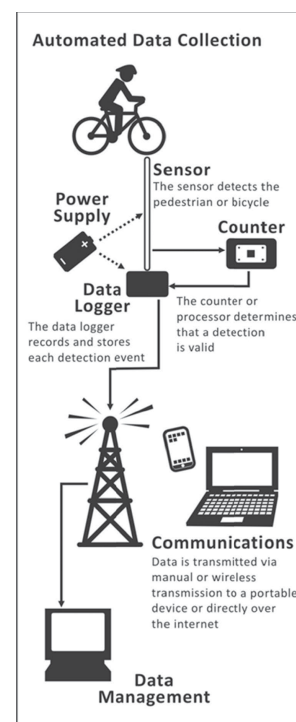
1.3.2 Counting System Components

Although it is easy to focus on the technology used to detect pedestrians or bicyclists when evaluating counting devices, it is important to remember that the sensor technology is just one piece of the overall counting system and that all of the pieces need to work well together for a successful application. This section briefly describes the elements constituting a counting device.

Sensor

The sensor is the portion of the counting device that detects pedestrians or bicyclists. Various sensor technologies are available for non-motorized counting, including

- The *human eye* (for manual counting in the field);
- *Video cameras* (for use with manual counting in the office or as an input to an automated method for identifying pedestrians or bicyclists);
- *Pneumatic tubes*, where a pulse of air is generated when a bicyclist rides over the tube;
- *Piezoelectric strips*, which emit an electrical signal when deformed by bicycle wheels passing over them;



- *Fiberoptic pressure* sensors, which detect changes in the amount of light transmitted through buried fiberoptic cable based on the amount of pressure (weight) applied to the cable;
- *Inductive loops*, where the magnetic field produced by an electrical current running through buried metal loops is changed when the metal parts of a bicycle pass over the loops;
- *Magnetometers*, which detect changes in the Earth's magnetic field when the metal parts of a bicycle pass over the detector;
- *Pressure* and *acoustic* sensors, which are placed under a pathway and detect the weight (pressure) or footsteps (acoustic) of passers-by;
- *Passive infrared* and *thermal* sensors, which detect the infrared radiation (heat) emitted by pedestrians and bicyclists;
- *Active infrared* and *radio beam* sensors, which send infrared light or radio beams from a transmitter to a receiver and detect when the beam is broken; and
- *Laser scanning*, in which laser pulses are emitted and the characteristics of the reflected pulses are used to detect pedestrians and bicyclists.

Counter (Processor)

The counter receives the sensor output and determines whether or not a detection should be recorded. In many cases, the counter's sensitivity can be adjusted to reduce the number of false-positive or false-negative detections. In some implementations, this is a component of the data collection unit, while in others this is a processing step undertaken on a personal computer after the data have been collected.

Data Logger

When a pedestrian or bicyclist is detected, this information is sent to the device's data logger. Some devices record every detection, along with the time of detection (*timestamping*), while others keep a running count of detections and store the totals in 15- or 60-minute *bins*. Typically, when the data logger's memory becomes full, the data logger begins to overwrite data, starting with the oldest data. The amount of available memory and the way it is used helps determine how often data must be downloaded from the device.

Power Supply

The counting device requires power to work, which can be provided by a replaceable battery, a permanent electrical connection, a solar panel, or other means. Battery life helps determine how often a maintenance trip must be made to the counter to change the battery.

Communications

A method is needed to transfer count data from the device to the user's database. Possible methods include communications ports for physically attaching a laptop computer or memory card, wireless (e.g., Bluetooth or WiFi) connections, or a cellular modem. The communications method has an associated cost (e.g., staff time to visit the counter to download data or subscription fees for cellular data service). The method may also influence how often data can be obtained from the device and how quickly problems with the device are detected.

Securement

A counting device usually needs some sort of physical housing (e.g., a box or a utility cabinet) to protect it from the elements and vandalism and a method of fastening it in place to prevent undesired movement or vibration and to discourage theft. During the research done for this project, it was sometimes difficult to obtain permission to install a device in a desired location if the method of securing the device was deemed to be visually unattractive. Additionally, one unit with a less-robust securement mechanism was stolen during the course of testing.

Data Management

Some counting products come with their own data management software; others require end users to manage the count data themselves (e.g., by storing it in a spreadsheet).

The Counting Device as a Whole

The complete counting device includes all of the above components. Different vendors may incorporate the same sensor technology, but use different components for other aspects of the device, which can affect the suitability of a particular product for a particular location. Some vendors offer the opportunity for the end user to customize certain components (e.g., the power supply). Finally, the customer service and training provided by the vendor plays an important role in a successful counting device deployment.



CHAPTER 2

Non-Motorized Count Data Applications

Chapter 2 Topics

- Measuring the usage of a pedestrian or bicycle facility
- Measuring the change in pedestrian or bicycling activity following the development or improvement of a facility
- Monitoring non-motorized travel patterns
- Using non-motorized count data to evaluate risk or exposure as part of safety analyses
- Applying count data when prioritizing transportation projects
- Using count data in developing and validating multimodal travel demand models

This chapter describes potential uses of pedestrian and bicycle data, using actual projects as examples of how the data can be applied. The practitioner survey conducted as part of the research leading to this guidebook found that the most common applications of non-motorized count data in the United States and Canada were (in decreasing order of usage):

- Tracking changes in pedestrian and bicycle activity over time,
- Evaluating the effects of new infrastructure on pedestrian and bicycle activity,
- Prioritizing pedestrian and bicycle projects,
- Modeling transportation networks and estimating annual volumes, and
- Conducting risk or exposure analyses.

2.1 Measuring Facility Usage

2.1.1 Potential Applications Details

Pedestrian and bicycle counting can serve as part of a larger transportation system monitoring program. This effort typically entails counting at set locations at regular intervals (e.g., annually) to identify how particular facilities are being used. As continuous data collection technologies are increasingly available, user volumes (especially on key facilities) can be observed throughout the year, providing a richer understanding of how usage changes over time.

An agency may also select locations to regularly collect non-motorized counts as a means of identifying growth trends in walking and bicycling on a particular facility or on the system as a

whole. The FHWA released a policy statement in 2010 that included the following recommended action:

“Collecting data on walking and biking trips: The best way to improve transportation networks for any mode is to collect and analyze trip data to optimize investments. Walking and bicycling trip data for many communities are lacking. This data gap can be overcome by establishing routine collection of non-motorized trip information. Communities that routinely collect walking and bicycling data are able to track trends and prioritize investments to ensure the success of new facilities. These data are also valuable in linking walking and bicycling with transit” (FHWA 2010).

As more agencies develop goals and targets for increasing the number of persons who walk and bike, having a database of pedestrian and bicyclist count data is critical for tracking progress and measuring success.

2.1.2 Example Applications

City of San Mateo, California

The City of San Mateo began conducting pedestrian and bicycle counts as a result of a Bicycle Master Plan adopted in 2011. The plan stated that bicycle counts “evaluate not only the impacts of specific bicycle improvement projects but can also function as a way to measure progress toward reaching City goals such as increased bicycle travel for trips one mile or less” (Alta Planning + Design, Bicycle Solutions, and Hexagon Transportation Consultants 2012). The city uses these counts to evaluate bicycle and pedestrian mode share and may create annual “report cards” in the future to document bicycling activity.

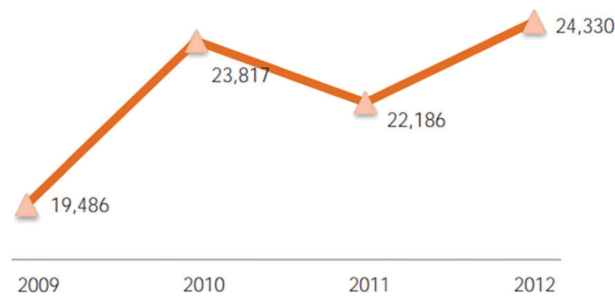
The City sees these counts as important for putting bicycling and walking on equal footing with motor vehicles. The counts “add legitimacy” to the non-motorized modes. The city conducts manual counts (at 17 locations at the time of writing), using both city staff and volunteers. Routine count locations were identified in the master plan and grouped into Tier 1 (high priority) and Tier 2 locations. The City hopes to expand its program to include all Tier 1 locations and to begin counting some Tier 2 locations as well. The City also conducts routine pneumatic tube counts, which are integrated into the motorized count database.

In addition, San Mateo County requires private developers to conduct vehicular, pedestrian, and transit counts as part of their development’s traffic impact study. The City of San Mateo adds the data from these studies to its count database.

Washington State Department of Transportation (WSDOT)

WSDOT’s *Washington State Bicycle Facilities and Pedestrian Walkways Plan* (2008) identified bicycle and pedestrian counts as a key data need for assessing growth in multimodal trips and measuring progress toward the state’s goal of doubling the number of bicycle and pedestrian trips by 2027. WSDOT launched the Washington State Bicycle and Pedestrian Documentation Project in 2008 to track changes in bicycling and walking across the state. The project has collected counts in late September or early October annually since 2008, in conjunction with the National Bicycle and Pedestrian Documentation (NBPD) Project.

The project relies on volunteers to collect manual counts at identified count locations throughout the state. The locations are selected by local count coordinators, following siting criteria suggested by the state, in an effort to make the data valuable to the local jurisdiction as well as to the state. The locations may be selected to demonstrate the prevalence of walking or biking, illustrate before-and-after volumes at a location with a planned improvement, or assess exposure rates at a high crash location. Local count coordinators are encouraged to choose count locations that demonstrate at least one of the following siting criteria (which



Source: Washington State DOT (2012).

Figure 2-1. Change in walking and bicycling activity at Washington State count sites, 2009–2012.

have been identified through the NBPD method as typical characteristics that provide valuable data):

- Historical count location
- Bicycle facility
- High collision area
- Smart growth area
- Transit corridor
- Planned project
- Mixed land use
- Stakeholder recommendations

Thirty-eight cities participated in the 2012 counts. In addition to tracking the total volume of pedestrian and cyclists at each location, Washington counts users by gender and (for bicyclists) by helmet use. Based on data collected at locations statewide, Washington has shown that non-motorized travel is up significantly since the project's inaugural counts in 2008. Because count locations have changed over the years, the total number of non-motorized travelers cannot be compared. However, the data from select locations where counts have been conducted consistently since 2009 can be isolated and compared, as shown in Figure 2-1. The graph suggests an overall increase in non-motorized travel, particularly between 2009 and 2010.

2.2 Evaluating Before-and-After Volumes

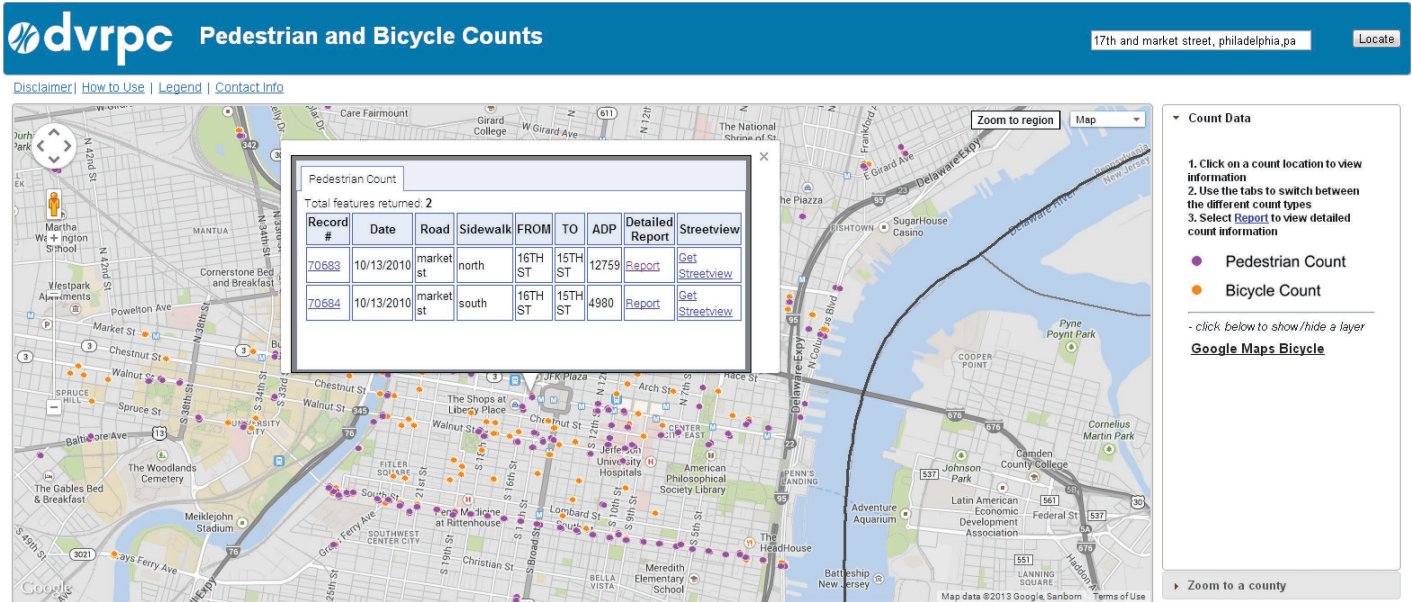
2.2.1 Potential Applications

Collecting bicycle and pedestrian counts before and after a new facility is opened can be valuable for measuring volume changes and making conclusions about the success of the facility. The data can also be used to forecast the usage of planned facilities and to justify additional system improvements based on past results.

2.2.2 Example Applications

Delaware Valley Regional Planning Commission, Philadelphia Region

The Delaware Valley Regional Planning Commission (DVRPC) has actively counted bicycles and pedestrians since 2010 and has data from over 5,000 locations throughout its region.



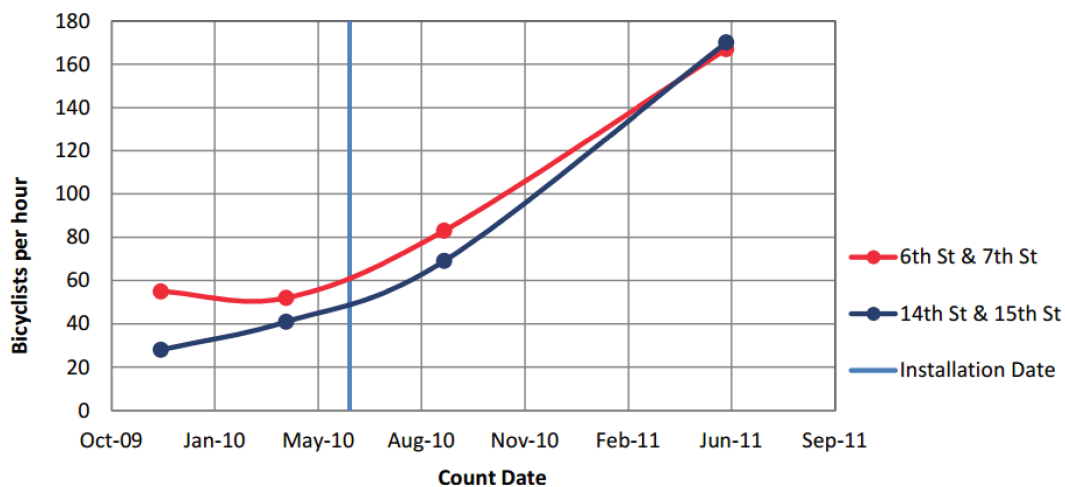
Source: DVRPC, <http://www.dvrpc.org/webmaps/pedbikecounts/>.

Figure 2-2. Example pedestrian and bicycle count website.

Counts are generally conducted as part of before-and-after studies of new infrastructure. All of the DVRPC data are accessible to the public on line, using a map-based application (Figure 2-2).

District Department of Transportation, Washington DC.

The District Department of Transportation (DDOT) evaluated three facilities where new bicycle treatments had been implemented. The evaluation used various data and analysis tools, including before-and-after bicycle counts. One of the treatments added buffered bicycle lanes in the center median of Pennsylvania Avenue between 3rd Street NW and 15th Street NW. Bicycle counts were collected before and after the installation to assess the change in bicycle volumes. As shown in Figure 2-3, bicycle volumes increased significantly after the treatment was installed.



Source: Kittelson & Associates, Portland State University, and Toole Design Group (2012).

Figure 2-3. Before-and-after bicycle facility usage example.

This information could be used to (1) demonstrate project success, (2) support installing similar treatments in the future, and (3) help estimate future bicycle activity levels when planning future treatments.

2.3 Monitoring Travel Patterns

2.3.1 Potential Applications

Continuous pedestrian and bicycle counts can be used to identify usage patterns across the day, week, or year, and to identify factors that influence bicycling and walking levels (e.g., weather, land use patterns, and transportation network characteristics).

Developing Extrapolation Factors

Extrapolation factors are used to expand short-duration counts to estimate volumes over longer time periods or to compare counts taken under different conditions. Volume patterns across the day, week, or year are identified so that shorter duration counts can be extrapolated to longer time periods. For example, if a given 2-hour period has been shown to typically contain 10% of the daily volume, then a 2-hour count during this same time period at a similar site could be multiplied by 10 to estimate the daily volume.

Extrapolation factors can be used to control for pedestrian and bicycle activity patterns near specific land uses, the effect of weather conditions, access/infrastructure sufficiency, or surrounding area demographics. Extrapolation is useful when resource limitations prevent organizations from collecting data over an extended period of time at all locations where volumes are desired. Chapter 4 provides additional information on how to apply extrapolation factors and the level of uncertainty associated with applying adjustment factors.

Evaluating User Behavior Patterns

Non-motorized counts can be used to evaluate user behavior patterns and to identify factors that influence bicycling and walking. Some factors that affect pedestrian and bicycle activity are outside an agency's control (e.g., the day of the week, temperature, and rainfall). For example, Copenhagen, Denmark, schedules extra buses for its busiest bus line on days when rain is predicted, because bike riders shift to transit on those days, and buses would become overcrowded if they operated under the regular schedule (Jacobsen and Lorich 2013). Other factors may be more controllable, such as land use type, facility type, or motorized vehicle volumes (e.g., through motorized traffic calming and diversion).

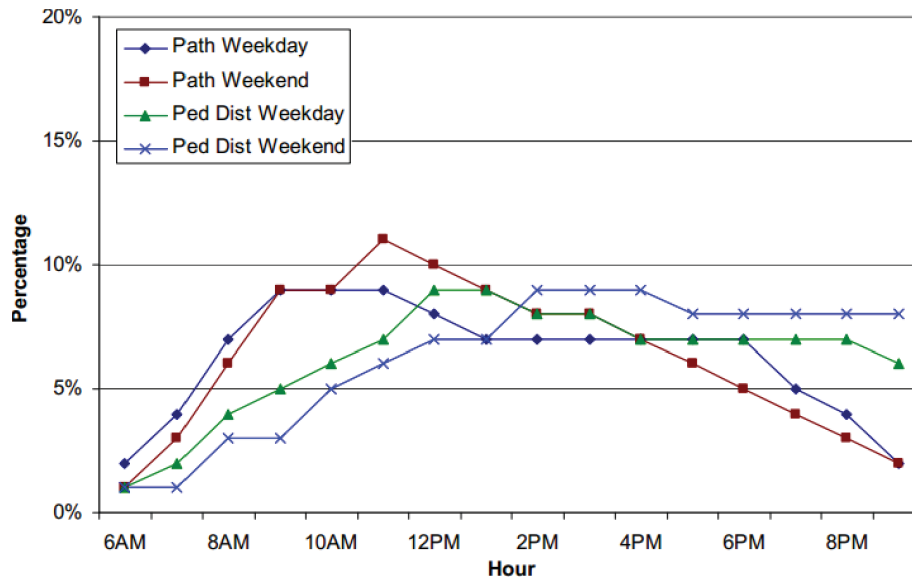
Understanding how these factors influence bicycling and walking rates can help agencies better plan their transportation systems.

2.3.2 Example Applications

San Diego County, California

The Seamless Travel Project, using San Diego County as a case study, developed a database of pedestrian and bicycle count and survey data to analyze and identify factors that influence bicycling and walking. The project evaluated the effects that land use, density, access, roadway traffic volumes, facility type, and other factors have on walking and bicycling rates. In addition, the project was designed to provide a comprehensive count of pedestrian and bicycle activity in the county.

The project included two manual peak-period counts (from 2007 and 2008) at 80 locations and 1 year of continuous automated counts at 5 locations. The data from the five locations were



Source: Jones et al. (2010).

Figure 2-4. Example of pedestrian travel patterns by facility type and day.

used to identify peak-hour patterns. For example, Figure 2-4 illustrates hourly volumes as a percentage of daily volume for two facility types (off-street paths and pedestrian districts) and two time periods (weekdays and weekends), based on counts taken between April and September. According to the project, this figure is expected to be “generally accurate for pathways and sidewalks in areas with moderate climates, relatively high visitor trips, and mixes of land uses (residential and commercial)” (Jones et al. 2010).

Mid-Ohio Regional Planning Commission, Columbus Region

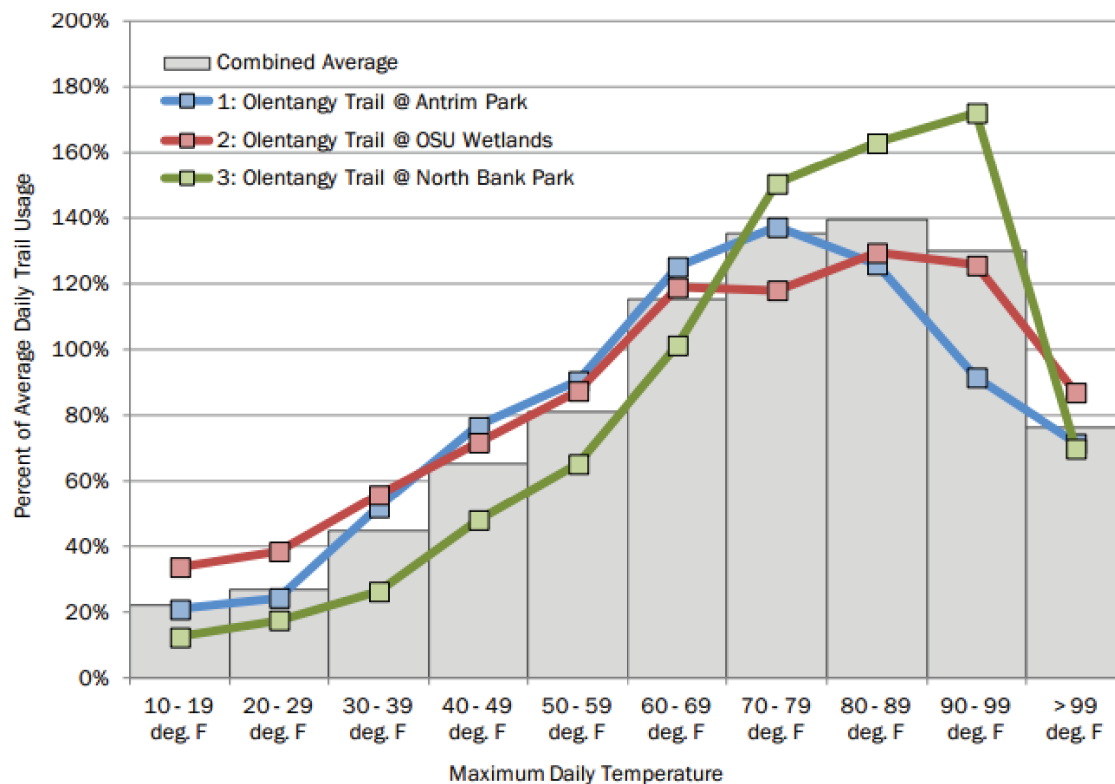
The Mid-Ohio Regional Planning Commission (MORPC) has conducted pedestrian and bicycle counts on off-street trails since about 2002. The counts document change in usage over time, which helps inform evaluations on whether to widen selected trails. In addition, MORPC has used the counts to assist with grant applications, provide information to elected officials, and support or justify budget decisions.

In 2012, MORPC produced a Trail Count Report as part of an effort to better understand how trail usage is influenced by various factors, including temperature and precipitation. Figure 2-5 illustrates the percentage of average daily trail usage by temperature on portions of one trail. These data helped the commission draw conclusions about which portions of the trail are most affected by weather, and thus which trail users are likely to be more or less reliant on biking or walking.

2.4 Safety Analysis

2.4.1 Potential Applications

Non-motorized counts can be used to inform a safety analysis of a facility or area and better evaluate crash data. Pedestrian and bicycle volumes may be used to quantify exposure and develop crash rates and to identify the before-and-after safety effects of upgrading a facility. Volumes may also be used to estimate pedestrian or bicycle miles traveled for use as a regional exposure metric.



Source: Mid-Ohio Regional Planning Commission (2012).

Figure 2-5. Example evaluation of temperature effects on trail usage.

Quantifying Exposure

Exposure relates to the frequency of a bicyclist or pedestrian being present in a conflict zone with the potential to be involved in a crash and is used in assessing risk. One of the biggest challenges in pedestrian and bicycle crash data evaluation is evaluating the number of crashes at a location without knowing the volume of pedestrians or bicycles at those locations. Crashes are often disproportionately high on suburban arterials, where there are few pedestrians, compared to downtowns, where there are more pedestrians. However, an analysis based only on the total number of crashes may not reveal this disparity.

Various methods have been proposed to measure an area's pedestrian and bicyclist exposure, considering such variables as population; volumes of pedestrians, bicyclists, and vehicles; and distance traveled (Molino et al. 2012). Some studies have investigated the potential for measuring pedestrian exposure based on the number of pedestrians observed in the roadway.

One of the simplest models of assessing pedestrian exposure defines relative risk as the number of annual pedestrian–vehicle collisions divided by the average annual pedestrian volume. This technique was pioneered by the City of Oakland, which applied the method in its first pedestrian master plan adopted in 2002. As noted in the plan, FHWA and the National Highway Traffic Safety Administration (NHTSA) have identified “pedestrian exposure data as the least understood and most important area of research for pedestrian planners and decision-makers” (City of Oakland 2002). The plan used model-generated pedestrian volumes and crash data to identify the city's most dangerous intersections; however, actual count data would be preferred to modeled volumes when available.

Most research has focused on collisions between vehicles and pedestrians or bicycles; agencies should also consider collisions between pedestrians and bicycles, collisions between two or more

bicycles, and accidents involving only a bicycle. Although these types of crashes are typically not fatal, they can still cause injury and damage.

Identifying Before-and-After Safety Effects

Non-motorized count volumes may be used to evaluate pedestrian and bicycle crashes and develop rates relative to the volume of users. These data can be used in crash prediction models to estimate the before-and-after safety effects of various safety treatments. The *Highway Safety Manual* (HSM) presents crash and analysis methods for quantitatively assessing crash frequency or severity and estimating the effect of countermeasures (AASHTO 2010). Section 3 of the HSM includes a discussion of roadway treatments for pedestrians and bicyclists, although crash modification factors (CMFs) were not available at the time of publication to quantitatively assess the effect of these treatments. FHWA hosts an online CMF clearinghouse, which provides a regularly updated repository of CMFs and includes research and data relevant to bicycle and pedestrian treatments.

2.4.2 Example Application

City of Montreal, Quebec

Strauss, Miranda-Moreno, and Morency (2014) describe the use of manual pedestrian and bicycle count data for 647 signalized and 435 unsignalized intersections in Montreal for evaluating pedestrian and bicycle safety. Annual bicycle, pedestrian, and motor vehicle volumes for each intersection were developed from 8-hour counts conducted by the City of Montreal on weekdays during warmer weather months in 2008 and 2009, using adjustment factors developed from the city's permanent count stations. A similar process was used to develop annual volumes by travel mode for the unsignalized intersections, but starting from 1-hour counts taken in summer and fall 2012. Injury crash data by travel mode were also available for all of the intersections over a 6-year period.

Based on these data, the researchers developed models estimating the change in injuries by mode that would be expected with changes in either intersection demand (e.g., motor vehicle right-turning volume) or intersection characteristics (e.g., total crosswalk width, bus stop presence, all-red traffic signal phase provided). For example, bicyclist injuries would be expected to increase by 10% for every 2.4% or 1.85% increase in right-turning and left-turning volumes, respectively, at signalized intersections. Pedestrian injuries would be expected to increase by 10% for every 3.2% or 4.2% increase in motor vehicle volumes at signalized or unsignalized intersections, respectively.

2.5 Project Prioritization

2.5.1 Potential Applications

Agencies may use multimodal counts to help identify high-priority locations for improvements. Existing pedestrian and bicycle counts may help define essential multimodal networks where projects should be a priority. In addition, an agency may use historic counts to identify which factors most influence rates of walking and bicycling and prioritize projects accordingly. Counts that measure improper user behaviors (i.e., wrong-way bike riding) can help indicate areas with deficiencies where improvements may be needed.

2.5.2 Example Application

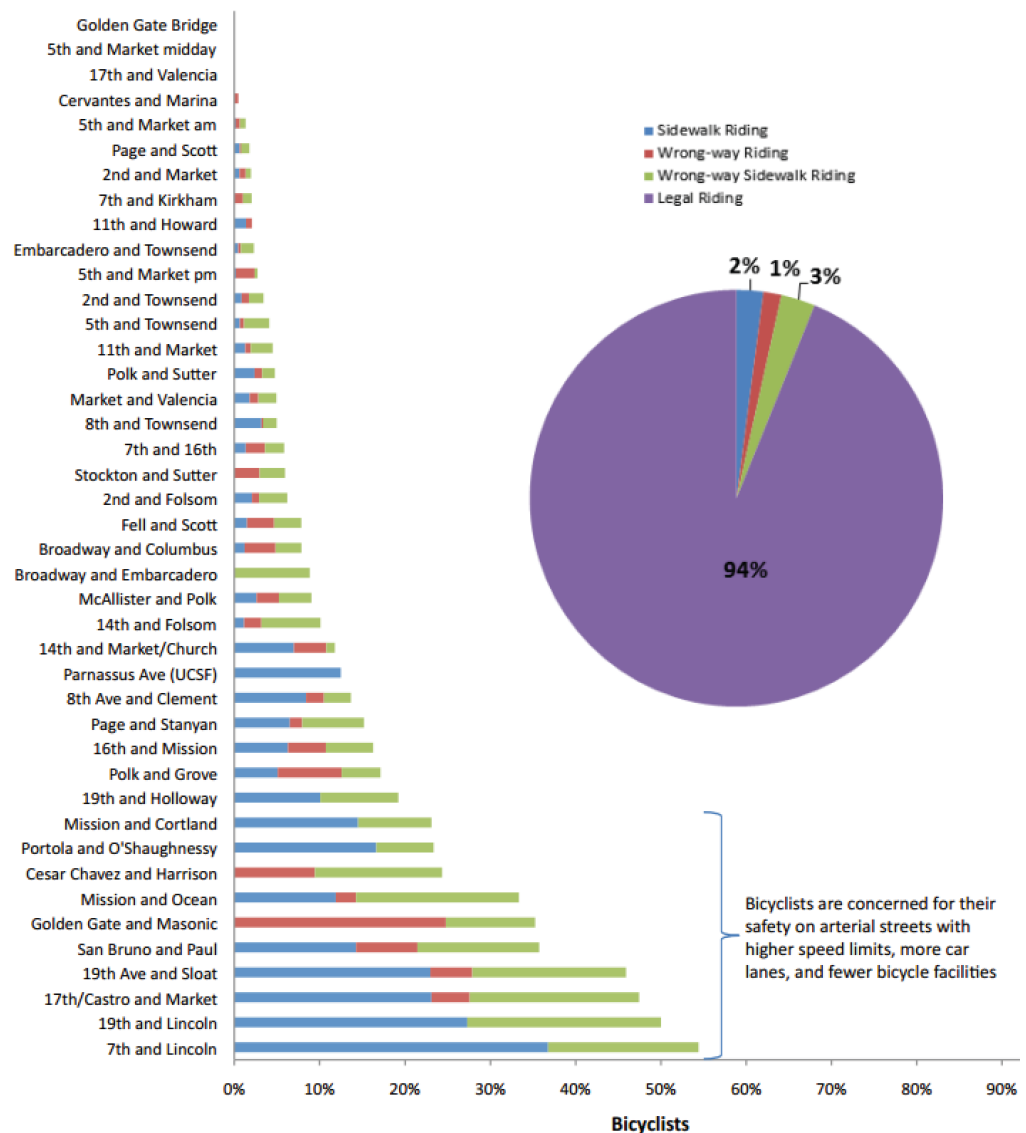
San Francisco Municipal Transportation Agency

The San Francisco Municipal Transportation Agency (SFMTA) has collected annual citywide bicycle counts since 2006. SFMTA started following the NBPD's guidelines for collecting manual

counts in 2011 in order to improve accuracy and create a comparable data set. In addition, SFMTA is installing permanent automated bicycle counters at key locations in the bicycle network. The automatic counters collect volume data over a 24-hour period to provide a more complete picture of ridership patterns. SFMTA uses the data to evaluate the usage of the bicycle network and to “help identify locations where additional infrastructure improvements may be needed” (SFMTA 2011).

At some locations, SFMTA collects data manually on the rate of wrong-way and sidewalk riding. These data identify locations where facilities may be inadequate or unsafe, so that SFMTA can improve conditions in these areas. Although 94% of riders were observed obeying the law, 6% of cyclists were observed riding on the sidewalk and/or in the wrong direction. Figure 2-6 graphs locations with the highest rates of improper riding. As seen in the figure, the report concludes that where higher rates of improper riding occur, bicyclists are concerned for their safety due to higher speeds, more car lanes, and fewer bicyclist facilities.

2011 Bicyclist Behavior by Location



Source: San Francisco Municipal Transportation Agency (2011).

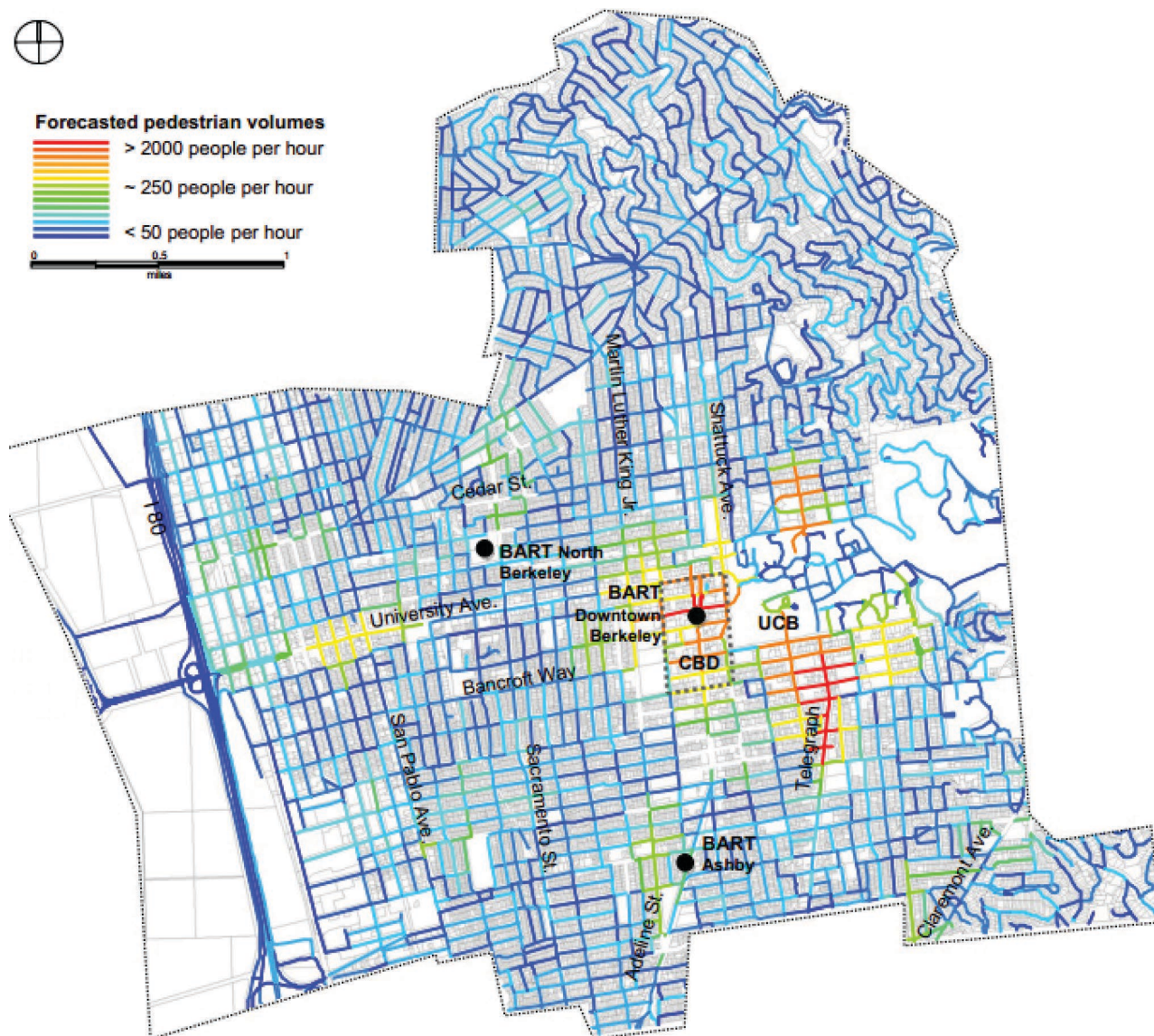
Figure 2-6. Use of manual counts to evaluate unsafe bicyclist behaviors.

2.6 Multimodal Model Development

2.6.1 Potential Applications

Although many jurisdictions have developed vehicle travel demand models to forecast future motorized vehicle volumes, relatively few areas have undertaken comparable efforts to assess pedestrian and bicycle demand. Multimodal travel demand modeling is an emerging field which has the potential to estimate pedestrian and bicycle demand over a large transportation network. Non-motorized counts are a key element in calibrating a multimodal model. Once developed and calibrated, such a model could be used to

- Estimate multimodal demand over a large network with limited new data collection,
- Estimate the influence of infrastructure changes (i.e., the addition of a new bike facility) on travel behaviors, and
- Project future multimodal demand.



Source: Alta Planning + Design (2010).

Figure 2-7. Example output from a pedestrian model calibrated with count data.

2.6.2 Example Application

City of Berkeley, California

The City of Berkeley maintains a pedestrian demand model. The model was developed based on an assessment of “spatial accessibility,” urban form, land use, and pedestrian observations. Pedestrian count volumes from 64 locations throughout the city were used to assess the model’s significance and validity. The comparison showed that the model forecasts approach 70% accuracy compared to the observed counts. Most pedestrian movement in the city is explained by average daily traffic, distance from the Central Business District (CBD), and the relative accessibility of a junction. Although the model can predict intersection volumes, pedestrian volume estimates were assigned to street segments, as shown in Figure 2-7.

As stated in Berkeley’s Pedestrian Master Plan, the model can be used to identify key areas of pedestrian activity and to “prioritize improvement options to target opportunities where streets are being used the most” (Alta Planning + Design 2010).

Data Collection Planning and Implementation

Chapter 3 Topics

- Planning a non-motorized volume counting program
- Implementing the count program

This chapter describes how to plan and implement a pedestrian and bicycle counting program and provides guidance on the various steps of the counting process, including technical and logistical considerations. This guidance is drawn from a comprehensive literature review, surveys of and interviews with transportation agencies that conduct pedestrian or bicycle counts, and field testing of counting devices. Case studies are referenced to illustrate key points. The full case studies are provided in Appendix A.

3.1 Chapter Organization

This chapter is divided into two main sections that address (1) planning the count program and (2) implementing the program. The subsections listed below describe the specific activities involved in each phase of the program. In the PDF version of this guidebook, click on any of the section names to go directly to that section.

Planning the Count Program

Specify the data collection purpose
 Identify data collection resources
 Select count locations and determine the count timeframe
 Consider available counting methods

Implementing the Count Program

Obtain necessary permissions
 Procure counting devices*
 Inventory and prepare devices*
 Train staff
 Install and validate devices*
 Calibrate devices*
 Maintain devices*
 Manage count data
 Clean and correct count data
 Apply count data

*Steps that only apply to counts using automated counting techniques.

Important Definitions

Counting product (equipment). The counting product is the complete set of equipment used to collect volume counts. Products incorporate

- The *counting technology* that detects pedestrians and bicyclists;
- Components to house, mount, and power the counting technology;
- Devices to store the count data; and
- Tools to download or export data.

Counting technology (device, sensor, method). A counting technology is the specific device or sensor that detects pedestrians or bicyclists. The counting technology is one component of the *counting product* provided by a vendor. Manual data collection uses human sight as the counting technology.

3.2 Planning the Count Program

Planning is an important first step in developing an efficient and useful pedestrian and bicycle counting program. Although it is possible to relatively quickly collect manual counts or to purchase and install automated counting technologies, this course of action may not produce useful, long-term results. Planning a count program typically involves the following steps:

- Specifying the general data collection purpose,
- Identifying data collection resources,
- Selecting count locations and determining the count timeframe, and
- Considering available counting methods.

The following sections present these steps in a particular order, but they are often considered iteratively. For example, count managers may reconsider the resources needed for data collection after they realize that they would like to count additional locations. Similarly, managers may revisit the number of count locations after recognizing that they would like to gather continuous counts over a long time period (which may require purchasing additional counting devices for more locations, or rotating existing devices among locations).

Organizations planning a pedestrian and bicycle count program for the first time should expect that their program will be modified in the future. Although most programs benefit from having some core data that have been collected consistently from start, many programs revisit their stated purposes, reassess resources, consider new or different count locations and time periods, and integrate new counting methods. This chapter provides general guidance for planning count programs, but the most effective programs are tailored to meet an organization's unique needs. Successful count programs result from experimenting and refining the approach over time.

Several other sources also provide useful guidelines for establishing pedestrian and bicycle count programs. These include Chapter 4 of the *Traffic Monitoring Guide* (TMG) (FHWA 2013) and the *Guide to Bicycle & Pedestrian Count Programs* (Portland State University 2014).

3.2.1 Specifying the General Data Collection Purpose

Chapter 2 describes reasons why transportation agencies and other organizations collect pedestrian and bicycle counts. These purposes include

- Measuring changes in pedestrian and bicycle activity relative to baseline levels;
- Documenting changes in activity levels after projects are implemented;

Considering Multiple Data Users

A transportation agency wants to document how pedestrian volumes change after sidewalks are added along 10 roadways. Initially, it plans to use staff to conduct 4-hour weekday afternoon counts at each location, both 1 week before and 3 weeks after sidewalks are installed. This plan would achieve the agency's immediate need: comparing volumes before and after the sidewalk installation.

However, there may be reasons to continue to count into the future. In particular, installing an automated counter at one location (situated where it will not be affected by the sidewalk construction) would allow the agency to develop a continuous set of count data that records variations in demand by hour, day of week, and season of year. These data could be used to

- Estimate annual pedestrian volumes from future short-term counts in other locations;
- Evaluate whether the sidewalks continue to influence pedestrian demand beyond 3 weeks, and
- Control for exposure when evaluating pedestrian crash risk.

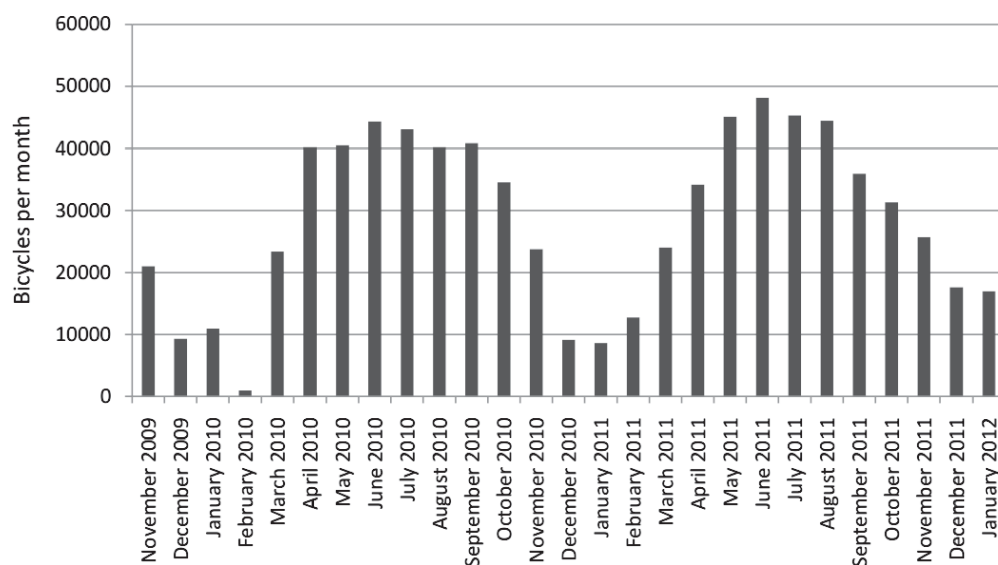
- Informing the general public about pedestrian and bicycle activity and trends;
- Monitoring variations in pedestrian and bicycle activity levels by time of day, day of week, or season of the year, and under different weather conditions;
- Identifying variations in activity in different types of locations (e.g., considering land uses and/or facility types) and calculating context-specific expansion factors;
- Assessing local and system wide activity to prioritize locations for new pedestrian and bicycle facilities;
- Quantifying exposure, as part of an analysis of pedestrian or bicycle crash risk at specific locations; and
- Developing models to predict future pedestrian or bicycle volumes at different locations throughout a community.

All of these purposes can be achieved—at least in part—by collecting continuous pedestrian or bicycle volume data over time. The ability to collect counts over an extended period of time is one of the most important benefits of automated pedestrian and bicycle counting technologies. In turn, the broad availability of non-motorized count data is an important part of ensuring a multimodal (or “complete streets”) approach to transportation issues within a community.

As an example, Figure 3-1 shows how continuous count data can be used to identify seasonal fluctuations in bicycle activity, as well as to document general increases in activity over time. This figure shows that bicycle activity on this trail is highest in the spring and summer months, and that bicycle volumes in 2011 were generally higher than in comparable months in 2010.

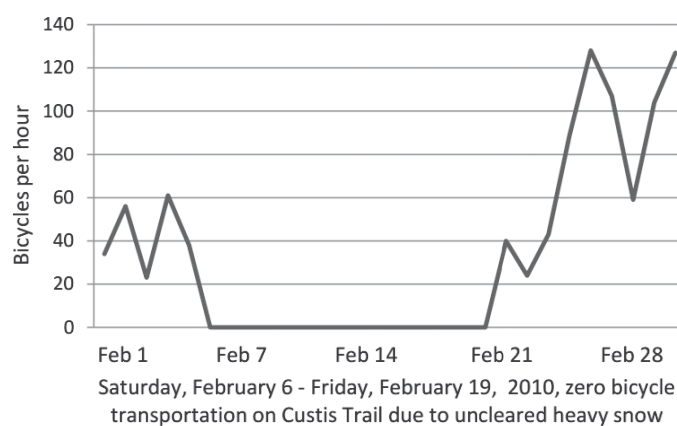
As another example, Figure 3-2 shows how continuous count data can reveal the effect of specific factors—in this case, uncleared snow between February 6 and 19—on bicycle activity.

Identifying the specific counting purpose (or purposes) is a critical first step in the data collection planning process. The count purpose drives decisions about where, when, and how to collect data. Practitioners should consider both current and potential future uses of data, as illustrated in the “Considering Multiple Data Users” sidebar.



Source: Arlington County, VA (2012).

Figure 3-1. Continuous count data from Custis Trail, November 2009–January 2012, Arlington County, VA.



Source: Arlington County, VA (2012).

Figure 3-2. Illustrative impact of uncleared snow on bicycle volumes.

Case Study Examples

The case studies in Appendix A illustrate other ways that continuous count data can be used:

- Identifying typical pedestrian or bicycle activity patterns in different parts of a community (Alameda County);
- Informing multimodal planning efforts (Arlington County);
- Developing planning-level demand models (San Francisco); and
- Estimating crash risk (UC Berkeley).

Options for Agencies with Limited Resources

Agencies with minimal or no dedicated budget for counting can still establish a count program through

- Organizing volunteers (see the Washington State DOT case study);
- Creating partnerships with other agencies (see the Columbus case study); and
- Compiling motorized traffic counts for intersections conducted for other purposes—these counts often include pedestrian and bicycle volumes.

3.2.2 Identifying Data Collection Resources

Available resources determine the scale of an organization's pedestrian and bicycle counting program. According to the practitioner survey conducted during the development of this guidebook, the most common barriers to collecting more pedestrian and bicycle data were

- Lack of staff time and volunteer interest, and
- Funding limitations or cutbacks.

Funding for count programs can come from internal agency budgets, external grants, or facility improvement projects (e.g., installing counting devices as a part of roadway or multi-use trail reconstruction, providing budget for before-and-after pedestrian and bicycle counts). However, even agencies with minimal staff time and funding can establish a count program. This outcome can be achieved, for example, by organizing volunteers or by creating partnerships with other agencies (including those, such as health agencies, not traditionally thought of as generators or users of count data). Keep in mind that although more data can be collected by using volunteers, staff time must be budgeted to provide high-quality training, coordinate volunteers, and enter data into the count database.

Even if an organization has no dedicated budget for pedestrian and bicycle counts, it may be possible to take advantage of other existing data collection efforts. For example, many transportation agencies and consultants routinely conduct or commission intersection traffic counts for traffic studies. Even though these efforts may be focused on automobile operations, pedestrian and bicycle count data are often collected, because non-motorized volumes influence traffic signal timing and automobile operations.

In addition, agencies may be able to mine existing data to identify instances where bicycle and pedestrian volume data were collected but not stored, because of a lack of formal means for reporting. Prior counts may not be consistent with current methods (due to lack of common standards or protocol), but they can give a community an initial sense of walking and bicycling activity and can be used to demonstrate the value of having good data. Existing counts also show where and when pedestrian and bicycle activity is missing, which helps build the case for filling those gaps.

Agencies with limited resources may be able to take advantage of volunteers. Most communities have citizens who are interested in pedestrian and bicycle issues, and some of these people are willing to be volunteers if they learn about an opportunity to assist the local pedestrian and bicycle program. Volunteers are frequently recruited for manual counts, where it is advantageous to get short-duration counts at multiple locations. These volunteer counts are often done on the same day or week of the year, as specified by the NBPD Project (www.bikepeddocumentation.org). When using volunteers, it is important to train them and monitor the quality of their counts during a training session before using them for official counts (for more information, see Section 3.3.4).

In some cases it may be appropriate to use volunteers to assist in installing, moving, and downloading data from automated counting devices. However, given the complexities associated with some technologies, this approach requires identifying volunteers with some degree of technical capacity, and it may be best suited for students at a local college or university. Most automated devices call for professional expertise to install and use, and quality control will be optimized by hands-on staff training and involvement, regardless of the count approach or technology selected.

By showing the utility of counts for producing policy-relevant results, a transportation agency can make the case that counting pedestrians and bicyclists is an important function that should be a routine part of their activities. Therefore, useful count results can lead to additional resources for counting. *Even data collected infrequently and opportunistically can lead to a permanent count program.* Nevertheless, as initial decisions about counting activities affect subsequent decisions about how, when, and where to collect data, it is important for agencies to think about how their programs may grow in the future. Both geographic (where) and temporal (when and how long to count) expansions can be planned systematically, so that the program ends up representing key geographic areas (or the whole community) and all important time periods. Any expansion should keep some original count sites and time periods so that past trends can be monitored into the future.

3.2.3 Selecting General Count Locations and Timeframe

Pedestrian and bicycle data collection programs can benefit from combining two approaches:

1. Gathering short-duration counts (typically less than 1 day to several days, but potentially up to several months) at many locations; and
2. Gathering continuous counts over multiple years at a small sample of locations.

The short-duration counts capture spatial variation in pedestrian and bicycle activity in different parts of the community. The continuous counts identify specific types of activity patterns and are used to adjust the short-duration counts. The TMG (FHWA 2013) recommends this approach (see TMG Chapter 2 for general guidance on selecting count locations and times, and Sections 4.4 and 4.5 of TMG Chapter 4 for more specific guidance on non-motorized counting).

Approaches for Selecting Count Locations

The following are possible options for selecting count locations:

- **Random locations.** Sites are selected randomly. This approach may not capture strategic locations, nor select sites appropriate for automated counting. Selecting randomly from within categories of desired characteristics (*stratified random sampling*) is an alternative.
- **Representative locations.** This approach balances available resources with spatial coverage. Identified sites, in aggregate, are representative of the community as a whole.
- **Targeted locations.** Sites are selected on the basis of being associated with particular projects, facility types, or locations with particular characteristics (e.g., safety concerns).
- **Control locations.** This approach compares sites affected by a project with unaltered sites (*control locations*) to determine how much of the observed change in demand can be attributed to the project.

Select General Geographic Locations

Resource limitations often prevent counting at every desired location, so particular locations must be chosen based on the primary purposes of the data collection program. Four approaches, described in more detail below, have been used for determining count locations:

- Random locations,
- Representative locations,
- Targeted locations, and
- Control locations.

Random Locations

Count locations can be selected randomly. For example, an agency can assign unique identification numbers to each of its intersections and use a random number generator to select which intersections to count. However, this *simple random sampling* approach may not capture strategic locations for counting. Additionally, random sampling may not identify locations suitable for automated technologies, because numerous site-specific factors ultimately determine suitability for a count location (e.g., opportunities to install equipment and patterns of pedestrian and bicycle movements). Random sampling can also result in selecting locations with very low volumes, which tend to have higher levels of variation over time than higher volume locations. High variability produces more error when estimating long-term (e.g., annual) volumes from short-duration counts.

There are alternatives to simple random sampling. Potential count locations can be stratified into categories according to particular characteristics, such as commuting versus recreational route, land use type, income category, or proximity to attractors (e.g., schools, parks, and transit stops). Analysts consider each category separately and select locations within each category randomly. This process, called *stratified random sampling*, can be used to ensure that there are at least a few count locations with each key characteristic of interest. This strategy has been used to select count locations when developing predictive pedestrian and bicycle volume models and safety performance functions (Schneider, Arnold, and Ragland 2009a; Schneider et al. 2010; Griswold, Medury, and Schneider 2011; Strauss, Miranda-Moreno, and Morency 2014). See the San Diego County case study for an example of stratified sampling.

Representative Locations

Most communities would like to measure how pedestrian and bicycle activity changes over time in the community as a whole. This objective requires counting at representative sites throughout the community. Representative locations could be identified using a random sampling process. However, it is more common to select representative sites using a systematic approach guided by a count manager or advisory group.

In order to be representative, count locations should be

- Located in different geographic parts of the community;
- Surrounded by different types of land uses;
- Found on different types of facilities (e.g., multi-use trails, bicycle lanes, sidewalks); and
- Reflective of the range of socioeconomic characteristics in the community as a whole.

Limiting count sites to locations that are convenient, have the highest pedestrian or bicycle volumes, or are expected to have the greatest increases in walking and bicycling does not produce a representative sample.

A set of representative sites can be used to compare changes in the number of reported pedestrian and bicycle crashes with changes in overall pedestrian and bicycle activity levels throughout the community. This approach allows analysts to track the relative risk of pedestrian or bicycle

crashes (per pedestrian crossing, per trail user, per bicyclist, etc.). In other words, representative counts control for exposure across the community as a whole.

Targeted Locations

Specific locations can be targeted for counting, recognizing that the count locations, in aggregate, will not be representative of the community as a whole. These locations are often related to particular projects, particular facility types, or locations with particular characteristics.

For example, some communities choose to count in specific locations with a high number of crashes (i.e., “hot spots”). If the community is interested in identifying the relative risk of one specific roadway segment versus another specific roadway segment, the agency may target counts at these two locations. After using the counts to control for exposure, the agency can determine which locations have the greatest crash risk and evaluate the roadway design and behavioral characteristics that might be making those sites dangerous.

Communities also target counts at locations where specific projects have been or will be implemented, to document changes in walking and bicycling after project completion. For this purpose, it is important to count at locations at or near the project, and to select *control locations* for comparison, described next.

Finally, “pinch points,” or locations where pedestrians and bicyclists must converge to cross a barrier (e.g., river crossings, freeway crossings, railroad crossings), are good locations to document large portions of a community’s pedestrians and bicyclists. One sampling strategy is to count at a series of pinch points (e.g., all bridges crossing a river that bisects a community or all pedestrian and bicycle crossings of a freeway loop around the CBD).

Control Locations

To get a true understanding of the effect of a specific project on pedestrian or bicycle activity or safety, it is also necessary to count at similar locations not directly affected by the project (e.g., at a location with the same number of roadway lanes and a similar surrounding neighborhood on the other side of town). These other locations are called *control sites*. Control sites account for broader influences on walking and bicycling (e.g., an increase in gas prices or a community-level pedestrian and bicycle promotion program), making it possible to quantify the change in walking and bicycling activity or safety actually due to the project of interest.

Some of the users of a new or improved pedestrian or bicycle facilities may have shifted from nearby parallel routes. Counts can be taken on these streets and corridors to help distinguish between new (or more frequent) non-motorized travel generated by the project and existing non-motorized travelers who have diverted to the new or improved facility.

Developing Factor Groups

When a goal of the counting program is to use long-term volume patterns to extrapolate short-term counts to longer periods of time (e.g., a year), it is important to extrapolate based on long-term volume patterns at a site with similar patterns to the count location being extrapolated. This is referred to as using an appropriate *factor group*. The need to establish factor groups then becomes a consideration when selecting the continuous count sites that will be used to develop the long-term volume patterns.

Research by the Colorado DOT (Nordback, Marshall, and Janson 2013) has used long-term automated counts from multiple locations to identify different factor groups (see the Colorado DOT case study for examples). Figure 3-3 shows how bicycle activity patterns from multiple automated monitoring stations can be used to identify a factor group on the basis of having similar daily volume patterns. For motor vehicle counts, the TMG (FHWA 2013) recommends having at least five to eight continuous count stations as the basis of each factor group.

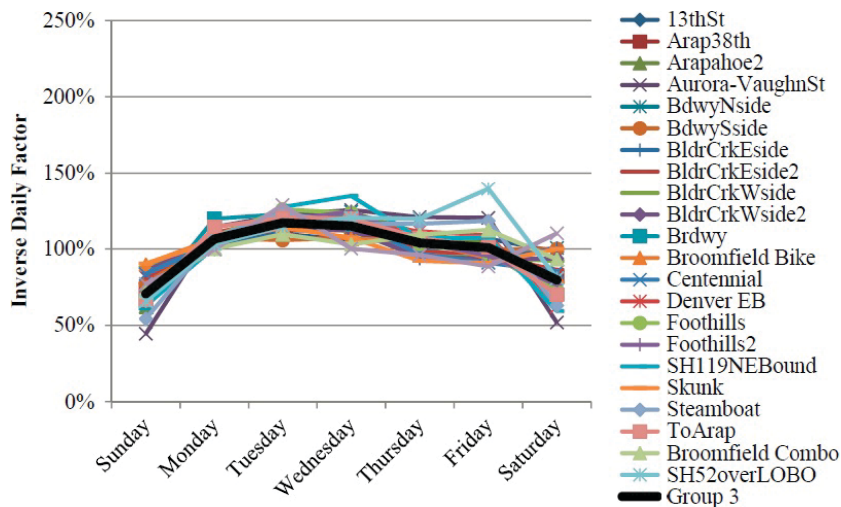


Figure 3-3. Colorado DOT commute trail factor group.

Recent research has provided guidance on applying factor groups for pedestrian and bicycle counting programs. Several studies have described how to define specific factor groups. In general, this is accomplished by gathering data from multiple automated count locations to identify which locations have “similar” volume patterns. A basic approach is to graph pedestrian or bicycle volume patterns by time of day, day of week, or month of year. Patterns that appear visually similar (e.g., higher volumes on weekends than weekdays or higher volumes during morning and evening commute periods than mid-day periods) are grouped together.

A statistically based approach to developing factor groups has been developed by Miranda-Moreno et al. (2013). This method uses two indices:

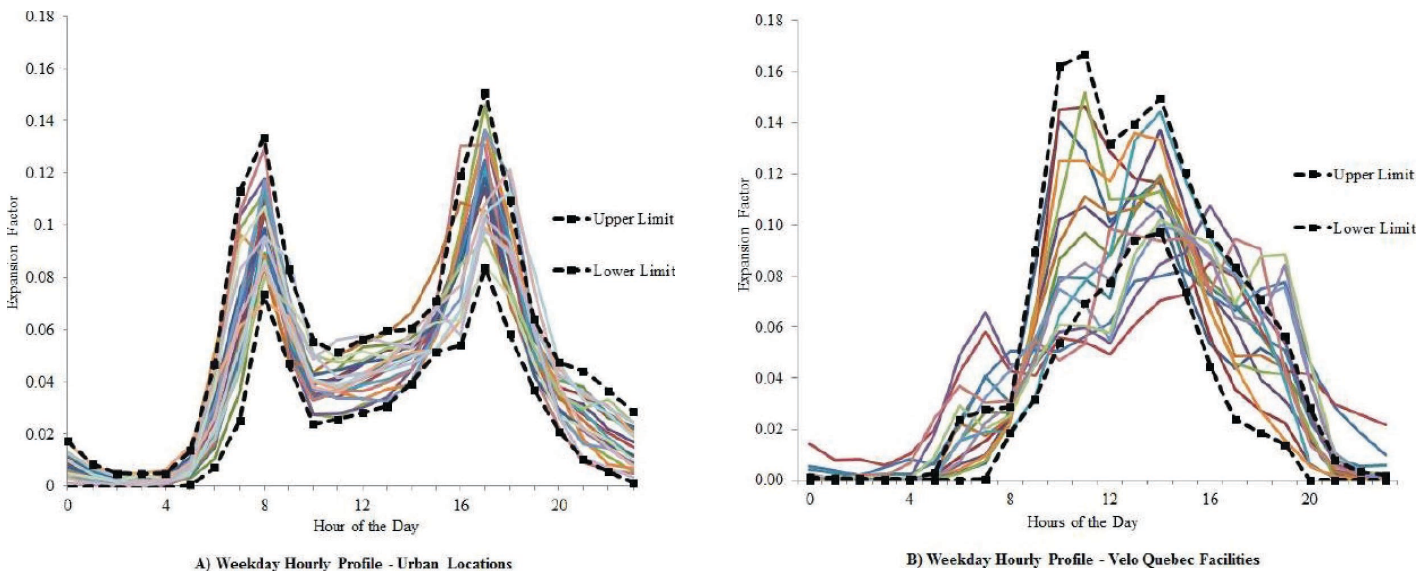
- WWI: weekend traffic volume divided by weekday traffic volume, and
- AMI: morning peak (7–9 a.m.) traffic divided by mid-day (11 a.m.–1 p.m. traffic).

Approaches for Developing Factor Groups

Factor groups are count sites that experience similar daily, monthly, and annual pedestrian and bicycle traffic patterns. These patterns may be due to similarities in local commuting activity and surrounding land uses. The typical traffic patterns observed at these locations are used as the basis for expanding short counts at locations with similar characteristics. Approaches to developing factor groups include:

- **Visual comparison** of volume patterns from continuous counts.
- **Statistical comparisons** of volume ratios derived from continuous counts.
- **Applying criteria** describing characteristics of interest (e.g., land uses) in selecting count locations to include in a given factor group.

A common element in all of these approaches is the need for continuous count data, which are only practically obtained from automated counting devices.



Source: Miranda-Moreno et al. (2013).

Figure 3-4. Examples of utilitarian (left) and recreational (right) bicycle activity patterns.

The relative values of these indices are used to classify count patterns into utilitarian (low WWI and high AMI), mixed-utilitarian (moderately-low WWI and moderately-high AMI), mixed-recreational (moderately-high WWI and moderately-low AMI), and recreational (high WWI and low AMI), two examples of which are given in Figure 3-4.

A practical disadvantage of this approach is that it does not yet provide guidance on how to determine which factor group should be applied at a particular short-count location (i.e., what characteristics make a location demonstrate utilitarian or recreational patterns?). This guidance is needed to be able to extrapolate short-duration count data. It is likely that this connection will be made in future research. The “Classification of Bicycle Traffic Patterns in Five North American Cities” case study provides an example of this statistical approach.

Another approach to developing factor groups was used by researchers who already knew the characteristics of specific sites where they wanted to estimate long-term volumes (e.g., annual) from short-duration counts (Schneider, Arnold, and Ragland 2009; Schneider et al. 2012). This approach grouped the short-duration count locations according to the characteristics likely to create the local activity pattern near the site (commercial land use vs. residential land use, employment density, etc.). Long-term automated counts were then collected at some sites in each category, and the average long-term count pattern for each category was used to extrapolate all short-term count locations in that category. This approach is limited by the restrictive criteria used to define a particular land use category.

Determine the Count Timeframe

Two aspects of timing are important for count programs: duration and frequency. The count duration will depend on the counting technologies and resources available to an agency. Most automated technologies can capture continuous counts for multiple months. These continuous count data can then be used to extrapolate short-term counts taken at similar locations (see the Alameda County case study for an example).

Count Duration

An important consideration when conducting counts is how long counting must occur to have a suitable amount of data for analysis. If data collection is to document an hourly volume pattern

How Long a Count Is Needed?

The count duration depends on (1) the purpose of the data collection and (2) the available resources.

Developing volume pattern data requires a few weeks (for hourly patterns) to a few months (for daily patterns) up to an entire year (for seasonal or monthly patterns).

Extrapolating short-term counts to longer (e.g., annual) time periods can be done with durations as short as 2 hours, but with potentially highly inaccurate results. Recent research shows that 4–7 days of counts are needed to reduce the error in an annual volume estimate to less than 20%. However, these require automated counting devices.

If it is not feasible to conduct counts longer than a few hours at a time, the following helps minimize the error in the volume estimates:

- Count at times with high activity levels (e.g., summer).
- Count during good weather.
- Conduct several short counts during different time periods.
- Extrapolate using a single day-of-year factor, rather than using day-of-week and month-of-year factors.

(how volumes change during the hours of a particular day), it may only be necessary to collect counts for a few weeks. Daily patterns (how volumes change by day of the week) may only need counts for a few months. Seasonal patterns (how volumes change by season of the year) are best identified with counts over multiple years. Benchmarking changes over time may require installing a counter permanently (or regularly rotating a counter to the site for a sufficient time period).

Many count programs with limited resources use short-duration manual counts taken once a year, or less frequently, to document changes in non-motorized volumes over time. Often, these counts have been used to estimate volumes over multiple years. However, very short counts (e.g., 2 hours) at a particular location are subject to high levels of variation, so they may produce inaccurate estimates of annual volumes. Similarly, conclusions about increases or decreases in pedestrian or bicycle activity based on an annual 2-hour count may not be accurate.

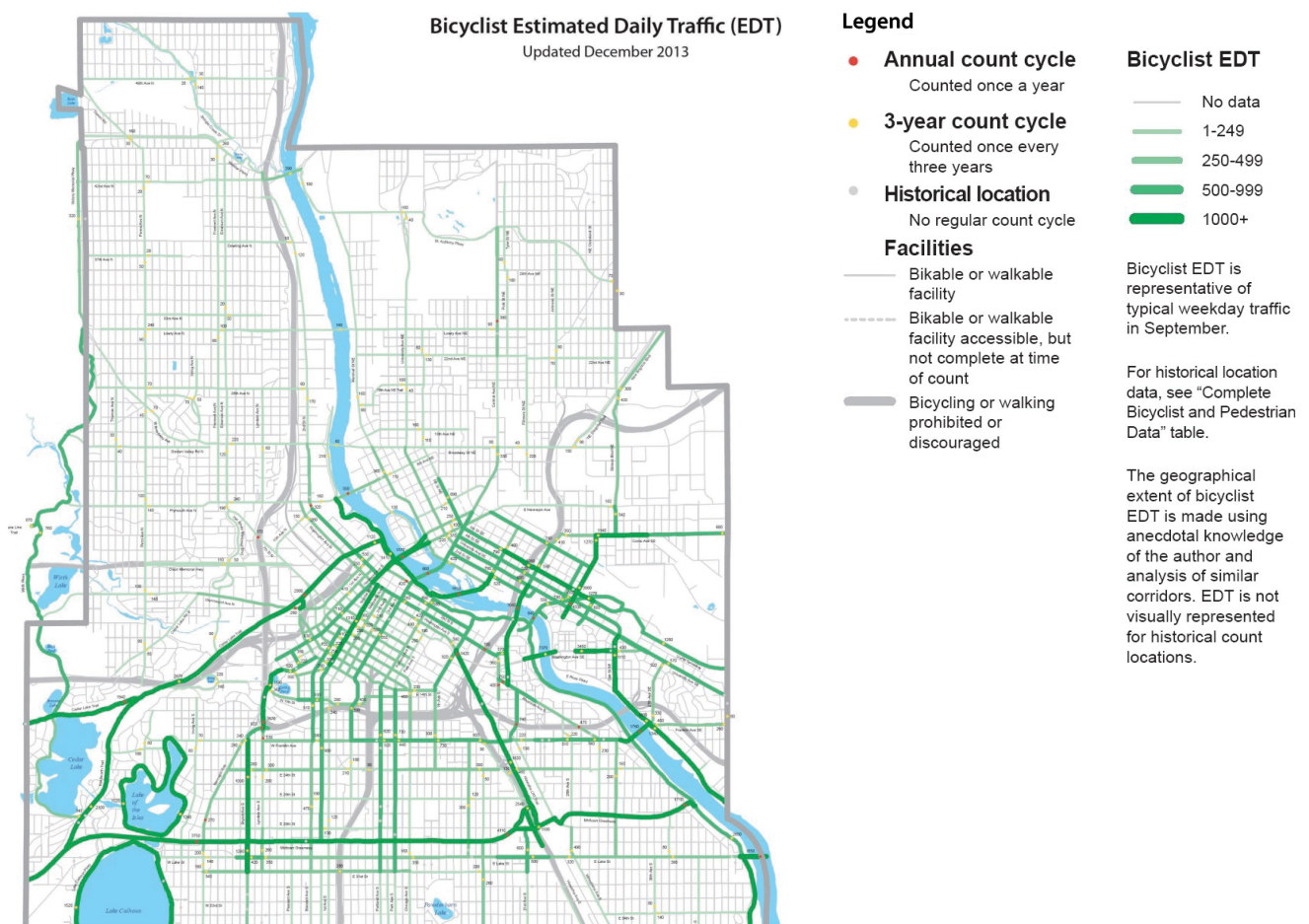
Although some variations can be accounted for using adjustment factors or models (e.g., to control for major weather conditions) (Nosal, Miranda-Moreno, and Krstulic 2014), others are very difficult to identify and correct. Increasing the count duration can improve the accuracy of extrapolation substantially (Milligan, Poabst, and Montufar 2013; Nordback et al. 2013; Hankey, Lindsey, and Marshall 2014; Nosal, Miranda-Moreno, and Krstulic 2014). Nordback et al. (2013) recommend a minimum count duration of 24 hours but suggest a longer period for more accurate annual estimates. In general, recent studies have suggested that counts should be taken for 4 days to approximately 1 week to reduce the error of the annual volume estimate to less than 20% (Nordback et al. 2013; Hankey, Lindsey, and Marshall 2014; Nosal, Miranda-Moreno, and Krstulic 2014). See Section 4.5.1, Temporal Adjustment Factors, for a more detailed discussion of these findings. Counting for 24 hours or longer necessitates using an automated counting device.

These studies have also shown that extrapolation errors are generally lower when counts are taken at times with higher activity levels (e.g., summer months rather than winter months in most regions of the United States or sunny days rather than rainy days). In addition, it is more accurate to extrapolate short counts from a single day-of-year factor (i.e., daily volume as a

percentage of the total annual volume) rather than using a two-step process to first estimate the weekly volume from a day-of-week factor and then estimate the annual volume from a month-of-year factor (Hankey, Lindsey, and Marshall 2014; Nosal, Miranda-Moreno, and Krstulic 2014). Collecting short (less than 24-hour) counts during several different time periods can also improve accuracy. A method for calculating the day-of-year factor is described in Appendix D.

Despite their limitations for estimating annual pedestrian or bicycle volumes, collecting short counts at particular locations can be useful for other purposes. For example, counts collected during a single peak hour of activity have been shown to be highly correlated with 12-hour counts on the same day (Hankey et al. 2012). In addition, short counts can also be useful for comparisons over time if they are taken at similar times of day, on similar days of the week, during similar seasons of the year, and under similar weather conditions. Furthermore, taking short counts annually, using a consistent method, at many different locations in a community (e.g., 30 to 50 locations) can be used to track trends over time (see the Washington State DOT case study for an example). Although individual sites may have high variability, the average count across a large set of locations can provide accurate information about trends in walking or bicycling. In addition, counts at many locations can provide useful information about geographic differences in pedestrian or bicycle activity (see the Minneapolis case study).

Figure 3-5 illustrates how manual counts at more than 300 locations have been used to create a citywide map of estimated average daily bicycle volumes.



Source: Minneapolis Public Works Department (2013).

Figure 3-5. Minneapolis bicycle count locations and bicyclist estimated daily traffic.

Count Frequency

Count frequency is defined as how often counts are collected at a given site. For permanently installed automated counters, the count frequency is continuous. At other sites, whether they are counted manually or with temporarily installed automated counters, the frequency might be one to a few times per year, depending on how the data will be used. For motor vehicle counts, the TMG recommends collecting short counts at all locations throughout a roadway system at least once every 6 years. More important roadways in the system should be counted at least once every 3 years. Communities should choose a frequency for pedestrian and bicycle counts that allows these communities to achieve their counting purpose with the available resources.

3.2.4 Considering Available Counting Methods

There are various methods available to count pedestrians and bicyclists. This section compares the most common counting technologies in U.S. practice at the time of writing, including manual counts, passive infrared, active infrared, pneumatic tubes, inductive loops, piezoelectric sensor, radio beam, and automated video. Specific details about each of these technologies, along with emerging technologies, are presented in Chapter 5.

Pedestrian and bicycle data collection programs often use more than one method. For example, certain counting technologies only count bicycles, while others count people regardless of mode. Collecting separate counts of both pedestrians and bicyclists at a location (e.g., mixed traffic) often requires using combinations of technologies. The TMG (FHWA 2013, pp. 4-3 to 4-5) provides more information about this approach. Agencies also incorporate more than one type of technology into their counting programs because certain technologies can be relatively costly to install, preventing them from being installed at all locations where counts are desired. However, using several different technologies (and potentially working with several different product vendors) can complicate the process of managing and analyzing data. Counting at locations with pedestrian, bicycle, and automobile traffic (e.g., intersections) is even more complex than counting just two modes, and additional research is needed to improve the technologies available for this purpose.

Manual Counts vs. Automated Counts

Manual counting, performed by human data collectors in the field, is a common data collection method. This was evident from the results of the survey conducted for this project, which showed that most pedestrian and bicycle counts available in many communities were gathered manually. Although automated technologies have improved significantly in recent years, manual counts will continue to be used by organizations that lack the financial resources, technical capacity, or regulatory permissions for deploying automated detectors in the public right-of-way. There is a tradeoff between the cost of installing a long-term counting technology to pick up temporal variations in volumes at a particular site and the cost of using short-term counting methods to pick up spatial variation in volumes at sites across a community (see the Minneapolis case study).

Manual counts will also be used where there is a compelling interest in documenting behaviors and other attributes, such as age, gender, helmet use, and use of assistive devices, that are only possible with manual observation (either in the field or by reviewing video) (see the Washington State DOT case study). The accuracy of manual counts can vary greatly depending on many factors, such as the experience of data collectors, the quality and complexity of data collection training and instructions, the layout of data collection forms, and site conditions (Diogenes et al. 2007; Schneider, Arnold, and Ragland 2009b).

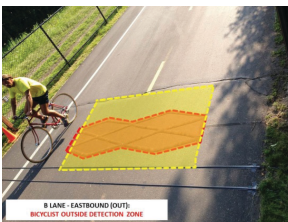
Questions to Consider when Selecting a Counting Method

All types of counting methods can achieve the general purposes of a non-motorized count program listed in Section 3.2.1. However, some methods are more effective for specific purposes. Selecting a counting method involves asking questions, such as:

- Who will be counted? (i.e., pedestrians, bicycles, both)
- What types of sites will be counted?
- What user characteristics (e.g., simple count, gender, behaviors) will be collected?
- What is the desired count duration and frequency?
- How well does a given counting method perform, given particular count site characteristics?
- What resources (e.g., cost, training, procurement lead time, data reduction) are required to use the counting method?
- How easy is it to work with the equipment? (e.g., durability, theft resistance, battery life)
- Do other agencies have experience using a given counting method or vendor?

Identifying Sites Appropriate for the Counting Method

Specific counting technologies require particular site characteristics. For example, passive infrared sensors should be directed across a sidewalk or multi-use trail facility into a wall or other object. They should not have other traffic in the background that is not using the sidewalk or trail, given that other traffic might be detected by the sensor. Inductive loops need to be installed in pavement on a roadway or trail, so they cannot be used on soft-surface trails. Radio beam technology requires placing a transmitter and receiver on opposite sides of a facility, so there need to be walls or posts available on both sides (or the ability to install them) to mount both components. All counting technologies are limited by detection range and user volumes.



Source: Tony Hull, Toole Design Group.

Bicyclist riding outside the detection zone.

One of the most important considerations for a site is the desired detection zone. This is the screenline or area where pedestrians or bicyclists will be counted. Each technology has its own type of detection zone, and it is essential to understand which pedestrians or bicyclists at a site will be counted and which will not be counted. For example, inductive loops only count bicyclists who pass over the width of the loops. If a multi-use trail is wider than the installed loop width, bicyclists who ride over a part of the trail not covered by the loops may not be counted. Given that the width covered by inductive loops and pneumatic tubes has some flexibility, the range of potential detection zone widths should be considered during site selection and installation.

Many technologies have detection zones intended for screenline locations. That is, pedestrians or bicyclists are counted when they pass an imaginary line across a sidewalk, bicycle lane, or multi-use trail. However, organizations may wish to count the number of pedestrians who cross a street within a crosswalk, or the number of bicyclists who go left, straight, or right at an intersection. These movements are complex. Therefore, with the potential exception of pedestrian detectors being installed where a crosswalk cuts through a wide median island, none of the automated technologies available for counting at screenline locations can be used for counting people using roadway crossings or open spaces. Instead, counts are typically collected at intersections by observing pedestrian or bicycle movements, or tracks, through an area-based detection zone. If a pedestrian or bicyclist track meets certain criteria (e.g., crosses the roadway centerline within the

crosswalk), it is registered as a count. This is typically done intuitively by manual data collectors in the field, or through manual or automated video image processing.

Other site characteristics that may affect particular counting technologies include

- Peak-hour user volume;
- Mix of users (e.g., pedestrians, bicyclists, automobiles);
- Facility width (detection zone width);
- Facility surface;
- Vehicular traffic flows or presence of vehicular traffic;
- Trees and other vegetation that could block a sensor or create background interference;
- Locations of snow and debris storage that could block a sensor;
- Windows that could deflect or distort a sensor beam;
- Metal or synthetic surfaces that may experience variation in radiant temperature when exposed to sunlight;
- Poles, walls, and other potential objects for mounting devices;
- General security (potential for theft or vandalism of devices);
- Built or social environment characteristics that create non-standard walking or bicycling movements (doorways, driveways, objects obstructing a travel path, bicycle racks, bus stops, food carts, “hangout” corners, etc.); and
- Adjacent land use characteristics that may influence bicycling and walking travel paths (e.g., plazas or parking lots that may encourage short cuts that divert bicycles or pedestrians away from the detection zone).

More details about the specific site requirements of particular counting technologies are presented in Chapter 5.

General Comparison of Counting Methods

Ten common pedestrian and bicycle data collection methods are compared according to key criteria in Tables 3-1 through 3-3. These tables provide a general overview of each technology for the purpose of comparison. Detailed descriptions of each data collection method are given in Chapter 5. The technology labeled as “automated video” uses computer algorithms to identify and count pedestrians and bicyclists from video images and is different than counting pedestrians and bicyclists manually from a video monitor. However, existing automated video systems may not use a completely automated counting process. They may also involve manual counts or manual data checks of some automated video processing. The combination of passive infrared and inductive loops is the most common method used to count pedestrians and bicyclists separately. However, other combinations, such as passive infrared and piezoelectric strips, or passive infrared and pneumatic tubes, could be feasible.

Table 3-1 compares user characteristics and site characteristics appropriate for each method. Methods may count pedestrians, bicyclists, or both types of users. Different counting methods are appropriate for particular types of facilities, such as multi-use trails, sidewalks, and bicycle lanes. Certain methods can also identify users’ direction of travel and differentiate between bicycles and motor vehicles.

Table 3-2 compares volume, width, and duration capabilities. *Maximum user* volume ranges are classified into general categories depending on when the counting method tends to start providing less-reliable counts. This user count range also depends on specific site characteristics (e.g., average user group size, mix of pedestrians and bicyclists, and detection zone width). Data used to determine maximum user volume ranges are presented in Chapter 4. *Detection zone width* ranges are classified into general categories. Most methods have detection zones that cover the width of an entire facility (e.g., sidewalk, bicycle lane, or multi-use trail). However, because

Table 3-1. Comparison of common pedestrian and bicycle counting methods: user characteristics and site characteristics.

Characteristic	Passive Infrared	Active Infrared	Pneumatic Tubes	Inductive Loops	Piezoelectric Sensor	Passive IR + Inductive Loops	Radio Beam (One Frequency)	Radio Beam (High/Low Frequency)	Automated Video ¹	Manual Counts ²
Type of users counted										
All facility users	Yes	Yes				Yes	Yes	Yes	Yes	Yes
Pedestrians only						Yes		Yes	Yes	Yes
Bicycles only			Yes	Yes	Yes	Yes		Yes	Yes	Yes
Pedestrians vs. bicycles						Yes		Yes	Yes	Yes
Bicycles vs. automobiles			Yes	Yes					Yes	Yes
Characteristics collected										
Different user types						Yes		Yes	Yes	Yes
Direction of travel ³	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes
User characteristics ⁴									Yes	Yes
Types of sites counted										
Multiple-use trail segments	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sidewalk segments	Yes	Yes				Yes	Yes	Yes	Yes	Yes
Bicycle lane segments			Yes	Yes	Yes				Yes	Yes
Cycle track segments		Yes	Yes	Yes	Yes			Yes	Yes	Yes
Shared roadway segments			Yes	Yes					Yes	Yes
Roadway crossings (detect from median) ⁵		Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes
Roadway crossings (detect from end of crosswalk)									Yes	Yes
Intersections (identify turning movements)										Yes

Notes: (1) Existing “automated video” systems may not use a completely automated counting process; they may also incorporate manual data checks of automated video processing.

(2) Includes manual counts from video images.

(3) Technologies noted as “Yes” have at least one vendor that uses the technology to capture directionality.

(4) User characteristics include estimated age, gender, helmet use, use of wheelchair or other assistive device, pedestrian and bicyclist behaviors, and other characteristics.

(5) Roadway crossings at medians potentially have issues with overcounting due to people waiting in the median. Median locations were not tested during this project.

Table 3-2. Comparison of common pedestrian and bicycle counting methods: volume, width, and duration capabilities.

Characteristic	Passive Infrared	Active Infrared	Pneumatic Tubes	Inductive Loops	Piezoelectric Sensor	Passive IR + Inductive Loops	Radio Beam (One Frequency)	Radio Beam (High/Low Frequency)	Automated Video ¹	Manual Counts ²
User volume ³	++	+++	++	++	+	++	++	++	+++	++
Detection zone width ⁴	++	+++	+	++	++	++	++	+	+++	+++
Count duration ⁵	+++	+++	++	+++	+++	+++	+++	+++	+	+

Notes: (1) Existing “automated video” systems may not use a completely automated counting process; they may also incorporate manual data checks of automated video processing.
(2) Includes manual counts from video images.
(3) +: provides consistent counts (although some accuracy adjustment may be necessary) up to approximately 200 users per hour, ++: up to 600 users per hour, +++: beyond 600 users per hour. These are approximate ranges under typical conditions. The range also depends on specific site characteristics (e.g., average user group size, mix of pedestrians and bicyclists, detection zone width). The maximum user volume range for manual counts assumes a single data collector is counting one type of user and no additional characteristics. Multiple manual data collectors can count more than 600 users per hour. Counts can be adjusted at user volumes above these levels.
(4) +: typical detection zone width narrower than 4 meters (13 feet), ++: narrower than 6 meters (20 feet), +++: 6 meters (20 feet) or wider. In the case of automated video and manual counts, the detection width may be 25 meters (82 feet) or wider.
(5) +: typically used for 48 hours or less, ++: typically used for non-permanent short- or longer-term counts, +++: often used for permanent count sites. Most inductive loops are installed in the pavement, but there are also varieties that can be installed on top of the pavement for up to 6 months.

Table 3-3. Comparison of common pedestrian and bicycle counting methods: resources.

Characteristic	Passive Infrared	Active Infrared	Pneumatic Tubes	Inductive Loops	Piezoelectric Sensor	Passive IR + Inductive Loops	Radio Beam (One Frequency)	Radio Beam (High/Low Frequency)	Automated Video ¹	Manual Counts ²
Equipment cost ³	\$\$	\$\$\$	\$\$	\$\$	\$\$	\$\$\$	\$\$\$	\$\$\$	\$\$	\$
Preparation cost ⁴	\$\$	\$\$	\$\$	\$\$\$	\$\$\$	\$\$\$	\$\$	\$\$	\$\$	\$
Installation time ⁵	⌚	⌚⌚	⌚	⌚⌚⌚	⌚⌚⌚	⌚⌚⌚	⌚⌚	⌚⌚	⌚	N/A
Hourly cost ⁶	\$	\$	\$\$	\$	\$	\$	\$	\$	\$\$\$	\$\$\$\$
Data collector training time ⁷	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚⌚⌚
Mobility ⁸	+++	++	+++	-	-	-	++	++	+++	+++
Pavement cuts	No	No	No	Yes	Yes	Yes	No	No	No	No

Notes: N/A: not applicable

This table presents generalized information specific to particular counting *technologies*. Other aspects of counting *products*, such as battery life and communication interfaces, are also important to consider but are highly vendor-specific. See the text following this exhibit for more details. See Chapter 5 for specific details (e.g., typical costs) related to each technology.

(1) Existing “automated video” systems may not use a completely automated counting process; they may also incorporate manual data checks of automated video processing.

(2) Includes manual counts from video images.

(3) \$: equipment (not including permitting and installation) typically cost less than \$1,000 as of 2013, \$\$: typically costs between \$1,000 and \$3,000, \$\$\$: typically costs more than \$3,000. The cost of most counting technologies is subject to economies of scale, so the per site cost can be reduced by purchasing more counters.

(4) Fewer dollar signs (\$) indicate that it takes less time (and therefore fewer financial resources) to find an appropriate site and to obtain any required permits to install the counting product. Preparation can range from less than one day for manual counts to several months for technologies with more restrictive installation requirements.

(5) More clocks (⌚) are given to methods that require more installation time (e.g., cut pavement, secure the data logger, test and adjust the equipment). Installation can range from no time for manual counts and less than 30 minutes for passive infrared to more than half a day for inductive loops.

(6) More dollar signs (\$) indicate that the method is more costly for an average hour of counts, given the typical count duration for a particular method. These costs can range from a few cents per hour for automated technologies (the full equipment, preparation, and installation cost is spread across months of counts) to more than \$50 per hour for manual counts (including training preparation time, management, and on-site labor costs).

(7) More clocks (⌚) indicate that more time is needed to prepare field data collectors to implement the counting method. A single data collector can be trained how to install or download data from a particular automated technology in less than 30 minutes, but it often takes more than one hour to thoroughly train data collectors to collect accurate manual counts.

(8) More pluses (++) indicate that a counting technology is easier to move after it has been installed. A minus sign (–) indicates that the technology is generally not intended to be used in more than one location based on the installation being permanent.

inductive loops have specific width requirements, they may not cover the entire facility (in the case of a multi-use trail) or they may cover a greater width than the facility (in the case of a bicycle lane). *Count duration* indicates the typical length of time that the counting methods are employed to collect data. In this table, methods typically used for less than 48 hours are classified as “short-term.” In particular, manual counts are commonly done for 2 hours and are rarely done for more than 8 to 12 hours. Methods often used to collect continuous counts for 1 year or more are classified as “long-term.”

Table 3-3 compares start-up, data collection, and data analysis resources. Similar guidance is provided in the TMG (FHWA 2013, Table 4.1). Resource considerations include technology cost, preparation cost, installation cost, hourly cost, and data collector training cost. Mobility (portability among multiple sites) and pavement cuts also affect the resources needed for counts.

Resource Considerations

All counting methods require resources, such as money and time. This section provides additional details about the resource categories listed in Table 3-3. Although the amount of resources required for most of these categories depends on the products and services offered by particular vendors, the resources required for each method generally have a similar magnitude, regardless of vendor.

- *Equipment cost.* This cost represents the cost of equipment, not including preparation and installation. In general, for short-term counts, automated technologies are more expensive on a per site basis than manual counts because the equipment cost is higher than the cost of several hours of labor. The least expensive automated counting technologies are pneumatic tubes, inductive loops, and piezoelectric sensors. The cost of most counting technologies is subject to economies of scale, so the cost of equipment per site can be reduced by purchasing more counters.
- *Preparation.* Preparation costs include the time required to identify an appropriate site, apply for an installation permit, and purchase a permit (if needed). Technologies that have more flexibility in their installation requirements tend to have lower preparation costs. In general, it is possible to count at nearly all potential sites using manual counts. In contrast, methods such as radio beam technology require installing a transmitter and receiver at an appropriate height in places that are free of obstructions between these components.
- *Installation.* Installation cost includes time and budget (1) required to cut pavement; (2) secure equipment to install poles, posts, and boxes; and (3) test and adjust the sensor. Installation time considers the typical time required to install equipment at a site. In general, the longest installation times for counting products on the market are for inductive loops and piezoelectric sensors, because they require pavement cuts. Other technologies with more parts (e.g., transmitter and receiver), such as radio beam, also tend to have longer installation times.
- *Hourly cost.* The cost per hour for manual data collection is higher than most other continuous counting methods. This is because once automated counting equipment is installed, it can count continuously for weeks, months, or longer periods. In contrast, the cost of labor for long-term, continuous manual counts is prohibitively expensive. The automated video count services available on the market at the time of writing are priced by the hour, so they also have a high hourly cost relative to other automated counting technologies.
- *Data collector training.* Training costs include the amount of staff management time and labor time required to prepare field data collectors to implement a counting method. In general, automated counting technologies require relatively little data collector training; once a data collector knows how to install or download data from a particular product, he or she can implement it efficiently. Manual counts tend to require extensive data collector training (often involving many data collectors) to obtain accurate counts.

- *Mobility.* Moving counting equipment to different sites makes it possible to capture a greater spatial variety of data with a single device. Using mobile counting methods enables agencies to reduce the number of individual equipment sets they need to purchase. Data collectors can move to any location easily, so manual counts have high mobility. Other methods have varying degrees of portability. Some devices can be easily unfastened or removed from poles; devices installed in pavement are very difficult to move or are not reusable; and other product components (e.g., the box with the data logger) may often be movable and reusable.
- *Pavement cuts.* In general, counting methods that require pavement cuts tend to take more time to obtain permits and cost more to install. Costs can be reduced if agencies have the in-house expertise to make pavement cuts and install equipment. These considerations are included in the preparation and installation characteristics above, but it is useful for agencies to understand explicitly which technologies require pavement cuts. The need for pavement cuts also requires disrupting facility traffic for several hours or even a day while the installation (or replacement, when the loops eventually fail) occurs.

There are many other important resource considerations when planning a count program. However, most of these resources depend more on the product and services offered by a particular vendor than on the counting method itself. These resource considerations include

- *Testing and adjustment.* Most automated counting technologies require testing and some adjustment in the field to optimize their accuracy and consistency. Vendors provide differing levels of customer service to support testing and adjusting their product after it has been installed. For manual counts, testing and adjustment involves monitoring data collector accuracy.
- *Durability and theft-resistance.* The containers used to house counting products, the materials used to seal counting technologies in the pavement, and the systems used to mount counting products onto structures affect overall durability and theft-resistance. Vendors use different materials and systems for each product. The product warranty and other agencies' experiences with product reliability and lifespan are important to consider.
- *Expected product use life.* Like all materials, counting equipment deteriorates over time. For example, although passive infrared sensors housed in boxes may last longer than 5 years, pneumatic tubes in heavy mixed traffic may need to be replaced in less than 1 month (e.g., one vendor recommends replacing tubes after 300,000 automobile hits). All automated counting devices should be checked regularly to ensure they are counting accurately. Equipment must be kept in a state of good repair, which depends on how devices are housed and installed, traffic conditions, weather and other site characteristics, and vendor maintenance services.
- *Battery life.* Battery life affects the frequency of maintenance visits to a given count site and battery replacement costs. Vendors use different types of batteries to power their technologies. These batteries can last from a few weeks to several years, and newer technologies tend to have improved power capability. For example, many use lithium battery packs that can have a lifespan of 1 to 2 years or more based on activity levels and device efficiency. Battery life also depends on battery manufacturers, which is especially important for devices that do not include a vendor-supplied power unit. In contrast, some products are hardwired, which require a site with electrical connections, but eliminate the need for batteries and battery-charge site visits. Some products also use solar power to charge the battery.
- *Data storage capacity.* The data logger's storage capacity determines how frequently data need to be downloaded from the count site. This timeframe also depends on the data logging technology, the volume of users at the site, and a product's user interface. Storage capacities can range from less than 1 month to multiple years. For most devices, the interval between downloads can be lengthened by adjusting the data logger's settings for how often events are recorded. For example, changing from 15-minute count intervals to hourly intervals can

reduce the amount of memory needed to store counts each day. (This is not possible when a product can only record counts in timestamp format.)

- *Downloading capability.* Ease of downloading reflects how long it takes a person to gather data from each count site and depends on the product's data logging technology and user interface. Some products require data to be downloaded on site using a portable storage device, such as a laptop or tablet; other products allow data to be downloaded remotely, usually requiring cellular transmission capacity that may entail monthly fees for service. Real-time data collection systems are very rare. The products reviewed during this research provided data that were analyzed through downloading and post-processing. The combination of data storage capacity and downloading capability can dramatically affect costs: if frequent in-person downloads are required and particularly if counters are in many different locations, gathering data can take a substantial amount of time. Many agencies with large-scale automated counting programs interviewed for this research have, or are moving to, a remote data downloading capability.
- *Database creation.* Creating a database from raw count numbers takes time. Counting products can compile data automatically into a database that shows counts by time period (or time stamp). Manual counts done on paper must be compiled by entering hand-written information into a database; manual counts performed using a counting device or mobile application can be compiled automatically.
- *File format and count interval options.* Converting data into a usable format also takes time. Vendors record data in various file formats. Some vendors offer data recording equipment that outputs time-stamped counts; others offer equipment that outputs the total count over a specific interval, such as 15 minutes or 1 hour. The specifics depend on the data logging technology and user interface developed by a particular vendor. Some products require the vendor's own software to read and export the data to other formats. At the time of writing, few products exported data in the format specified by the FHWA Office of Highway Policy Information Travel Monitoring Analysis System (TMAS) 3.0. However, vendors may provide this option in the future so that it will be easy to compare data collected by different products in different communities.
- *Data cleaning.* Cleaning data refers to removing incorrect counts or missing data (i.e., counts that do not represent what is supposed to be measured) from a count database. The time required to clean a database depends on how often anomalies are in the count pattern at a particular site. Anomalies may be related to the type of technology as well as specific site characteristics (e.g., large platoons of pedestrians or bicyclists, people tampering with the counter, objects temporarily blocking a sensor) (see Section 3.3.9). Time to train an analyst in data cleaning is also a cost to consider.

When assessing locations where permanent counters are being considered, it can be helpful to initially collect volumes using short-term counting methods (e.g., manual counts or pneumatic tubes). Performing a test count can help confirm that volumes are roughly as expected and that a permanent counter would prove valuable. Short-term term counts can provide a better sense of travel patterns and help in stratification of sites.

Count Accuracy and Consistency

Count data accuracy and consistency are also important to consider when selecting a technology. *Data accuracy* reflects the magnitude of the difference between the count produced by the technology and the actual ("ground truth") count gathered manually from video data (or gathered using some other means of obtaining a precise estimate of the actual count). This difference typically depends on user volumes, movement patterns, traffic mix, and environmental characteristics. The most common source of inaccuracy is occlusion, or undercounting, which occurs when multiple users pass a detector at the same time and the sensor fails to register more

than one count. Known sources of inaccuracy can be corrected, provided that the device errors are consistent. *Data consistency* reflects the remaining variability in the count data after being corrected for expected under- or overcounting, given specific conditions. This variability typically depends on the counting technology itself, how a specific vendor uses the technology in a particular product, and the quality of the installation. Data accuracy and consistency for specific technologies are discussed in detail in Chapter 4.

Emerging Technologies

Counting technologies will continue to develop so that they are easier to use and perform better at a lower cost. Although the technologies presented in Tables 3-1 through 3-3 were commonly available at the time of this report, practitioners should also consider emerging technologies. This project's research suggests that thermal, ultrasonic, and fiberoptic sensors may become more common counting technologies on the U.S. commercial market in the coming years. Other technologies that track user movements, such as GPS and WiFi/Bluetooth technologies, may be crowd-sourced to estimate counts at specific locations.

3.3 Implementing the Count Program

After planning is completed, the count program can be implemented. Implementation typically involves the following steps:

- Obtaining permissions,
- Procuring counting devices,
- Making an inventory and preparing devices,
- Training staff,
- Installing and validating devices,
- Calibrating devices,
- Maintaining devices,
- Managing count data,
- Cleaning count data, and
- Applying count data.

The first eight bullets (through “managing count data”) are described in Sections 3.3.1 through 3.3.8, respectively. These sections cover the process of obtaining data from automated counters, from permission to installation to downloading raw data. The remaining subsections of Section 3.3 and subsequent material in Chapter 4 cover three important types of data adjustments used in traffic monitoring: (1) cleaning erroneous data, (2) correcting for systematic errors generated by the counting method, and (3) expanding counts from shorter time periods to estimate pedestrian and bicycle activity over longer time periods.

Cleaning erroneous data involves identifying when a count is likely to represent a time period when an automated counter was not observing the intended pedestrian or bicycle movements. Data from these time periods are discarded or replaced by better estimates. This concept is covered in Section 3.3.9.

Correcting for systematic errors involves applying a correction function that removes the expected amount of under- or overcounting for a particular counting technology (often due to occlusion). This concept is first discussed in Section 3.3.9, but it is the main topic in Chapter 4.

Expanding short counts to longer time periods involves applying an expansion factor to a count collected for a short time period. The expansion factor is based on the type of activity pattern assumed to exist at the site, and it can account for the effects of weather on pedestrian and bicycle volumes. This concept is also covered in Chapter 4.

Permitting Considerations

The permitting process can be an unanticipated challenge to installing automated counting equipment, especially for organizations or agencies that do not maintain the public right-of-way where devices will be installed. Therefore, it is important to anticipate permitting needs early in the process of planning a count program. The following actions may help make the permitting process easier:

- Identify all organizations that own the right-of-way, poles, and buildings where equipment may be installed. Multiple organizations may need to provide permission.
- Ask contacts at the organization(s) with jurisdiction over the site where equipment will be installed whether or not a permit is necessary. Some temporary devices may not require a permit; some installations can be approved informally by e-mail.
- Understand exactly how the device will be installed, including specifications such as mounting devices and pavement cuts. This can help make communication efficient and reduce approval time.

3.3.1 Obtaining Permissions

Before installing counting devices at a site, check with local agencies, utilities, and other organizations responsible for managing poles, signs, pavement, walls, or other features at the site. In many cases, permission is required. Permission may be given informally by email or letter, but often requires obtaining an official permit and/or posting a bond (e.g., roadway alteration permit, right-of-way use permit, and utility permit). Many different types of agencies grant permission (e.g., public works departments, parks departments, and utilities), and it may be necessary

Working with Other Agencies

Sometimes an agency wants to perform counts on a pedestrian or bicycle facility owned by another agency. In these cases, inter-agency coordination becomes especially important.

The Alameda County (California) Transportation Commission has worked with the East Bay Regional Park District to install counters when trails are constructed, as it is more cost-effective than installing them later.

Arlington County, Virginia operates counters on multiple-use paths owned by the National Park Service, a regional park authority, and the District of Columbia DOT (the Key Bridge), and planned to soon have a counter on state DOT right-of-way. These counters typically involved filing some sort of permit, although the counter in the regional park was covered by an existing memorandum of understanding.

Keep in mind that the partner agency's permitting procedures may not have been developed with counters in mind. Developing relationships with partner agency staff and agreeing to share data can help smooth the process of getting the counters installed.

to obtain permission from more than one agency at a single location. In most cases, equipment is installed on public property, but permission from the property owner(s) will also be necessary if equipment will be located on private property (e.g., a building wall).

Ask for permission early in the process. Sometimes the permitting process can be so onerous that it is worthwhile to select a different count site. Use of video technology, either for counting or for validating other technologies, may be problematic in locations where privacy is a concern, and may not be permissible in some jurisdictions.

3.3.2 Procuring Counting Devices

Choosing good equipment and a good vendor is important when using automated technology as part of a count program. The sensor technology itself is supported by other equipment, such as mounting devices and data loggers, that is also essential for the success of a counting product, and the vendor's customer service record is important to consider.

The Transportation Research Board does not endorse particular products or vendors. However, based on the product testing conducted during the development of this guidebook, the following is a list of recommended questions that potential customers should ask vendors when selecting equipment. Some of these questions may help inform the selection decision; others will help in setting expectations and planning for the eventual installation. Agencies may wish to include some of the questions below in a request for proposals (RFP) when soliciting vendors to provide counting equipment. Providing specific questions and expectations in an RFP can help agencies obtain the best possible counting technology for their needs. Several of the issues behind these questions are discussed in more detail in subsequent sections.

- *Out-of-the-box readiness.* In what form will the product be shipped? Will it require some assembly in an office or workshop before it is taken to the field? Will the device arrive mounted in an anti-theft box? After an order is placed, how long will it take to ship the equipment to the client?
- *Additional needs for the product to function.* Is any extra equipment (e.g., wrenches, screws, fastening devices, batteries, or an electrical connection) required to install the product that is not included when it is shipped? What extra equipment is required to communicate with the device (e.g., SIM cards, smartphones, and tablets)? Are extra services required (e.g., a cellular data subscription or a service agreement with the vendor for downloading and processing data from the product)?
- *Warranty/expected use life.* Does the equipment have a warranty? If so, what is its length? If there is no warranty, how long is the equipment expected to continue counting accurately? Most products tested for this study did not include a warranty, but vendors were willing to help with installation and troubleshooting. While there is little research on the accuracy of counting devices over long periods of time, the accuracy of pneumatic tubes and inductive loops may decline with age if these technologies are not maintained properly. For pneumatic tubes, proper maintenance includes replacing the rubber tube component of the equipment relatively frequently, especially when installed in mixed traffic. The frequency of tube replacement depends on vehicular traffic intensity; one vendor recommends replacing tubes after 300,000 automobile hits. For bicycle-specific inductive loops, proper maintenance includes replacing the inductive loop component occasionally (e.g., every few years).
- *Site specifications.* What specific site or environmental conditions are required for installing the device so that it counts correctly? Some devices need to be installed at a particular height above the ground, pointed at a wall, or installed on a facility that has a specific maximum width. These requirements are typically set by the device manufacturer based on their testing and experience.

- *Performance factors.* What specific site or environmental conditions must be avoided so that the device counts correctly? For example, some devices are affected by moving branches, windows in the background, electrical lines, or other factors.
- *Installation complexity.* How much time does it take to install the product and calibrate the device in the field? This includes getting the device to perform its basic function of registering counts. However, it also includes making sure the device is recording pedestrians and bicyclists as intended and making necessary adjustments (including modifying device settings for placement, sensor height, sensitivity, and other factors that may affect user detection) to ensure the data collection is reliable.
- *Contractor installations.* Will it be necessary to hire a contractor to install the device? Some devices require more technical skills and electronics knowledge than others. Some devices require more disruption at the installation site than others. Devices that require pavement cuts or an installation at a height above the normal reach of a person are more likely to require a contractor.
- *Device security/durability.* How secure will the device be after it is installed? How often does the vendor receive reports of stolen devices or replacement of vandalized units? Are any extra security options available for sites that may have a higher risk of theft or vandalism?
- *Purchase versus lease.* Is there an option to rent or lease the equipment? If equipment can be rented, when does it need to be returned, and what is an acceptable condition of the equipment at the time it is returned? Is a “rent-to-own” or trial period purchasing option available?
- *Data downloads.* What options are available for downloading the data? Some products require agency staff to go to the site and physically connect a laptop to the counter to download data. Other products have Bluetooth capabilities that allow agency staff to download data directly to a mobile device or computer. Some vendors can also capture data from their own product using cellular data technology and post it to a cloud storage space where it can be accessed by their clients.
- *Data formatting and compatibility.* What data formats are used? Most vendors make it possible to download data to a spreadsheet (e.g., .csv, .xls, .dbf). Some vendors also provide a proprietary format that can be read by their own analysis software. The format of the count database itself can also vary from individual, time-stamped counts to the total number of users detected over a specific time period (e.g., 15 minutes or 1 hour). Can the data be exported in FHWA’s specified format (discussed in Section 3.3.9)?
- *Performance history.* Has the equipment been used elsewhere, and has it gotten positive reviews? After going through the rest of the questions, it is helpful to contact other organizations to ask for their personal experiences with the equipment and vendor.

It is also recommended that potential customers ask the following general questions about the services that a vendor provides:

- *Installation support.* Will a vendor representative be on site on the day the equipment is installed? If no representative can be present, will someone be available by phone to answer questions? Some vendors may expect a local agency to do the installation themselves. Other vendors may ask to install their own device so that it meets their standards. Having a vendor representative on site will likely affect the overall installation cost (either billed as a specific item or incorporated into the product cost).
- *Ongoing customer support.* Is routine customer service included in the purchase price? Is routine customer service available, if it is not included with the purchase price? What is the general level of customer service provided (e.g., phone hotline, direct phone number and email of the vendor representative, site visits to fix problems with devices)? In some cases, purchasers may be expected to deal with problems and maintenance on their own after products are installed.

- *Calibration support.* Will a vendor representative be on site to help calibrate the counting device when it is first installed? Will a vendor representative be able to assist with recalibrating the device in the future? How difficult is recalibrating a device, and what specific modifications need to be made in the field in order to recalibrate?
- *Hardware and software upgrades.* Does the vendor regularly upgrade the equipment or software associated with the product, and if so, are the current equipment purchases compatible and supported when upgrades occur? Are there costs or licensing fees associated with these upgrades?



Source: Tony Hull, Toole Design Group.

Example of unpacking a counting product to inventory its contents.

3.3.3 Inventorying and Preparing Devices

Equipment should be inventoried soon after it is received from a vendor. An inventory will document whether or not all of the expected equipment has been delivered. In addition, an inventory is useful for identifying any additional tools or supporting equipment that may be necessary to obtain in advance of field installation (e.g., wrenches, screws, fastening devices, and batteries). Preparing the counting equipment should be done in the office or shop, where the equipment can be laid out in an organized manner. Preparations include assembling specific components and testing to make sure that batteries, loggers, and other electronic components work. Advance preparations make the actual field installation effort much more efficient than opening the equipment boxes for the first time at the data collection site. The following is a checklist for preparing equipment prior to installation in the field:

EQUIPMENT PREPARATION CHECKLIST	
	Take pictures of the equipment immediately after opening the boxes.
	Inventory the equipment received.
	Compare the equipment received to the product's parts list.
	Make a list of the main pieces of hardware included in the shipment.
	Create a database that lists each counter. This information will help track the history of each counter, regardless of where it is installed or moved. This step can be especially helpful when compiling historical data from the device and when communicating with the equipment vendor.
	<i>Equipment data:</i> serial number, date of manufacture (if available), date of arrival.
	<i>Installation data:</i> Date of installation, dates of moves, location information (e.g., latitude and longitude, site description).
	Review the full installation instructions.
	Contact the vendor to clarify any installation steps that are unclear.
	Identify any hardware and tools not provided with the product that will need to be obtained prior to installation.
	Obtain any additional hardware or tools required for installation.
	If necessary to communicate with the device, obtain a SIM card and set up a cellular data plan for the device.
	Label equipment with contact information. This provides information to citizens and police who may be concerned about an unknown device in a public space and will aid recovery in the event that the counter is removed or stolen.

3.3.4 Training Staff

Staff training is important for both automated and manual counting, although the kind of training involved is very different for the two types of counting.

Automated Counting

Staff training for automated counting devices focuses on making sure the device is working properly and on downloading data from the device. Many organizations use more than one person to monitor their counters, so it is essential for all staff to be able to monitor and consistently

adjust all of the equipment. The following is a checklist of things to consider when visiting automated counters in the field (not all items are applicable to all counting products):

EQUIPMENT MONITORING CHECKLIST	
	Sensor height. Is the sensor still mounted at the correct height?
	Sensor direction. Is the sensor still pointed in the correct direction?
	Clock. Is the device's clock set correctly?
	Cleaning. Remove dirt, mud, water, or other material that may affect the sensor or other vital components.
	Battery. Is the remaining battery life sufficient to last until the next scheduled visit?
	Obstructions. For example, is vegetation growing too close to the device?
	Unanticipated site problems. For example, is the pole being used for bicycle parking, or are people congregating in the area (as opposed to walking past the counter)?
	Pedestrian or bicycle detection. Are pedestrians or bicyclists passing through the counter's detection zone being counted? If not, can the counter's sensitivity be adjusted in the field, or does it need to be removed for repairs?
	Download data. Use the same export option consistently to ease the data management burden back in the office.
	Securement. Are the installation elements and locking devices still secure and durable? Poorly secured or loose fitted devices are more vulnerable to theft and vandalism.



Source: Lindsay Arnold, UC Berkeley Safe Transportation Research & Education Center.

Downloading data from an automated counter in the field.

Staff training increases efficiency, because a data collector who forgets one of these steps may need to return to a site more than once. In addition, well-trained staff members can detect existing or imminent equipment problems while they are downloading data.

Manual Counting

To obtain the most accurate and consistent manual counts, data collector training is essential. The benefits of manual count training apply both to people who are counting in the field (e.g., using clipboards, clickers, or mobile device counting applications) and to people who are taking counts from video recordings. Training should help data collectors understand the following:

- *The overall purpose of the counting effort.* Data collectors who understand how the data will ultimately be used are more likely to concentrate and take the job seriously.
- *Definitions of “pedestrian” and “bicyclist” (or “bicycle”).* Make sure the data collectors understand the definitions of pedestrian and bicyclist used in the community. Tricky aspects of these definitions include skateboarders (typically counted as pedestrians), babies being carried or pushed in a stroller (typically counted as pedestrians), people walking their bicycles (typically counted as pedestrians), dogs on leash (not typically counted, but their owners are), and bicyclists on a tandem bicycle (typically counted as two bicyclists but one bicycle).
- *Exactly when a person should be counted.* For trails or roadway segments, pedestrians and bicyclists are typically counted when they pass an imaginary line from either direction. At intersections, some methods count pedestrians only when they cross the street (specifically, when they pass the centerline of the roadway being crossed). In this case, pedestrians who turn right or left at a corner but do not cross the street are not counted. Furthermore, should pedestrians be counted at an intersection if they cross outside the crosswalk lines? Some methods specify that all pedestrians crossing within 50 feet of the crosswalk lines should be counted. Finally, some methods count bicyclists when they arrive at an intersection, while others do not count a bicyclist until he or she goes left, straight, or right—an important consideration to correctly classify bicyclists who dismount and walk their bicycle after arriving at an intersection.
- *Priority of characteristics to count.* While most automated technologies register a single count each time a pedestrian or bicyclist enters the counter's detection zone, manual data collectors can observe pedestrian and bicyclist characteristics and behaviors. Manual observers may be asked to also document age, gender, helmet use, assistive-device use, turning movements, or behavior each time a pedestrian or bicyclist is counted. This information can provide a rich set of data for



Source: Robert Schneider, UC Berkeley Safe Transportation Research & Education Center.

Field data collector training.

analysis. However, collecting more characteristics and behavioral data increases the complexity of the data collection effort and can diminish counting accuracy, especially in locations with high pedestrian and bicycle volumes. Therefore, it is important for the data collector to know which characteristics are the most important to document. The highest priority should be to collect volume by mode (i.e., get the total count right). It may be necessary to use additional observers to document pedestrian and bicyclist characteristics and to count complex sites effectively.

If volunteers are used for manual counts in the field, training is essential. In addition to communicating all of the key information, above, it is also important for data collection managers to recognize volunteers who should not participate in counting activities. During training, it is important for the count manager to evaluate the capacity of each volunteer for conducting the count. It may be necessary to exclude volunteers who may not be reliable for showing up at a particular count location and time or cannot demonstrate effective capability to follow the count protocol. The Washington State DOT case study provides an example of working with volunteers.

Field data collectors should be trained to be aware of their surroundings and to be careful in and around traffic and should bring a letter or some other form of official documentation that describes the counting effort. (See Appendix B for an example of information provided at a manual data collection training session.) Having a letter on hand can help the data collector avoid being distracted from their task by anybody coming up and asking questions.

Finally, when planning manual counts, it is important to identify when a site may need more than one data collector. In general, locations with higher user volumes or a greater mix of pedestrians and bicyclists require more data collectors.



Source: Tony Hull, Toole Design Group.

Technician initiating device for field deployment.

3.3.5 Installing and Validating Equipment

Equipment installation can be one of the most challenging steps in the data collection process. Count managers should budget significant time for installation to ensure that it is done correctly. The installation process involves everything from obtaining necessary permits to planning and scheduling an equipment installation date to verifying that the equipment continues to work several weeks after initial installation. Unless an organization has significant previous experience with the equipment, it is important to work closely with the equipment vendor during the installation process.

The following is a checklist of the steps involved in preparation for an installation (not all steps apply to every counting technology or product):

INSTALLATION CHECKLIST: ADVANCE PREPARATION	
	Site visit to identify the specific installation location. Specifically, note poles that will be used, where pavement will be cut, or where utility boxes will be installed to house electronics. Verify that no potential obstructions (e.g., vegetation) or sources of interference (e.g., doorway, bus stop, and bicycle rack) are present.
	Obtain and document necessary permissions. Permits or permissions may include right-of-way encroachment permits, pavement cutting permits or bonds, landscaping permits, or interagency agreements. Obtaining these permissions may take up to several months, particularly if other agencies are involved.
	Create a site plan. Develop a detailed diagram of the planned installation on an aerial photo or ground-level image documenting the intended equipment installation locations and anticipated detection zone (after installation this will be useful for validating equipment either visually or with video monitoring). This diagram may be useful for obtaining installation permissions and working with contractors. Figure 3-6 provides an example site plan.
	Hire a contractor if necessary (or schedule appropriate resources from within the organization).
	Arrange an on-site coordination meeting involving all necessary parties (e.g., staff representing the organization installing the counter, permitting staff, contractors). If possible, a vendor representative should be on hand or available by phone. It may take several weeks to find a suitable time when everyone is available.
	Check for potential problems. Problems with the site may include interference from utility wires, upcoming constructions projects, hills, sharp curves, nearby illicit activity, and nearby insect and animal activity. Some of these conditions can be identified from imagery, but they should also be evaluated in the field.

The following steps are recommended upon arriving at the site on the installation day:

INSTALLATION CHECKLIST: ARRIVAL AT THE SITE ON THE INSTALLATION DAY	
	Review the site with the vendor and other parties to verify there are no potential problems with the site (e.g., interference from utility wires, evidence of planned construction, frequent obstructions [e.g., delivery trucks] in the installation area).
	Prepare the site. Perform any maintenance or preparations for the installation, such as clearing vegetation or sweeping pavement surfaces where inductive loops or pneumatic tubes will be installed.
	Record detailed notes on any aspects of the site mentioned by the vendor as potential issues that could affect accuracy.
	Take a picture of the site before the counter is installed.

The following steps are recommended during the actual installation:

INSTALLATION CHECKLIST: COUNTER INSTALLATION	
	Maintain a safe work zone. If the installation requires working within or disrupting the traveled way, be sure to establish a work zone, including required signs and detours if needed to avoid creating a safety hazard for the installation team or passers-by.
	Install the counter according to vendor specifications. Document any deviation from the specifications (e.g., difference in mounting height due to site constraints).
	Record detailed notes on any difficulties with the installation—this information may make future installations go more smoothly.
	Take pictures during installation. Action photos (e.g., cutting pavement, securing equipment to poles, installing batteries) are useful for documenting that the correct steps were followed. They are also useful for reports and presentations.
	Sync the device's clock with the actual time. The actual time can be obtained from many sources; for example, most smartphones regularly sync with the actual time.
	Verify that the device is working and recording data correctly. Ideally, this activity will be done while the vendor is present. It may include watching counts register on the device, or taking manual counts for 15–60 minutes that can be compared with data downloaded from the device.
	If the test count is not sufficiently accurate, calibrate the device if possible by adjusting the sensor's sensitivity and repeating the previous step.



Source: Tony Hull, Toole Design Group.

Example picture documenting detection direction at a multi-use trail site.

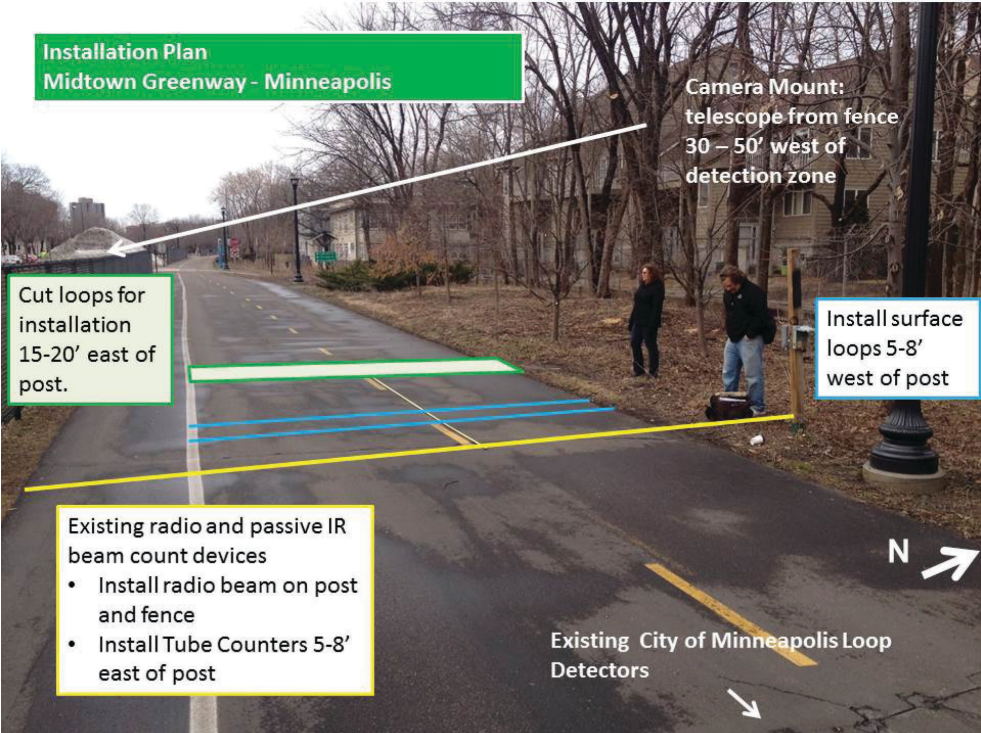


Source: Ciara Schlichting, Toole Design Group.

Example of a picture documenting the installation of inductive loops.

Once the device has been installed and appears to be working as intended, the following steps are recommended prior to leaving the site on the installation day:

INSTALLATION CHECKLIST: POST-INSTALLATION	
	Take a close-up picture of the device. Consider collecting a GPS point to document the exact coordinates where the device is installed.
	Take pictures of the device vicinity. Take at least one picture each from the front in the direction of travel, from the back in the direction of travel, and perpendicular to the direction of travel.
	Take a picture depicting the counter's detection zone. In the picture, have the vendor (or another expert) indicate exactly where the detection zone should be, using chalk, paint, etc. This picture helps when comparing video or manual ground truth counts with the device's counts, when assessing the device's accuracy.



Source: Tony Hull, Toole Design Group.

Figure 3-6. Example equipment installation plan at a multi-use trail site.

Once the counter has been installed, it is important to follow up periodically to ensure that the counter is still working appropriately. This activity includes the following actions:



Source: Frank Proulx, UC Berkeley Safe Transportation Research & Education Center.

Validation of pneumatic tube (roadway) and passive infrared sensor (on pole) during installation.

INSTALLATION CHECKLIST: FOLLOW-UP ACTIVITIES	
	Create a site description sheet or diagram containing the notes and photos from the installation day.
	Revisit the site after a couple of days to download data, to check that the recorded volume patterns seem reasonable. It is important to catch any systematic problems with the counter or site conditions right away.
	Revisit the site at least every 3 months —sooner if required for battery replacement or data downloads—to make sure the device is still working. This step is not necessary for temporary installations.
	Monitor count data and patterns routinely to identify any significant anomalies or deviations that could suggest an equipment malfunction. It is advisable to conduct 1–2 hour manual validation counts annually, or as needed based on data anomalies. This step is not necessary for temporary installations.

An important step in the equipment installation process is validation: determining whether or not a device is working properly. Validation involves testing the device both on the installation day and several days after installation. Immediately after a device is installed, the installation team should check that pedestrian or bicyclists are being detected and recorded. This check involves taking manual counts of all pedestrians or bicyclists who pass the detection zone during an initial test period (typically 15 minutes to 1 hour). These manual counts are compared with the total count shown on the device’s data logger or the total count downloaded from the device.

Another check should be conducted several days after the installation is complete. It should follow the same procedure as the initial check, comparing manual to automated counts. This second test can spot changes in the device that may have occurred over more than a day (due to sun and shade, heating and cooling, etc.). Importantly, the initial days of data should be downloaded and reviewed to see if there are any strange patterns in the data (e.g., abnormally high hourly counts or unexpected zero counts during the middle of the day). These strange patterns may indicate a problem with the device, but they may also indicate abnormal behaviors at the site (e.g., a delivery truck parked over the sensor, a bicycle parked in front of the sensor, pedestrians or bicyclists walking back and forth in front of a sensor). Ideally, abnormal pedestrian or bicycle movements at a site will be identified before a site is chosen. However, if these site problems are revealed in the first few days of testing the device, it may be beneficial to move the device to a different location at the site or to a completely different site.

While testing a device requires additional time, it will help ensure that high-quality data are being collected. It is much better to identify and fix problems early in the process than to collect many months' worth of data that cannot be used.



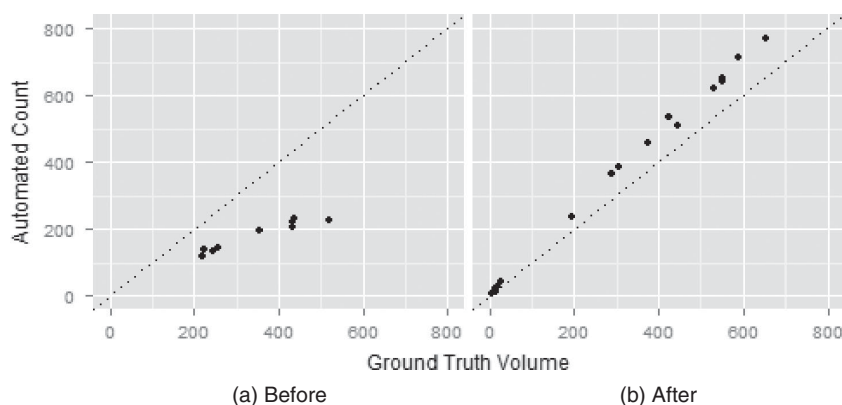
Source: Tony Hull, Toole Design Group.

Validation count at an inductive loop site.

3.3.6 Calibrating Devices

The sensors used in some counting technologies, such as inductive loops and pneumatic tubes, can be adjusted to make the sensor more or less sensitive and thereby less prone to non-detections (undercounting) or false-positive detections (overcounting). The initial test period during installation can suggest whether or not a sensitivity adjustment is needed. Figure 3-7 compares the accuracy of a pneumatic tube counter before and after calibration—the count accuracy improved after the counter's sensitivity was adjusted.

Validation counts should also be taken in future months and years to monitor a device's accuracy. This step is particularly important for counters using inductive loops or pneumatic tubes, because it is possible that, if not maintained properly, these types of sensors may become less accurate over time (see Section 3.3.2 for more detail). If a counter appears to be too inaccurate, contact the vendor to see if the device can be recalibrated or if certain components of the device should be replaced. It is important to work closely with vendors when calibrating counters, because vendors are typically the most knowledgeable about how a device detects users and how



Source: NCHRP Project 07-19 testing.

Figure 3-7. Illustrative comparison of pneumatic tube accuracy before and after calibration.

the device may be adjusted. Vendors can and should provide feedback to customers on how to achieve accurate results.

Counters that output data in a timestamp format (i.e., where each individual user detection is recorded), rather than as 15-minute or 1-hour totals, may allow for better troubleshooting of accuracy issues. A vendor or count manager can test how pedestrians or bicyclists passing the sensor at different speeds, in different locations, and in different group sizes affect the count accuracy. Some products allow the user to observe counts occurring in real time on site, even if they are only saved in a binned format. This is sometimes done with an LED indicator or by connecting to the device with a computer.

When a device is recalibrated, it is important to differentiate the data collected before and after the recalibration. It may be possible to apply an adjustment factor to the data collected before the device was recalibrated. When there is insufficient data history, or where missed or inaccurate counts cover an extensive period of time, it may be necessary to exclude data from the time period where the count accuracy is suspect.



Source: Tony Hull, Toole Design Group.

Technician inspecting a counting device.

3.3.7 Maintaining Devices

Counting equipment must be regularly maintained to ensure accurate consistent counts. In particular, staff should visit permanent count sites regularly (at least every 3 months) to check that devices are still present (not stolen or vandalized), pointed in the correct direction, and in working condition (see the follow-up activities checklist provided earlier). Staff should check for the accumulation of dirt, mud, water, or other materials that could affect the sensor or other equipment components. In addition, staff should download and review the count data to make sure that the equipment is working properly.

Staff should also conduct accuracy tests to determine whether or not the counting technology is maintaining an acceptable level of accuracy. Accuracy checking may be done less frequently than routine site visits, but it should be done at least once per year. If the counting technology has become less accurate over time (this can occur after several months for pneumatic tubes or after several years for inductive loops), it may be necessary to recalibrate the device, as discussed in the previous section.

Chapter 5 provides more detailed information about the maintenance needs associated with specific counting technologies.

3.3.8 Managing Count Data

Various systems are available for managing data after they have been downloaded from the counter, including agency-developed spreadsheets, vendor-supplied software, software developed in-house, and cloud-based repositories.

Based on the practitioner survey conducted for this research, the most common count management tool is using a spreadsheet to compile and analyze count data. Spreadsheets typically represent specific time periods as rows and individual counters or directions (e.g., “Counter A, Northbound” and “Counter B, Southbound”) as columns. Each cell contains the count from a specific counter for a particular time period. Populating the database with counts requires copying data from the counter’s output files into the spreadsheet, making sure that counts are pasted into the correct time periods. This approach requires staff time to download the data (often involving a field visit) and add the data to the spreadsheet. Because this effort can place a burden on staff resources, other options are also available to manage count data.

Understanding Unusual Counts

On August 23, 2011, a magnitude 5.8 earthquake hit Washington, D.C., a region not typically known for its seismic activity. The Metrorail subway shut down for the day, resulting in extremely high volumes of bicyclists and pedestrians being counted crossing the Key Bridge into Arlington, Virginia. Without the contextual knowledge of the earthquake and transit closure, the counted volumes—roughly double the count on a normal day—could have been written off as a sensor error.

Some vendors provide custom software that imports the output files from their products into a spreadsheet. This approach can help avoid mistakes from manually copying counts between data files. In addition, some vendors' software provides tools to create graphs and tables showing changes in counts over time. Practitioners should also be aware that some vendors' products require sensor data to be analyzed on the customer's computer using specially developed software. This requires an extra step for the analyst, but reduces computational power needed on site (which increases battery life and decreases equipment costs).

Organizations with in-house programming expertise can develop their own software to compile data from the counting equipment. This approach may make it possible to automate certain calculations and graphics production, at the cost of the up-front investment to develop and test the software. This approach entails a risk that if the person who developed the software leaves the organization, it may be difficult to update the software in the future.

Some vendors also offer a service (typically involving a monthly or annual subscription) where count data are automatically uploaded to a designated web page or cloud repository. This approach can save an organization from having to make field visits to download data directly, keeping in mind that some field visits will still be necessary to check and maintain the counters.

Finally, approximately one-third of this project's survey respondents stated that their pedestrian or bicycle count data were included in, or could be easily linked to, an existing motorized count database. When possible, agencies should consider building on the expertise and data management systems they have already developed for their motorized count data. In addition to saving time and effort by using an existing framework, integrating pedestrian and bicycle counts into a motorized count database can help an agency create a fully multimodal traffic monitoring system.

3.3.9 Cleaning and Correcting Count Data

Cleaning Count Data

Once counts are in a database format, they should be reviewed for unusual data. Some unusual counts are incorrect measurements by the technology itself (i.e., missing counts or counts of movements not intended to be counted). Potential reasons for incorrect counts include

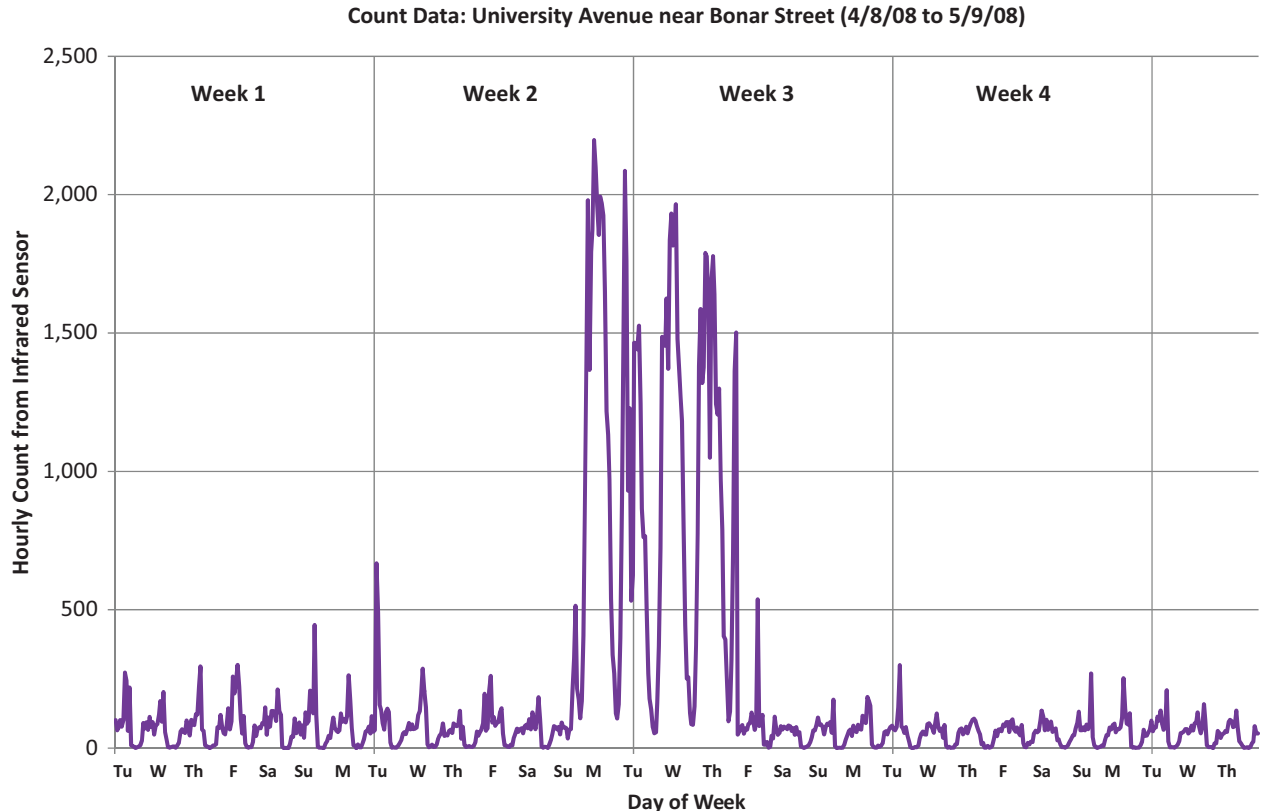
- Blocked sensor (e.g., delivery truck in front of or on sensor, bicycle parked in front of sensor, person standing in front of sensor).
- Multiple counts of the same person (e.g., where people often walk back and forth in front of the sensor, such as near a bus stop or near a corner of an intersection with high pedestrian activity).
- Equipment malfunction (e.g., power is lost temporarily, component wears out, detection sensitivity changes, sensor is bumped or turned the wrong way).

- Incorrect initial installation (e.g., sensor is pointed at a doorway or other background that creates false counts at certain times; sensor is at a location where people gather at particular times; equipment is not sealed correctly, resulting in water damage, tampering, or rapid deterioration).

Incorrect counts do not include regular undercounts due to occlusion. Occlusion is a limitation of the technology itself and is addressed by the correction factors described in Chapter 4. Incorrect counts also do not include temporary changes of activity patterns, such as re-routing of pedestrian or bicycle traffic due to construction or other rare events (e.g., festivals, field trip groups, and weather events). These changes in activity patterns may look like incorrect counts, but are actually measured correctly by the counter. Reviewing weather data, local event schedules, and other sources can help analysts understand why abnormal counts may have occurred.

The level of effort used to clean data should be commensurate with the end use of the data. If, for example, the data are being used to develop day-of-week and month-of-year expansion factors that will be used to convert short-term counts to annual volumes, then a careful check of the data would be warranted. If, on the other hand, the data will only be used to report monthly or annual volume totals for that location, then checking and correcting for short periods of missed data will likely not change the result in a meaningful way.

Figure 3-8 shows a selection of raw count data from a passive infrared counter. In this case, the sensor was moved from pointing across the sidewalk to pointing across the roadway and was not discovered for a week. During the week when the sensor was pointing the wrong way, recorded counts were up to 10 times higher than normal levels. It is likely that the infrared sensor counted



Source: Robert Schneider, UC Berkeley Safe Transportation Research & Education Center.

Figure 3-8. Example of incorrect pedestrian counts due to sensor pointed in wrong direction.

a portion of motor vehicles that used the roadway, given that their engines and passengers are sources of heat. If the erroneous counts are not removed from the dataset, erroneous conclusions would result about the level of pedestrian activity at this location.

The only certain way to identify the difference between an incorrect count and a temporary change in the normal activity pattern is to observe the site (either with a field data collector or reviewing a video) and then compare the automated count with the ground truth count. However, analysts can review raw data for unusual spikes or dips (often counts of zero) and then decide whether or not to flag them as “probably incorrect” counts. One strategy to identify a “probably incorrect” count is to compare it with similar counts before and after it was collected. A count of zero pedestrians during 1 hour in the middle of a day averaging more than 200 pedestrians per hour is “probably incorrect.”

Although it is possible to review each individual count period for unusual counts, it is impractical (and potentially error-prone) to attempt to manually identify “probably incorrect” counts from multiple months of raw data. Therefore, an organization may choose to establish standards for identifying counts that are “probably incorrect.” Different thresholds could be set for a single observation period and for multiple observation periods. For example

- *Single observation threshold.* For the count in question, consider the counts taken at the same time of the week in the previous 4 weeks and in the following 4 weeks. The count is “probably incorrect” if it is more than two standard deviations above or below the average of the eight same-time-of-week counts. The same-time-of-week counts should exclude holidays.
- *Multiple observation thresholds (four consecutive count periods).* For the four consecutive count periods in question, consider the counts taken at the same time of the week in the previous 4 weeks and in the following 4 weeks. For each of the four periods, calculate the average and standard deviation of the eight corresponding same-time-of-week counts. The four consecutive hours of counts are “probably incorrect” if each individual count in the series is more than one standard deviation above or below the average of its eight corresponding same-time-of-week counts. The same-time-of-week counts should exclude holidays.

Another automated approach to identify incorrect counts was proposed by Turner and Lasley (2013). This method incorporates differences in directional counts (e.g., eastbound vs. westbound) and separates weekday from weekend data. Outliers are identified based on the interquartile range of all counts of a particular type. The authors recommended having an experienced professional perform a targeted manual review of portions of the data to identify possible anomalies not highlighted by the automated process.

After an incorrect count is identified, it can be omitted or cleaned. Omitting counts will leave gaps in the pedestrian or bicycle activity pattern when it is reported. Cleaning involves replacing the incorrect count with an estimate of the correct count (i.e., an imputed value). This replacement can be done using a process similar to the technique used to identify “probably incorrect” counts. For example, if the incorrect count was from a summer Tuesday between 10 a.m. and 11 a.m., an analyst can substitute the average value from the previous 4 weeks of counts on Tuesdays between 10 a.m. and 11 a.m. and the following 4 weeks of counts on Tuesdays between 10 a.m. and 11 a.m.

Care must be taken not to use counts from time periods that had different characteristics (e.g., using data from sunny days to estimate an incorrect count from a rainy day; using data from a holiday to estimate an incorrect count from a regular workday). However, if the time period with incorrect data has different weather characteristics than the comparison time periods, it is possible to apply a regression model that includes weather and time period variables to estimate the count for that time period (Wang et al. 2014). Additionally, before determining that a count is erroneous, consider carefully whether or not the unusual count can be explained by a special event or other temporary change in activity pattern.

Clean pedestrian and bicycle counts can be integrated with automobile traffic count databases. Approximately 30% of the respondents to the practitioner survey conducted as part of the research behind this guidebook integrated non-motorized count data into motorized count databases (or developed a parallel and easily linked database). Most transportation agencies have georeferenced traffic count locations (e.g., mileposts or GPS coordinates), so pedestrian and bicycle counts can be added to the appropriate location in a count database. In some cases, additional data fields are needed to create a complete multimodal count database. These fields may specify the type or direction of the movement being counted, the pedestrian or bicycle facility type, or the specific type of counting technology used. To make data easier to share among agencies and to report to a national repository, pedestrian and bicycle data fields should be consistent with the data format specified in the FHWA's Office of Highway Policy Information Travel Monitoring Analysis System (TMAS) 3.0.

Correcting Count Data

After the raw counts have been cleaned, they are ready to be corrected (i.e., adjusted for systematic under- or overcounting due to the specific counting technology used). The process of correcting data is the focus of Chapter 4.

3.3.10 Applying Count Data

At this point, the count data have been collected, adjusted, cleaned, and stored and are ready to be used. Chapter 2 provides examples of how non-motorized count data can be put to use.

Adjusting Count Data

Chapter 4 Topics

- Sources of automated counter errors
- Measured accuracy and precision of automated sensor technologies
- Correction factors for automated counters, used to adjust raw counts to more closely represent the ground truth
- Expansion factors, applied to short-duration counts to estimate volumes over longer periods of time
- Example application of applying correction and expansion factors

4.1 Chapter Overview

This chapter discusses two types of factors that can be applied to raw count data: correction factors and expansion factors. *Correction factors* account for systematic inaccuracies in automated counter technology. *Expansion factors* are applied to short-duration counts to estimate volumes over longer periods. The process of identifying potentially incorrect counts (e.g., due to a sensor being blocked, a battery becoming depleted, or other problems that prevent a sensor from “viewing” the activity scene correctly) is different from the process of correcting counts that have been collected by a fully engaged sensor, which is covered in this chapter. Techniques for identifying and removing potentially incorrect counts are discussed in Section 3.3.9, Cleaning and Correcting Count Data.

4.2 Sources of Counter Inaccuracy

Several systematic sources of error are inherent in automated pedestrian and bicycle counts. This chapter presents methods for correcting raw automated count data to achieve more accurate volume estimates, but making a “correction” does not necessarily make a count perfectly accurate. The following are potential sources of counting errors that arise from automated counters.

4.2.1 Occlusion

Some counter technologies count users who cross an invisible screenline. When two or more people cross the line simultaneously, an undercount occurs because the device only detects the person nearest the sensor. In previous research, this effect has been found to become more



Source: NCHRP 07-19 field testing video.

Example of occlusion of a passive infrared sensor. The red triangle indicates the sensor's detection zone.

Two Classes of Adjustment Factors

Two types of factors can be applied to count data when developing volume estimates:

- **Correction factors** are developed from validation counts and account for systematic inaccuracies in counter technology. These factors are used to adjust the raw counts to more closely represent the ground truth.
- **Expansion factors** are applied specifically to short-duration counts to estimate volumes over longer periods.

pronounced with higher volumes (i.e., errors are non-linear) (Ozbay et al. 2010, Schneider et al. 2012). This effect was observed for the passive infrared, active infrared, and radio beam sensors tested in NCHRP Project 07-19. The effects for passive infrared sensors, however, were somewhat ambiguous: a strong occlusion effect appeared for one product, while the other product did not demonstrate this effect as strongly.

4.2.2 Environmental Conditions

Environmental conditions, such as weather and lighting, may cause counting inaccuracies in different counting technologies, because of particular characteristics of those technologies.

Hot Temperatures

Passive infrared and thermal sensors detect people based on the temperature gradient between persons and the background. If the ambient temperature is close to that of the surface of a human being, the gradient may be weak and hence detections may be missed. However, this effect was not observed during NCHRP Project 07-19 when temperatures exceeded 90°F. However, some vendors advise that passive infrared sensors in direct sunlight can become overheated and significantly overcount.

Cold Temperatures

Andersen et al. (2014) performed controlled tests of pyroelectric (passive infrared) sensors in a very cold setting. They found that errors increased when a person wore a heavily insulating down jacket and passed at the edge of the stated detection range of the counter. However, errors were not substantially greater than the vendor-specified $\pm 5\%$. Passive infrared sensors tested as part of NCHRP Project 07-19 did not suffer accuracy problems at temperatures below 30°F, based on 11 hours of data with a mean temperature of 20°F and a minimum temperature of 10°F.

Pneumatic tubes are suspected to undercount in cold temperatures as the rubber hardens, but this effect has not been formally documented. Pneumatic tubes are not recommended for use during snow or leaf-fall conditions—they can easily be damaged or dislodged by snow plows or street sweepers.

Precipitation

Precipitation has been suggested as a potential error source for all types of optical sensors (e.g., passive infrared, active infrared, and automated video). This effect was not observed with the passive and active infrared sensors tested by NCHRP Project 07-19, although only limited data

were collected during heavy precipitation events. Anecdotal reports from active infrared sensors have suggested very high overcount rates in heavy rain and snow. These errors are high enough (i.e., 3,000–5,000 people/hour) that they can be easily identified and cleaned out of the data.

Lighting

Low lighting has also been suggested as a problem for optical sensors; however, this effect was not seen in NCHRP Project 07-19 for active or passive infrared sensors.

4.2.3 Counter Bypassing

Even though a counter may accurately count the pedestrians or bicyclists that pass through its detection zone, it may still not count all of the users if it is possible for users to bypass the detection zone. For example, inductive loop sensors may not cover the entire facility width, leaving “blind spots” on the edges of the path. A beam-type sensor mounted to a pole within the walkway will miss pedestrians who walk on the other side of the pole. Therefore, site selection should consider how easily persons can avoid being counted, also keeping in mind that some types of counters are more obvious than others, which may cause bicyclists to avoid them as potential hazards.

4.2.4 Mixed-Traffic Effects

Two sets of bicycle-specific pneumatic tubes were tested by NCHRP Project 07-19 at a mixed-traffic site, Rue Milton in Montreal. The tubes at this site had higher accuracy and consistency results than bicycle-specific pneumatic tubes tested overall by NCHRP Project 07-19, despite a very large range of bicycle volumes. The data collection site experiences relatively low motor vehicle traffic volumes, so additional research is needed to explore the accuracy rates of pneumatic tubes on shared-use lanes with higher motor vehicle volumes and speeds.

Hjelkrem and Gæver (2009) tested two models of pneumatic tubes in mixed traffic and found bicycle count accuracy rates of –27.5% and –1.9%. They also tested inductive loops in mixed traffic and found a bicycle count accuracy rate of –16.5%. ViaStrada (2009) tested two models of inductive loops in New Zealand at four on-road sites, with accuracy rates ranging from –10% to +4%. Nordback et al. (2011) tested inductive loops capable of distinguishing bicycles from other vehicles on shared roadways and found a bicycle count accuracy rate of +4%. The TMG (FHWA 2013) suggests that magnetometers might not perform well for bicycle counting in mixed traffic with motor vehicles.

4.3 Measured Counter Accuracy

Table 4-1 summarizes the accuracy and consistency of all the sensor technologies tested by NCHRP Project 07-19. Accuracy refers to how close, on average, the automated count is to reality. Consistency refers to the counter’s ability to reproduce consistent levels of accuracy across multiple observation periods. Three metrics are provided:

- *Average Percentage Deviation (APD)* represents the overall divergence from perfect accuracy across all data collected. This metric does not differentiate over- from undercounting, which may tend to cancel each other out, resulting in the metric making a technology look more accurate than it actually is under some circumstances.
- *Average of the Absolute Percent Difference (AAPD)* is a measure of the counter’s consistency. Greater consistency (i.e., a lower AAPD value) is useful, because it makes it possible to apply a single adjustment factor with confidence that the result will consistently be closer to the actual



Source: NCHRP 07-19 field testing video.

Example of a missed bicycle detection. The inductive loops capture bicyclists in the left-side bicycle lane, but not bicyclists riding with traffic on the right side of the street.

Undercounting and Overcounting

Undercounting is when fewer bicyclists and/or pedestrians are counted than actually passed a site. **Overcounting** is when a technology records more bicyclists and/or pedestrians than actually passed a site.

Undercounting can and should be expected for even the most effective automated counting technologies. It can occur for a number of reasons, such as occlusion (e.g., when pedestrians walking side-by-side pass a counter and the sensor detects one instead of two people), environment (e.g., a cold morning on which pneumatic tubes may not compress sufficiently to record the bicyclists riding across them), and other similar situations.

Overcounting is a more significant issue because it is the result of false detections. This is likely due to broken equipment (e.g., damage during transport) or improper installation (e.g., counter not calibrated correctly, site condition such as windows create false positives for infrared counters).

count. At higher values of AAPD, the counter is less consistent in its detection error, which means that more error will remain in the results after applying an adjustment factor.

- *Pearson's Correlation Coefficient (r)* is a measure of linear correlation between two variables. The values presented here are calculated between the hourly manual and automated counts for a given technology. Pearson's coefficient can take values anywhere between -1 (perfectly negative linear correlation) and $+1$ (perfectly positive linear correlation). The closer this value is to $+1$, the more appropriate it is to use a multiplicative adjustment factor.

The project's final report (Ryus et al. 2014) describes how these metrics are calculated.

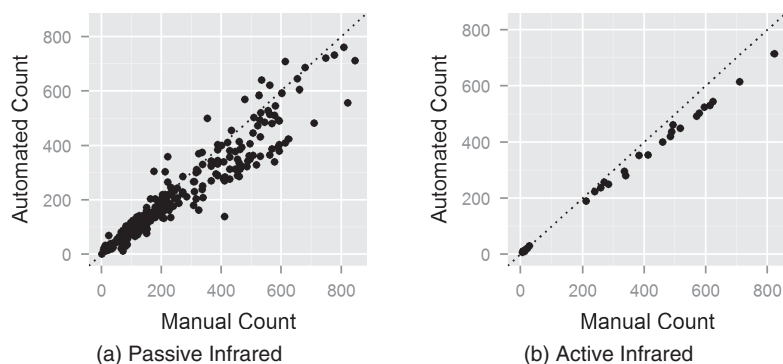
Figure 4-1 demonstrates how to interpret APD, AAPD, and r values. This figure presents the passive infrared and active infrared sensor data collected during NCHRP Project 07-19. These devices have similar APDs, indicating similar levels of accuracy, but the passive infrared data

Table 4-1. Accuracy and precision rates of sensor technologies tested by NCHRP Project 07-19.

Sensor Technology	APD	AAPD	Pearson's r	Hours of Data	Hourly Volume (Avg./Max.)
Passive infrared	-8.75%	20.11%	0.9502	298	240 / 846
Active infrared	-9.11%	11.61%	0.9991	30	328 / 822
Radio beam	-18.18%	48.15%	0.9503	95	129 / 563
Bicycle-specific pneumatic tubes	-17.89%	18.50%	0.9864	160	218 / 963
Inductive loops (detection zone)*	0.55%	8.87%	0.9938	108	128 / 355
Inductive loops (including bypass errors)*	-14.08%	17.62%	0.9648	165	200 / 781
Piezoelectric strips	-11.36%	26.60%	0.6910	58	128 / 283
Combination (pedestrian volume)	18.65%	43.78%	21.37%	47	176 / 594

Notes: APD = Average percentage deviation, AAPD = average of the absolute percent difference, r = Pearson's Correlation Coefficient, Avg. = Average, Max. = Maximum.

*Detection zone results refer to the accuracy of the device with respect to the bicycle volume that passed through its detection zone. Errors are larger when comparing the device's count to the actual volume on the facility, including bicyclists that bypassed the detection zone.



Source: NCHRP Project 07-19 testing.

Figure 4-1. Comparative accuracy and precision of passive infrared and active infrared sensors.

have a much higher AAPD. Similarly, the active infrared data have a correlation coefficient extremely close to 1. This difference can be seen in the plot as the greater degree of spread in the data. The lower AAPD indicates that one can have more confidence in the adjusted count result after applying an adjustment factor to the active infrared data, compared to the passive infrared sensor data.

4.4 Counter Correction Factors

Correction factors correct for systematic counting errors associated with a particular technology, such as those associated with occlusion. Applying a correction factor produces a better estimate of the “true” count of pedestrians or bicyclists who passed through the counter’s detection zone. As discussed in Section 4.2.3, even a perfectly accurate counter may not count all facility users, if users can bypass the counter’s detection zone. These correction factors do not account for bypass errors, which are highly site specific. When working with technologies susceptible to bypass errors, count program managers are encouraged to develop site-specific factors to account for typical levels of bypass errors.

4.4.1 Correction Factors Developed Through NCHRP Project 07-19 Testing

Table 4-2 presents simple multiplicative factors developed from the field tests conducted by NCHRP Project 07-19. These are multipliers applied to the raw count to estimate the true count. For example, if the raw count was 100 bicycles in an hour and the counting technology in use has a correction factor of 1.20, the estimate of the true count would be 120. The project’s final report (Ryus et al. 2014) provides details on how these factors were developed.

When possible, products from more than one vendor were tested for each technology evaluated. TRB does not endorse specific products; therefore, individual product results are anonymized in the table. Where results varied significantly between different products implementing the same technology, users are advised to use site- or product-specific calibration to develop accurate correction factors, because the errors seem to indicate potentially significant variation in performance among the vendor products available at the time that testing occurred. Site-specific calibration is also recommended when technologies shown in Table 4-2 were only tested in one location, resulting in insufficient data on whether or not the results are representative of the technology overall. The process of generating local correction factors is described in Section 4.4.2.

Comparison with Previous Research

Previous research has primarily focused on active and passive infrared, inductive loops, and pneumatic tube sensors. Consistent definitions of error rates and data collection protocols have not been used, which makes direct comparisons difficult. NCHRP Project 07-19's findings show similar or improved accuracy, compared with previous research.

Passive infrared sensors were previously shown to undercount non-linearly (Schneider et al. 2012, Ozbay et al. 2010), which this study agrees with. The average error rate of –9% determined by NCHRP 07-19 was roughly similar to or slightly better than findings in previous research, and Product A's performance was better than this, suggesting that innovations in product design may have occurred since previous research was conducted. Previous work on active infrared (Jones et al. 2010) suggested a non-linear adjustment function, which was also found by NCHRP 07-19.

Inductive loops appear to perform similar to or slightly better than the results presented in Nordback et al. (2011), although the detection zone was not clearly defined in the earlier study.

Pneumatic tube findings are similar to those presented in Hjelkrem and Giæver (2009) and ViaStrada (2009).

Table 4-2. Simple counter correction factors developed by NCHRP Project 07-19.

Sensor Technology	Adjustment	
	Factor	Hours of Data
Passive infrared	1.137	298
Product A	1.037	176
Product B	1.412	122
Active infrared*	1.139	30
Radio beam	1.130	95
Product A (bicycles)	1.470	28
Product A (pedestrians)	1.323	27
Product B	1.117	40
Bicycle-specific pneumatic tubes	1.135	160
Product A	1.127	132
Product B	1.520	28
Surface inductive loops	1.041	29
Embedded inductive loops	1.054	79
Piezoelectric strips*	1.059	58
Combination (pedestrians)	1.256	47

Notes: *Factor is based on a single sensor at one site; use caution when applying.

Multiplicative factors, as shown in Table 4-2, are the easiest form of correction factor to interpret and estimate. For most applications, using simple multiplicative factors is sufficient. However, in some cases, automated data can be corrected to be closer to the ground truth volume by introducing higher order terms, interaction terms with environmental factors affecting counter accuracy, or both. More complicated functional forms have been estimated using the NCHRP Project 7-19 data. A selection of these is presented in Table 4-3 and the full set can be found in the project's final report (Ryus et al. 2014). The functions presented here are limited by the amount of data collected during the project and are recommended to be revisited as more validation data becomes available.

For an example application of the functions presented in Table 4-3, take the third passive infrared equation. In equation form, this would be

$$\begin{aligned} \text{Manual Count} = & 1.125 \times \text{Automated Count} - 3.358 \times \frac{(\text{Automated Count})^2}{10^4} \\ & + 0.015 \times \text{Automated Count} \times \text{Facility Width} \end{aligned}$$

The models presented in Table 4-3 are shown with the Akaike Information Criterion (AIC), a measure of model fit used in comparing multiple models for the same dataset. The AIC represents the level of unexplained variation in the data and is penalized by adding additional terms to the model—hence, the lower the AIC value, the better fitting the model. However, AIC values are only meaningful when used in comparing multiple models on the same dataset, not as an absolute measure of fit.

As discussed in Section 4.2, despite previous findings in the literature in some cases, various environmental factors were not found to affect accuracy, including the following:

- Hot and cold temperature effects with active and passive infrared sensors,
- Cold temperature effects with pneumatic tubes, and
- Lighting effects with active and passive infrared sensors.

Table 4-3. Counter correction factors developed by NCHRP Project 07-19.

Technology	Automated Count	Automated Count ² /10 ⁴	Facility Width (ft) × Automated Count	Temperature (°F) × Automated Count	AIC
Passive infrared	1.137	---	---	---	3288
	1.313	-3.995	---	---	3258
	1.125	-3.358	0.015	---	3237
Active infrared†	1.139	---	---	---	232
	1.100	0.787	---	---	230
	1.413	0.868	---	-0.004	219
Radio beam	1.130	---	---	---	987
	1.857	---	-0.053	---	986
Pneumatic tubes*	1.135	---	---	---	1584
Inductive loops	1.050	---	---	---	829
	0.906	0.685	---	---	771
Piezoelectric†	1.059	---	---	---	607
	1.562	-3.246	---	---	594

Notes: *Bicycle-specific products.

†Factor is based on a single sensor at one site; use caution when applying.

AIC = Akaike Information Criterion.

Why Develop Site-Specific Factors?

The correction factors presented in Tables 4-2 and 4-3 were developed from NCHRP 07-19 field testing. Depending on the specific counting technology, the factors are based on data from 1–6 sites using 1–2 products implementing the technology.

However, different errors can occur, based on a site's unique traffic and environmental characteristics. For example, sites where occlusion is more likely to occur (e.g., due to high volumes, wide facilities, frequent grouping of pedestrians) will tend to require a larger upward adjustment.

The NCHRP 07-19 testing also found substantial differences in the required correction factor between different products implementing the same sensor technology. It can also be expected that vendors will continue to work to improve their products and that new products will come onto the market.

Finally, while the NCHRP 07-19 testing generally found linear relationships between correction factors and volume, there is the potential for a non-linear relationship to exist.

Therefore, it is recommended that organizations develop site- or device-specific correction factors for their counters.

Possible explanations for differences between the NCHRP Project 07-19 results and previous results in the literature on environmental effects on count accuracy include (1) improvements in how vendors have implemented technology and (2) insufficient observations in the NCHRP Project 07-19 dataset for specific environmental conditions (e.g., heavy rain or heavy snow).

Based on the NCHRP Project 07-19 results, a simple multiplicative factor is sufficient in most cases for improving the accuracy of data collected with automated counters. However, the more complicated correction functions in Table 4-3 are recommended to be considered for higher volume sites when using passive infrared sensors, active infrared sensors, inductive loops, and piezoelectric strips; to correct for facility width when using passive infrared and radio beam sensors; and to correct for temperature when using active infrared sensors (although the effect is not strong). In either case, using a locally developed, site-specific correction factor or function is preferable to using a factor from Table 4-2 or 4-3, because a locally developed factor will account for the unique characteristics of a particular counting product installed at a particular site. Section 4.4.2 describes how to create site-specific correction factors.

Additionally, it is important to develop factors to account for bypass errors when using devices susceptible to this effect (e.g., inductive loops and pneumatic tubes). Inductive loops yielded a wide range of bypass error rates during NCHRP Project 07-19 testing, which appeared to vary according to individual site characteristics. The sites with the highest bypass error rates were two on-street bicycle lanes (APD = -46.62% and -25.49%), where bicyclists frequently traveled into the shared-use lane, and the Midtown Greenway in Minneapolis (APDs = -37.32% and -20.29%) where both sets of inductive loops being tested were substantially narrower than the facility width. Lower bypass errors occurred on the Loyola multi-use path in Davis, California (APD = -1.56%); on the Key Bridge between Arlington, Virginia, and Washington, D.C.; (APD = 7.95%), and the Rue University cycle track in Montreal, Quebec (APD = -2.44%). The latter facilities had inductive

loops that extended over most of the facility width, as well as channelization features that forced bicyclists to ride over the sensors.

4.4.2 Developing Site-Specific Correction Factors

Developing a local correction factor requires conducting manual counts and comparing the results to the automated counter data. The comparison data can be collected with traditional in-the-field manual counts or by developing manual counts from video footage. Conducting manual counts in the field can be more straightforward, but is prone to error during high-volume situations and must be completed in real time (Diogenes et al., 2007). Video-based manual counts require field trips to set up and take down the video camera, but the resulting video can be sped up or slowed down to accurately and efficiently accommodate high- and low-volume time periods. Appendix C provides the count protocol used in this study, which includes details of how to conduct quick computer-based manual counts from video images.

One of the primary challenges in collecting data for developing correction factors is synchronizing the counter's clock with the video camera's clock. If there is a high degree of confidence that the two clocks are synchronized, then shorter count intervals (e.g., 15 minutes) are recommended, assuming the counter can produce the shorter interval. This approach reduces the time required to develop the correction factor, compared to using 60-minute count intervals. However, if there is a lower degree of confidence in the synchronization of the two clocks, longer count intervals (e.g., 60 minutes) should be used.

The reason for the different count intervals is best explained through an example. If a counter and camera happen to be about 20 seconds off, this condition may result in one or two persons miscategorized by time in each interval. At a location with 120 bicycles an hour, a 15-minute count might be approximately 30 bicyclists. However, if two bicyclists are missed in 15 minutes, the error in the "ground truth" count would be approximately 6%, while for an hour interval, missing two bicyclists would result in an error of slightly less than 2%.

A minimum of 30 time periods worth of ground truth data (i.e., approximately 8 hours of counts when 15-minute data are collected, or 30 hours of counts when 60-minute data are

Device Accuracy and Detection Zones

To determine a counter's accuracy, it is necessary to have a clear understanding of its detection zone. For example, inductive loops will capture bicyclists that ride over or in the immediate vicinity of the loops. To measure the accuracy of the loop technology, only those bicyclists that rode through the loops' detection zone should be compared to what the loops sensed. A product's vendor should be able to specify the product's detection zone.

To determine how effectively a counter captures the complete picture of bicycle or pedestrian activity at a specific site, the site's true bicycle and/or pedestrian volume (as determined from manual counts in the field or from video) should be volumes recorded by the counter. If relatively large volumes of pedestrians or bicyclists are not being counted because they are not passing through the counter's detection zone, a different sensor technology, or a different implementation of the same technology, may be needed to capture an accurate picture of the site's activity.

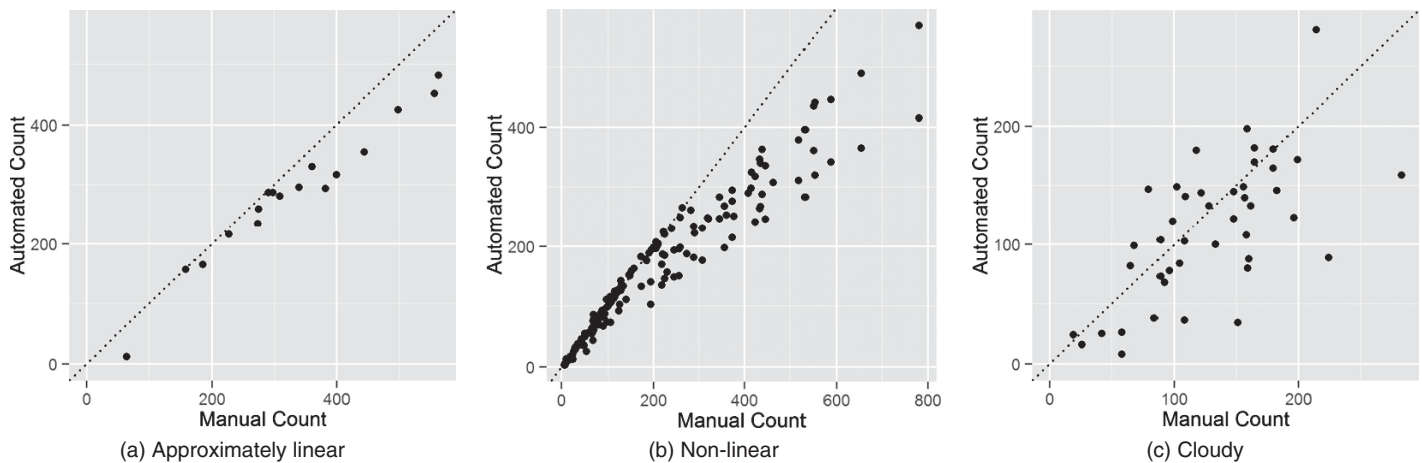


Figure 4-2. Examples of potential scatterplots when developing correction factors.

collected) is recommended when developing correction factors. Time periods should include a range of volumes, including some time periods when peak volumes occur. These ground truth validation counts can be collected in person or using video footage, as detailed in Appendix C.

Once the ground truth data have been collected, they can be plotted against the automated counter's counts, as illustrated in Figure 4-2. If the counts generally appear to fall along a straight line, as in Figure 4-2(a), then the correction factor is calculated as the ground truth count divided by the recorded count. If the counts appear to curve or follow some other non-linear shape, as in Figure 4-2(b), then statistical methods will be needed to fit a curve to the pattern (a spreadsheet's curve-fitting tools may be sufficient for this purpose). Finally, if the count pattern appears to be more of a "cloud," as in Figure 4-2(c), then the counting device may not be installed or calibrated properly and should be adjusted prior to collecting new ground truth data.

As previously noted, the accuracy of any counting technology with a limited detection zone (e.g., inductive loops) can be quantified in one of two ways: (1) comparing counts over the entire facility width or (2) comparing counts just within the counter's detection zone. The former is the preferred option (provided there is a predictable detection aversion factor) when developing site-specific correction factors, because the resulting factor will account for errors resulting from the sensor itself as well as site-specific errors resulting from persons passing outside the device's detection zone. The latter is the preferred option when a device will be used for short-term counts at a variety of locations.

4.5 Expansion Factors

Expansion factors are used to estimate pedestrian or bicycle volumes under conditions different than actually counted. Similar to the well established procedures for estimating long-term motorized traffic volumes, permanent counters are used to develop these factors. Expansion factors include the following types of adjustments:

- *Temporal adjustments.* Temporal adjustments are used to estimate volumes at a different time, or for a longer time period, than was counted. A common application is to expand a short-term count to an estimate of annual volume.
- *Environmental adjustments.* Environmental adjustments are used to estimate what the counted volume would have been under different conditions than occurred during the count. For example, a count taken during rainy, hot, or windy conditions could be adjusted to estimate the volume that would have been seen on a good weather day.

Estimating Pedestrian Volumes Around a University Campus

Researchers at the University of California, Berkeley used a combination of short-duration (2-hour) manual counts and continuous automated counts to estimate pedestrian volumes around the campus periphery as a proxy for exposure.

Three passive infrared sensors were mounted at locations near the edges of campus for 15 months to estimate temporal adjustment factors specific to the three edges. Two-hour pedestrian crossing counts were collected at most intersections around the campus.

Pedestrian volumes for a 10-year period were then estimated at each intersection based on the short-duration intersection counts and the adjustment factor for the appropriate campus edge. The 10-year volumes were used to normalize the number of pedestrian-involved crashes at each intersection to identify the riskiest locations for pedestrians around the campus periphery.

- *Land use and facility type adjustments.* These adjustments can be used to account for differences in volumes attributable to differences in the surroundings of a count site, compared to a continuously counted control site.

Expansion factors are typically applied to sites sharing an activity profile (e.g., commuter vs. recreational route or shopping district vs. residential area) similar to that of the continuously counted site(s) used to develop the expansion factor. Groups of sites sharing similar profiles are also known as *factor groups*; Chapter 4 of the *Traffic Monitoring Guide* (FHWA 2013) provides more details on how to identify factor groups.

4.5.1 Temporal Adjustment Factors

Temporal adjustment factors are used to account for peaking patterns—the tendency for pedestrian or bicycle volumes to be distributed unevenly throughout the day, week, or year. For example, high pedestrian volumes may be present on sidewalks in a CBD at 5 p.m., with low volumes present at 3 a.m. A popular recreational trail may have higher bicycle volumes on weekends than weekdays.

Adjustment factors can be applied to short-duration counts to estimate volumes over a longer time. For example, if counts are collected at a site for 1 week in January, the data represent 1 week of activity, but not necessarily a representative or “average” week. Therefore it is not appropriate to multiply the count total by 52 and expect to arrive at a reasonable annual estimate. Depending on the region and associated climate where the count was taken, seasonal impacts on bicycling and walking will vary significantly. Therefore, it is necessary to develop a seasonal adjustment factor based on continuously monitored control sites so as to provide a more accurate understanding of how a week in January compares to a typical week during the year.

At the most basic level, permanent count data can be collected at one location in a city, with the observed year-round patterns used to expand short-term counts at other sites in the city. However, when possible, multiple permanent count sites should be used because various activity profiles inevitably exist within a given city. An ideal number of permanent count stations has not been identified. The *Traffic Monitoring Guide* (FHWA 2013) recommends three to five continuous count stations per factor group, but recognizes that the limiting factor in most cases will be the available traffic monitoring budget.

Table 4-4. Example temporal expansion factor calculation.

Month	San Francisco			Arlington, Virginia		
	Monthly Volume	Percentage of Annual Volume	Expansion Factor	Monthly Volume	Percentage of Annual Volume	Expansion Factor
January	44,143	8%	12.52	2,985	5%	20.85
February	44,254	8%	12.49	2,450	4%	25.40
March	38,600	7%	14.32	3,112	5%	20.00
April	49,366	9%	11.19	5,581	9%	11.15
May	55,143	10%	10.02	6,298	10%	9.88
June	53,335	10%	10.36	6,408	10%	9.71
July	52,788	10%	10.47	6,815	11%	9.13
August	54,522	10%	10.14	7,697	12%	8.08
September	52,054	9%	10.62	7,701	12%	8.08
October	42,393	8%	13.03	6,136	10%	10.14
November	35,651	6%	15.50	3,983	6%	15.62
December	30,343	5%	18.21	3,062	5%	20.32
Total	552,592	100%	---	62,228	100%	---

Temporal expansion factors are simple to apply. A look-up table is generated from the permanent count data, giving the percentage of the total volume observed during each time period. For example, Table 4-4 contains illustrative expansion factors from a site in San Francisco and a site in Arlington, Virginia, both of which count bicycle volumes in a bicycle lane. These factors could be used to adjust monthly counts at sites having similar characteristics to one of these locations. Based on the data shown in the table, bicycle volumes at the Arlington site show a stronger seasonal variation than those at the San Francisco site.

These factors can be refined and improved over time by analyzing data from more sites over a greater period time, ideally reaching a point where the activity profile becomes highly predictable and thus more reliable for factoring short-duration counts. In further refining these factors, it is important to consider how the surrounding land uses will influence bicycle and pedestrian activity. For example, recreational areas are likely to have different temporal peaking characteristics for pedestrian and bicycle activities than CBDs. One would expect to see higher peaking characteristics for recreational pedestrian and bicycle activity during non-work days and hours (e.g., weekends and evenings), and one would expect to see higher peaking characteristics for a CBD during weekday commuting periods.

An expansion factor is calculated as follows for a given site:

$$\gamma_t = \frac{\sum_{i=1}^N Volume_i}{Volume_t}$$

where

- γ_t = the expansion factor for time period t ,
- $Volume_i$ = the volume during time period i ,
- $Volume_t$ = the volume during time period t , and
- N = the set of all time periods i .

In Table 4-4, N is the set of all months in the year. However, N could well be the set of all hours in a day, days in a week, or any other conceivable time period. As an example of how to use this formula, the expansion factor for the San Francisco site in January is calculated as follows: the sum of the monthly volumes over the course of the year was 552,592; the monthly volume for

To Round or Not To Round?

Remember that any volume estimates based on extrapolation are just that—estimates. They are by no means precise, and to present them as such can be misleading.

When presenting volume estimates, they should be rounded and specified as approximate values. For example, if the 327,065 bicyclists/year volume presented in this section were calculated, it should be presented as “approximately 327,000/year.” This will help to avoid giving false impressions of the degree of accuracy of the estimates.

However, if volume estimates are being used as an intermediate step in a calculation (such as when they are used for exposure in a pedestrian crossing risk evaluation), rounding should not be performed. There is no reason to say that 327,000 bicyclists/year is a more accurate value than 327,065 bicyclists/year, so the unrounded value should be passed to the risk calculation.

Specific applications (e.g., reporting to the FHWA) may specify that volume should not be rounded (or vice versa), and specific agencies may have their own adopted rounding procedures (often based on AASHTO [2009] guidance).

January was 44,143; and $(552,592) / (44,143) = 12.52$, which is the expansion factor for January shown for the San Francisco site in Table 4-4.

Once a set of expansion factors has been developed, the factors can be used to expand a short-term count at a comparable site. For example, 1 month’s worth of pneumatic tube data might be collected in June at another site in San Francisco with characteristics similar to the permanent count site. First, the raw data from the counter would be corrected to account for systematic errors associated with the tube counter, using data from Table 4-2, Table 4-3, or a local correction factor, if available. The corrected counts could then be multiplied by the expansion factor for June—in this case, 10.36—to estimate annual bicycle volumes at the short-term count site. If the corrected monthly count was, for example, 31,570 bicyclists, then the estimate of annual average bicycle traffic (AABT) would be $31,570 \times 10.36$, or 327,065.

As noted in Section 3.2.3, short-term counts are most accurately expanded when the original count covers a substantial period of time (e.g., weeks). Even so, the estimated long-term volume may be substantially different from the true volume. Improvements on basic day-of-week and month-of-year expansion factors can be made in several ways. First, additional multiplicative factors can be applied to correct for weather patterns or land use characteristics. Second, separate factor groups can be estimated to account for different activity patterns based on land use and facility type. These types of factors are discussed in following subsections. Third, a day-of-year expansion factor can be applied in lieu of the traditional combination of day-of-week and month-of-year factors. This approach has been shown to substantially outperform the traditional approach in both bicycle-only monitoring situations and in mixed bicycle and pedestrian situations (Hankey et al. 2014, Nosal et al. 2014). Further details of this approach are provided in Appendix D.

4.5.2 Land Use Adjustment Factors

Land use adjustment factors can be used to account for differences in volumes that are attributable to differences in the surroundings of a count site, compared to a continuously counted

control site. This approach is more robust for estimating pedestrian volumes than bicycle volumes, because bicycle trips tend to be longer and more “through traffic” is counted that does not necessarily have much relation to the surrounding land use characteristics. These factors are separate from the time-of-day factors.

Possible land uses to control for include broad characterizations (i.e., residential, industrial, and CBD) (Hocherman et al. 1988), socioeconomic variables (e.g., population density, employment density, and median household income) (Ryan et al. 2014), or degree of land use mixture (e.g., entropy index, dissimilarity index, interspersed index, juxtaposition index, and contagion index) (Cervero 1989, Cervero and Kockelman 1997, Hess et al. 2001).

4.5.3 Weather Adjustment Factors

Counts can be adjusted based on the weather patterns for the day on which counts are collected. For example, if volumes in a city are observed to drop to 60% of “normal levels” during rainy weather, and short-duration counts are conducted on a rainy day, the estimate of annual traffic should be adjusted upward by 67% (i.e., $1/0.6$) to account for weather.

Weather-related phenomena have been documented in the literature. Table 4-5 presents a summary of weather-related effects on volumes.

The literature review found in this project’s final report (Ryus et al. 2014) summarizes the findings of the studies cited in Table 4-5. If continuous counts are available for the entire year, the day-of-year method described in Appendix D can be used, because it incorporates weather effects that may have occurred on any given day.

4.6 Example Application of Factor Adjustment Methods

The following example uses 1 month of data collected in October 2013 using a passive infrared sensor at the study site, located on a multi-use path on a university campus. This example is intended as a simplified hypothetical exercise of working with raw data to arrive at an estimate of annual volumes.

Step 1. Check Data for Anomalies

Figure 4-3 plots the raw data downloaded from the counter at the study site for the month of October 2013.

The counter appears to have been out of commission for a few days—it is unlikely that the volumes would be 0 for such a long period. To correct, one approach is to *impute from surrounding data*. However, one should be careful not to interpolate from a special event, weather anomaly, or other special situation that might lead to drastically “abnormal” volumes.

In this case, the analyst is reasonably certain that the data from the previous and following weekends reflect typical conditions and can be used. So, the average values for each of those days are taken. For example, the volume from 10–11 a.m. on Sunday, October 13 is estimated as the average of the volume from 10–11 a.m. on Sunday, October 6 (46) and the volume from 10–11 a.m. on Sunday, October 20 (41), resulting in an estimated volume of 44. These imputed values are shown by the blue dashed line in Figure 4-4. (In this simplified example, only the preceding and following Sunday are used; the approach recommended in Section 3.3.9 would use 10–11 a.m. data from the four preceding and four following Sundays.)

Table 4-5. Weather-related effects on non-motorized volumes documented in the literature.

Weather Factor	Source	Description	User Type	Effect
Rain	Cameron, 1977	Shopping districts in Seattle, WA	P	0.05 in/day reduced traffic by 5% below average in summer, no effect in December
Precipitation events	Aultman-Hall et al., 2009	CBD in Montpelier, VT	P	13% lower average volumes during precipitation
Cloudy	Schneider et al., 2009	Counts throughout Alameda County, CA	P	Multiplicative factor of 1.05
Cool temperatures ($\leq 50^{\circ}\text{F}$)	Schneider et al., 2009	Counts throughout Alameda County, CA	P	Multiplicative factor of 1.02
Hot temperatures ($\geq 80^{\circ}\text{F}$)	Schneider et al., 2009	Counts throughout Alameda County, CA	P	Multiplicative factor of 1.04 (hours 1200–1800) Multiplicative factor of 0.996 (hours 0000–1200 and 1800–2400)
Rain	Schneider et al., 2009	Counts throughout Alameda County, CA	P	Multiplicative factor of 1.07
Temperature ($< 28^{\circ}\text{C}$)	Miranda-Moreno and Nosal, 2011	Separated bicycle facilities in Montreal, QC	B	10% increase corresponds to 4–5% volume increase
Temperature $\geq 28^{\circ}\text{C}$ and relative humidity $\geq 60\%$	Miranda-Moreno and Nosal, 2011	Separated bicycle facilities in Montreal, QC	B	Volume decrease of 11–20%
Humidity	Miranda-Moreno and Nosal, 2011	Separated bicycle facilities in Montreal, QC	B	100% increase corresponds to 43–50% decrease in volume
3-hour lagged precipitation	Miranda-Moreno and Nosal, 2011	Separated bicycle facilities in Montreal, QC	B	25–36% reduction in volume
1-hour lagged precipitation	Chapman Lahti and Miranda-Moreno, 2012	Pedestrians in Montreal, QC	P	8% decrease on weekdays; 11% decrease on weekends
Precipitation	Flynn et al., 2012	Bicyclists via survey	B	Twice as high likelihood with no morning precipitation
Temperature	Lewin, 2011	Bicycle volumes	B	Highly correlated ($R^2 = 0.50$)

Notes: P = pedestrian, B = bicyclist, CBD = central business district.

Example Raw Data

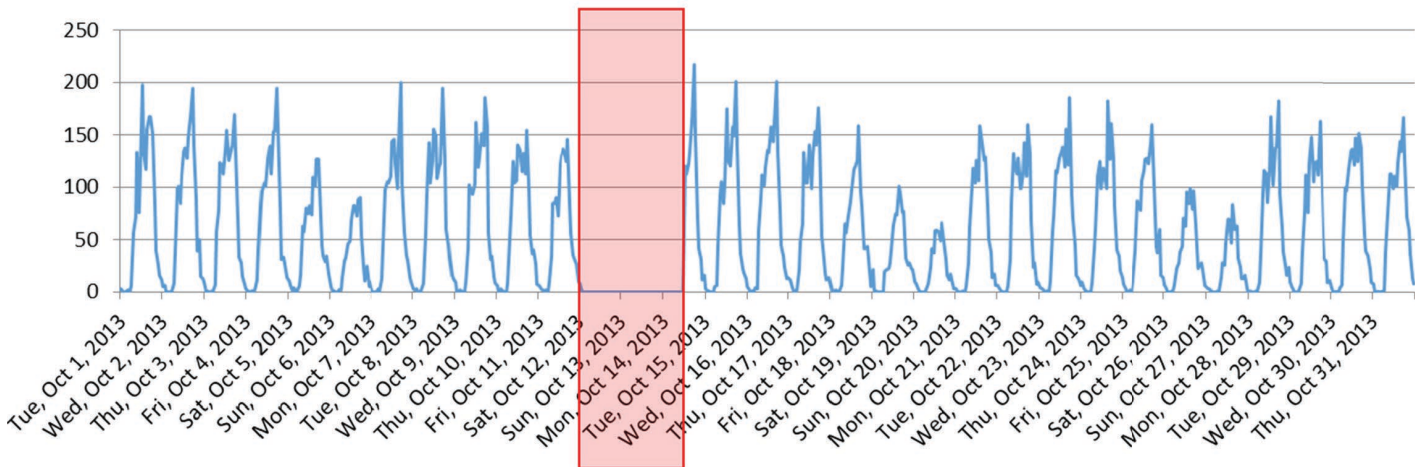


Figure 4-3. Raw data from the counter.

Step 1A. Establish Site-Level Data Correction Factors

Manual counts can be conducted at the study site and compared with the automated data from the counter. These counts are used to estimate a site-specific correction factor, as discussed in Section 4.4.2. Manual counts are collected in 15-minute intervals for 6 hours at the study site, for a total of 24 data points from which to calculate a correction factor. (This simplified example uses fewer data points than the recommended 30.)

Figure 4-5 compares the manual and automated counts. The dashed line corresponds to perfect accuracy. In other words, data points (corresponding to 15-minute count intervals) falling below the dashed line represent periods when net undercounts occurred, while data points falling above the line represent periods when net overcounts occurred. The thick solid line shows

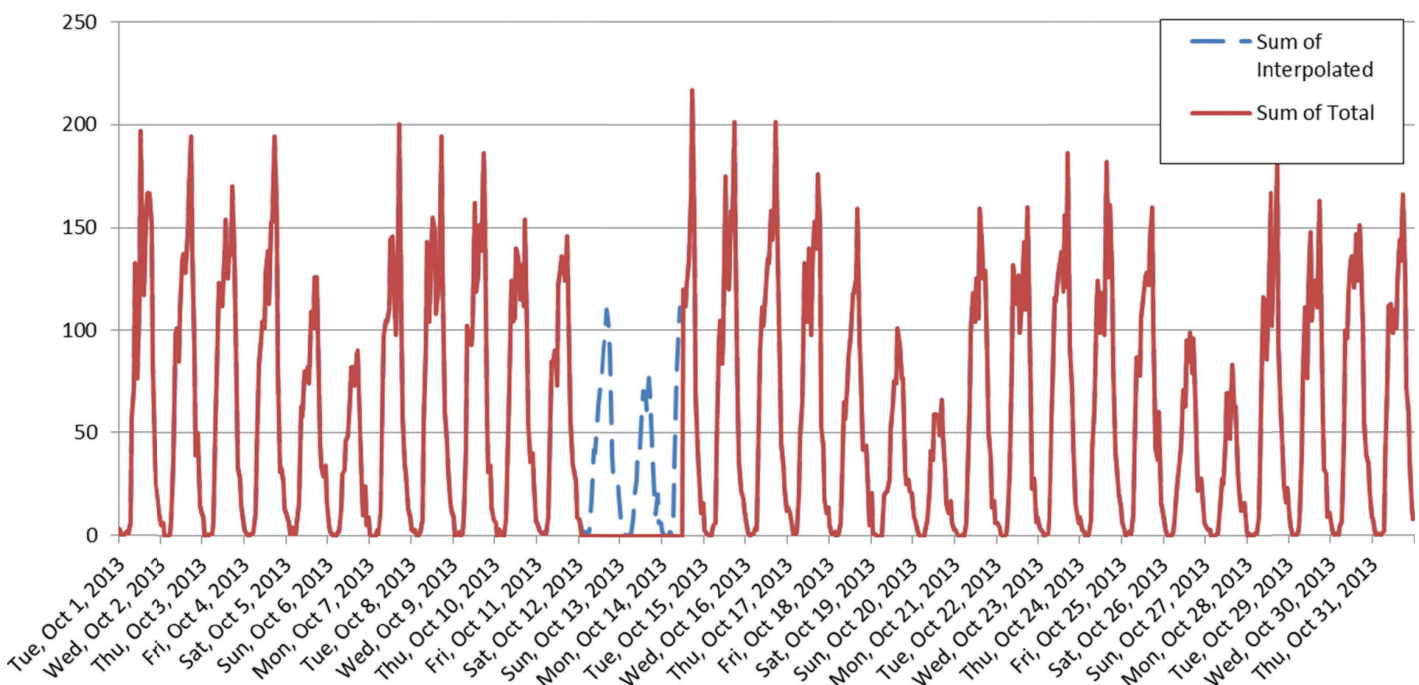


Figure 4-4. Raw count data with missing data imputed.

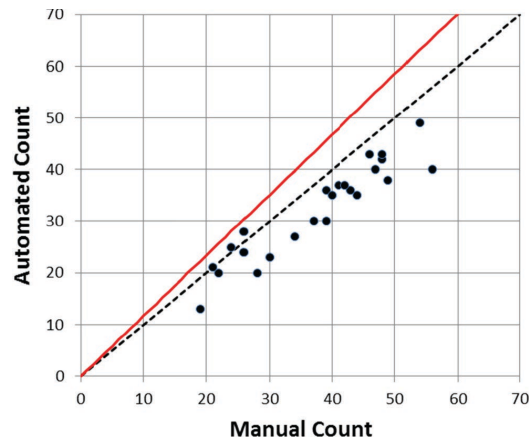


Figure 4-5. Example calculation of a local correction factor.

the adjustment function, which is a mirror image of a best-fit line through the data points. Automated counts should be multiplied by the slope of the thick solid line to bring them closer to the perfect accuracy line.

Based on the slope of the adjustment function shown in Figure 4-5, a correction factor of 1.167 (e.g., 70/60) is estimated.

Step 2. Correct Data with an Appropriate Correction Factor

In the next step, the raw count data are corrected for undercounting, using either the site-specific correction factor developed in Step 1A, or using a general factor or function such as those presented in Tables 4-2 and 4-3. To use a correction factor, multiply the raw automated count values by the adjustment factor. If local data suggest a non-linear relationship between the manual and automated data and, therefore, that an adjustment function would be more appropriate, the raw automated count values and any other variables used in the function are provided as inputs to the function.

Figure 4-6 shows the corrected count data, after the correction factor of 1.167 that was determined in Step 1A is applied.

Step 3. Expand to Annual Volumes

In this step, unless the annual volumes at the study site are known, an assumption must be made about which factor group the site belongs to. Given that this site is on a university campus (where people have very irregular schedules), its volume profiles do not fit cleanly into a “traditional” utilitarian or recreational pattern. These monthly counts should therefore be expanded using continuous data from an automated count station on a mixed-use path at another university or college in a similar climate (or, even better, another site on the same university campus). To demonstrate how to apply these expansion factors, assume the volumes shown in Table 4-6 have been counted by an automated count station on another mixed-used path on the same university campus.

The corrected monthly volume for the study site in October was 50,232. Given that this site is on the same university campus and on the same type of facility (a mixed-use path) as the automated count station site, the study site’s October volume can be multiplied by the count station’s expansion factor for October to obtain an estimate of AADT. In this case, $50,232 \times 10.431 = 523,970$, which is rounded to the nearest thousand (i.e., 524,000) in consideration of the various assumptions involved.

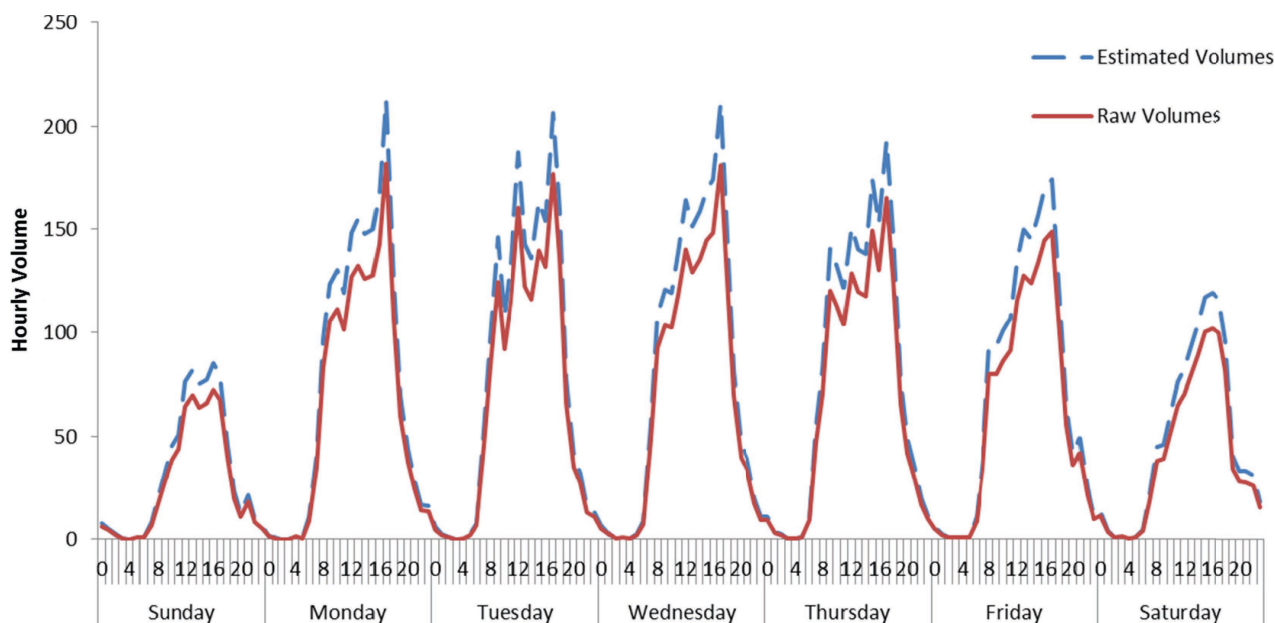


Figure 4-6. Count data after applying a correction factor.

Next, consider what could be done if only the first 8 days in October had been counted at the study site, resulting in a corrected volume of 14,031 for those days. One way to handle this would be to assume that all of the 31 days in October are roughly equal in terms of volume and expand the corrected volume by the proportion of the month it represents. In this case, the estimated annual volume would be $(14,031) \times (31/8) \times (10.431)$, or approximately 567,000. This result is different than the estimate that used a full month's worth of data.

An alternative approach, given the availability of daily volumes from the automated count station, would be to use the day-of-year approach (described in Appendix D). From Table 4-6, the annual volume at the count station was 460,531. If the total volume at the count station for the first 8 days of October was 11,073, then the AADT for the study site could be estimated as $(14,031) \times (460,531/11,073)$, or approximately 539,000, which is closer to the estimate based on an entire month's worth of data.

Table 4-6. Example count station data for university campus mixed-use path.

	Monthly Volume	Fraction of Year	Extrapolation Factor
January	30,513	6.63%	15.087
February	43,101	9.36%	10.681
March	51,029	11.08%	9.021
April	52,049	11.31%	8.845
May	60,324	13.10%	7.631
June	29,210	6.35%	15.760
July	24,021	5.22%	19.165
August	21,031	4.57%	21.889
September	56,201	12.21%	8.191
October	44,134	9.59%	10.431
November	38,519	8.37%	11.951
December	10,219	2.22%	45.049

Note: These data have been invented for this example and should not be used as extrapolation factors for an actual facility.

Sensor Technology Toolbox

Chapter 5 Topics

Chapter 5 summarizes typical applications, installation considerations, relative level of effort and cost, strengths and limitations, accuracy, and usage of 14 existing and emerging counting technologies and methods:

- Manual in-field counting
- Manual counts from video
- Automated counts from video
- Pneumatic tubes
- Inductive loop detectors
- Passive infrared
- Active infrared
- Piezoelectric strips
- Radio beams
- Thermal
- Laser scanners
- Pressure and acoustic pads
- Magnetometers
- Fiberoptic pressure sensors

This chapter summarizes existing and emerging sensor technologies available for non-motorized counting. Many of the technologies were developed for motor vehicle counting but have been adapted for non-motorized travel. Other technologies are more specific to non-motorized counting. Each counting technology or method (in the case of manual counting) is presented in its own subsection, along with the following information:

- **Description** of how the counting technology or method detects pedestrians or bicyclists.
- **Typical applications** for the technology.
- General **installation considerations** for the technology. Manufacturer's installation recommendations take precedence over these general considerations.
- Relative **level of effort and cost**, drawing from the literature, vendor-provided information, and the research team's experience. Specific product costs are subject to change and the cost of additional services (e.g., pavement cutting) vary greatly by region, size of the order (e.g., consideration of economies of scale), and whether or not an organization can perform the work in house or has to contract it out.

- **Strengths and limitations** of the technology or method, drawing from the literature and the research team’s experience.
- **Accuracy**, drawing from the NCHRP Project 07-19 testing when possible, and supplementing from the available literature.
- Description of current **usage**, drawing from the NCHRP 07-19 practitioner surveys and interviews.



Source: Robert Schneider, UC Berkeley SafeTREC.

Counters using data collection sheets.

5.1 Manual In-Field Counts

5.1.1 Description

Human data collectors can record pedestrian and bicycle volumes using paper sheets, traffic count boards, “clicker” counters, or smartphone apps. Counts are usually recorded for 1 to 4 hours in discrete time intervals, generally 15 minutes, although counts can be collected in shorter intervals if desired. Some count boards can timestamp all data points. Data collector training, motivation, and management are important for obtaining accurate manual counts.

5.1.2 Typical Applications

Manual counts can capture both pedestrian and bicycle volumes and can capture other information as well (e.g., gender, helmet use, or risky behaviors). They can capture both screenline volumes and intersection turning movement and crossing volumes.

Manual counts are most appropriate for collecting data over a relatively short time on any facility type. They are one of the few approaches that can capture turning movements or additional information about users. Because of low additional costs per site, manual counts can be used to inexpensively increase the number of sites observed. They are also a good starting point for new count programs, both because of low start-up costs (the only significant cost is labor) and to help in prioritizing sites for installing automated counting equipment. Finally, manual counts are necessary for validating automated counting equipment.

5.1.3 Installation Considerations

Before collecting counts, the site should be assessed to determine the specific location(s) at which the manual counter(s) should be positioned to most easily view users. Based on the anticipated user volumes and the kinds of information that will be collected, more than one person may be needed. A general rule of thumb is that one person should be expected to capture no more than 200 data points per hour (including the actual volumes as well as any additional attributes). The National Bicycle and Pedestrian Documentation Project (NBPD, Alta Planning + Design 2012) recommends that counters working longer than 2 hours be relieved for restroom breaks at least every 2 hours and provided 30-minute lunch periods. Counters should be trained on how to classify users and collect data. Appendix B provides example data collector instructions for collecting manual counts at intersections. In addition, the NBPD provides training materials and sample count and survey forms at bikepeddocumentation.org.

5.1.4 Level of Effort and Cost

The costs of conducting manual counts are largely determined by the number of hours of data that are collected. Data collectors (either staff or volunteers) must be trained, but multiple people can be trained simultaneously. Sections 3.2.2 and 3.3.4 discuss the potential benefits and disadvantages of using volunteers to conduct counts and stress the importance of training

Manual Count Summary**Maximum user volume:** Up to 600 persons per hour per counter**Detection zone width:** >75 feet**Typical count duration:** 4 hours or less**Typical equipment cost (2013):** <\$1,000**Relative preparation cost:** Low**Typical installation time:** Negligible, beyond arriving on site early to orient one's self**Typical data collector training time:** >1 hour**Relative hourly cost:** Very high, can exceed \$50/hour for training, management, and on-site labor costs**Mobility:** Excellent, no assembly required for human counters

volunteers. Hand-written data sheets, if used, must be gathered, compiled, and reduced into a spreadsheet, which can be time-intensive. (Count boards, smartphone apps, and similar tools can export the data into a spreadsheet-compatible format.) Labor costs typically include training time, travel time to and from the count site, and preparation time (counters should arrive on site early to orient themselves), in addition to the actual time required to perform the counts.

Two person-hours are generally required per 1 hour of counts performed (including preparation time and training), plus additional time if the data must be manually entered into a spreadsheet or database. Additional person-hours are required at high-volume locations and when additional user information is being collected. The cost of labor drives the overall cost per count. This is in contrast to most automated count technologies, where the equipment capital cost drives the overall cost.

5.1.5 Strengths and Limitations

Strengths

- Flexibility to gather additional data about traveler (i.e., directional information, gender, and behaviors).
- Applicable to all site types and users.
- No installation costs or impacts.
- Extremely mobile.

Limitations

- Short-term counts only.
- More personnel needed at higher volume locations or to collect additional information (i.e., higher costs).
- Subject to data collector fatigue and (with volunteers) possible count biases.

5.1.6 Accuracy

Accuracy depends on data collector behavior. It improves with training and experience and decreases with count duration and quantity of additional information collected. One study of manual intersection counts at busy intersections in San Francisco found undercount rates ranging between 8% and 25% for 15-minute intervals, compared to manual counts conducted on video footage (Diogenes et al. 2007). Accuracy was worse at the beginning and end of the data collection period, which is likely attributable to a familiarization interval (which can be mitigated by more on-site time prior to beginning counts) and fatigue.

5.1.7 Usage

The NCHRP Project 07-19 practitioner survey found that manual counts are the most prevalent approach in the United States for collecting non-motorized volumes. Of respondents who performed counts, 93% included manual counts as part of their pedestrian data collection program and 87% included them as part of their bicycle data collection program. Most respondents used manual counts taken annually at strategically chosen and distributed locations, using agency staff, volunteers, contractors, or some combination of these.



Source: Frank Proulx, UC Berkeley SafeTREC.

Technician installing video camera.

5.2 Manual Counts from Video

5.2.1 Description

Manual counts can be made from video footage collected with a temporarily or permanently installed camera. Videos are reviewed manually on a monitor after they are collected, with the data collector counting using a paper sheet, a handheld counter, or a computer. Specialized keyboards are available commercially that can be plugged directly into a computer.

Manual counts from video were used to develop the ground truth counts in the NCHRP Project 07-19 research. The process used is described in the project's final report (Ryus et al. 2014).

5.2.2 Typical Applications

Manual counts on video can be used to capture pedestrian and bicycle volumes, including crossing counts and turning movement counts at intersections. They might be useful for observing individual characteristics (e.g., gender and helmet usage), although these details can be hard to discern in lower resolution video images or in images taken from a distance. Specific behaviors that would be missed by most automated technologies can be observed (e.g., wrong-way riding, traffic control device compliance, and sidewalk riding).

Manual Count from Video Summary

Maximum user volume: More than 600 persons per hour per counter, but higher volumes require more data-reduction time (e.g., slower playback speed and more frequent need to rewind)

Detection zone width: >75 feet

Typical count duration: 4 hours or less, but longer counts can be performed by spreading the work over multiple data reduction sessions

Typical equipment cost (2013): <\$1,000

Relative preparation cost: Low

Typical installation time: <30 minutes

Typical data collector training time: >1 hour

Relative hourly cost: Very high, can exceed \$50/hour for training, management, and labor costs

Mobility: Very good, only a camera needs to be installed

5.2.3 Installation Considerations

Video cameras should be installed high enough above the street (e.g., 10+ feet) to deter theft. They should also be mounted in inconspicuous cases that are resistant to theft or in vandalism-resistant cases. When mounting the camera, make sure that the desired detection zone is being clearly recorded and is not likely to be obscured (e.g., by tree branches moving in the wind or by stopped trucks or buses). Site visits are typically required every 2 to 3 days when video is being collected to ensure the camera is working properly, swap memory cards, and replace camera batteries as needed.

5.2.4 Level of Effort and Cost

Consumer-grade camcorders can be mounted in secure boxes for a low-cost solution. Higher quality cameras can be used to collect more detailed video or to remotely transfer video. A monitor or computer capable of video playback is also needed. Computer software to assist with recording counts may also be helpful. Equipment cost is typically lower for this method than for automated counters; however, labor costs are also required for video reduction and camera set-up, maintenance, and take-down, and to periodically conduct quality-assurance checks of the counts. As with manual in-field counts, the cost of reducing video data is largely determined by the number of hours of data collected. Appendix C provides the protocol used by NCHRP Project 07-19 to develop manual counts from video.

5.2.5 Strengths and Limitations

Strengths

- Flexibility to gather additional data about users (i.e., directional information, gender, and behaviors).
- Applicable to all site types and users.
- Flexibility to slow down or speed up video data during reduction based on volume of users.
- Data collectors do not have to spend hours in the field—a constraint during poor weather conditions or nighttime data collection.
- Video can be reviewed at times other than when data are collected to accommodate busy schedules.
- A single data collector can reduce data for the same time period at multiple sites after video cameras are set up.

Limitations

- Short-term counts only, because of the labor costs involved with reducing data.
- Frequent field visits are necessary to set up cameras, replace batteries and memory cards, and take down equipment.
- Video cameras are susceptible to theft unless well-obscured and placed out of convenient reach.
- Problems can arise with video footage (e.g., corrupt files or poor vantage points) requiring the video to be retaken.
- Requires a fixed pole at the location or a portable pole for mounting the camera.

5.2.6 Accuracy

Video-based manual counts are presumed to be the most accurate way of collecting count data, given the ability to re-watch video data and to slow down the playback speed as needed. However, objects that block the camera's field of view (e.g., large vehicles such as buses and trucks) can result in missed detections, particularly if they stop for a period of time. No controlled tests (specifying the number of people using a facility) appear in the literature, and such tests would be difficult to arrange for large volumes. This method was used to develop the ground truth validation counts for NCHRP Project 07-19.

5.2.7 Usage

The NCHRP Project 07-19 practitioner survey found that 44% of respondents who performed pedestrian counts used manual counts from video data as part of their pedestrian data collection program. (The question was not asked in conjunction with bicycle data collection; however, given the similar pedestrian and bicycle counting responses for other counting methods and technologies, the proportion would be expected to be similar.)



Source: Ling et al. (2010).

Detection of pedestrians using automated video counting.

5.3 Automated Counts from Video

5.3.1 Description

Pedestrians or bicyclists are counted from video images by using computer algorithms to identify when changes in the background image are pedestrians or bicyclists passing through the detection area.

5.3.2 Typical Applications

Automated counts from video can capture pedestrian or bicycle volumes. They can capture both screenline volumes and intersection turning movement volumes, although it may take multiple cameras to collect data from an entire intersection. Automated video collection is typically used for up to 1 week at a time, because of data storage limitations for video images.

5.3.3 Installation Considerations

Mount the camera high enough to capture the desired area, using existing infrastructure if possible, but trying to avoid sources of vibration (e.g., traffic signal mast arms). Typically, a mounting height of approximately 25 feet is required. The camera will need to be placed within a certain distance of the roadway (e.g., 12 feet) and can be expected to capture a detection zone

Automated Video Count Summary

Maximum user volume: >600 persons per hour

Detection zone width: >75 feet

Typical count duration: ≤48 hours

Typical equipment cost (2013): \$1,000–3,000

Relative preparation cost: Medium

Typical installation time: <30 minutes

Typical data collector training time: <30 minutes

Relative hourly cost: High, at the time of writing, this technology was only available as a vendor-supplied service

Mobility: Very good, only a camera needs to be installed

of a certain size (e.g., out to 150 feet). Therefore, multiple cameras may be required to capture an entire intersection. Care should be taken to avoid environmental conditions that could affect results, such as glare from nearby streetlights or the sun.

5.3.4 Level of Effort and Cost

The level of effort is medium relative to other technologies and requires setting up and taking down the video camera and sending the video to the vendor for processing. The one commercial system in the North American market at the time of writing operated as a service, meaning that videos were sent to the vendor to be processed by the vendor's system. According to the vendor, its staff reviewed the data produced by the automated system. The cost per count is medium to high, relative to other technologies.

5.3.5 Strengths and Limitations

Strengths

- Minimal human time required to collect counts.
- Can provide intersection turning movement and crosswalk counts.
- Portable and straightforward to install where camera mounting locations are available.
- Video can be used for additional purposes (e.g., facility evaluation and user behavior studies).

Limitations

- Short-term counts only.
- Not currently possible to process video in-house (requires a vendor to do the processing).

5.3.6 Accuracy

The accuracy of the automated video counting service available in the marketplace has not been rigorously tested. However, one could perform one's own checks by making manual counts from a sample of videos sent to the vendor for processing and comparing one's results to the vendor's results.

5.3.7 Usage

Of those project practitioner survey respondents who performed counts, 18% used automated video as part of their pedestrian counting program and 17% used it as part of their bicycle counting program. Much of the work to develop improved systems for collecting automated counts from video is still in the research stage and not yet commercially available.

5.4 Pneumatic Tubes

5.4.1 Description

This technology is applied by stretching one or more rubber tubes across the roadway or pathway. Although general purpose counters (GPCs) typically used for motorized vehicle detection and classification can be used to count bicyclists, specialized bike-specific counters (BSCs) are also available, which only count bicyclists. When a bicycle or other vehicle passes over a GPC tube, a pulse of air passes through the tube to a detector, which then registers a count. Multiple tubes can be used to determine speed and directionality. In some cases, the number of axle hits is divided by two to deduce the number of bicyclists. In other cases, more complicated classification algorithms



Source: Karla Kingsley, Kittelson & Associates, Inc.

Bicyclist riding over pneumatic tubes.

can be applied to the pattern of axle hits to determine the vehicle speed and classification. This process can either occur in real time or on a personal computer after the data have been recorded.

BSCs designed for bicyclists can be used on bike-specific facilities or in mixed traffic. When used in mixed traffic, the difference in the air pulse created by heavier motorized vehicles can be detected and disregarded, so that only bicyclists are counted. Tubes designed for bicyclists are generally smaller, to minimize the bump as cyclists ride over them, and are more sensitive, to better detect bicyclists.

5.4.2 Typical Application

Pneumatic tubes can be very effective when bicycle data need to be collected for several days up to several weeks. Tubes are most appropriate for paved surfaces with minimal pedestrian use and temperatures above freezing, because tubes may not maintain their properties in cold weather and can deteriorate. Tubes can be used on bike-specific facilities or in mixed traffic. When used on street, tubes can be placed just across the bike facility or across the entire roadway. If only bicycle counts are needed, placing BSCs across just the bike facility is preferred, given bicyclist comfort considerations and reduced wear and tear on the tubes. If both motorized traffic volumes and bicyclist volumes are required, then placing GPCs across the entire roadway is necessary.

5.4.3 Installation Considerations

Tubes are installed across the paved surface in a location where bicyclists are unlikely to stop. The tube should adequately cover the bicycle travel path, while minimizing exposure to motor vehicles. Locations and times when street sweeping or snowplowing occurs should be avoided, because those vehicles can dislodge or destroy tubes. Tubes can be affixed to the roadway using either mastic tape or nails and brackets. Some jurisdictions may oppose having nails in their roads, because of concerns about pavement damage. Care should be taken to consider bicyclist safety and to minimize the risk of a nail or metal fixture puncturing a bike tire, by placing metal objects outside the bicycle facility or by using tape to secure the tubes.

Pneumatic Tube Summary

Maximum user volume: Provides consistent results up to 200 users per hour; counts can be corrected at higher volumes

Detection zone width: <20 feet

Typical count duration: Non-permanent short- and longer-term counts

Typical equipment cost (2013): \$1,000–3,000

Relative preparation cost: Medium (potential need for permits)

Typical installation time: <30 minutes

Typical data collector training time: <30 minutes

Relative hourly cost: Medium, equipment costs are spread over more data-collection hours than for manual counts

Mobility: Very good, equipment can be removed and taken to a new site

Follow the manufacturer's instructions on spacing and settings. If GPCs are being used, the settings need to be modified to apply a classification scheme to sort vehicles and isolate bicycle data. The manufacturer may suggest appropriate settings; research is being conducted to develop classification schemes to improve pneumatic tube accuracy.

5.4.4 Level of Effort and Cost

The level of effort is low, relative to other technologies, and requires setting up and taking down the tubes. Most jurisdictions are likely already familiar with the set-up process because of their experience with pneumatic tubes for counting motorized vehicles. The cost is typically low to set up the equipment and process the counts.

5.4.5 Strengths and Limitations

Strengths

- Portable.
- Easy to set up.
- Can capture speed and directionality of bicyclists when two tubes are used.
- Most jurisdictions are familiar with the technology, because they already use it for counting automobiles.

Limitations

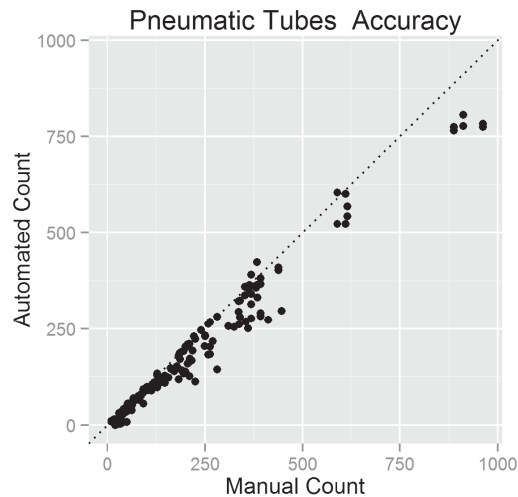
- Susceptible to theft, vandalism, dislodgement, and wear and tear, requiring routine maintenance.
- May require permission from local jurisdiction for installation, which sometimes requires not using nails.
- May not maintain properties in very cold conditions and can deteriorate under high-traffic conditions. One vendor of BSCs claims to have observed their tubes to last for approximately 300,000 vehicle hits.
- Not usable during times when street sweeping or snowplowing occurs, because the tubes can be dislodged or destroyed.

5.4.6 Accuracy

NCHRP Project 07-19 tested two models of BSC tubes, primarily on multiple-use paths and bicycle lanes. The testing found that the tubes generally undercounted, but that overcounting sometimes occurred at higher volumes. One tested model performed substantially better than the other model, with a correction factor of 1.127 versus 1.520 (a factor of 1.00 indicates that no correction is needed). The average percentage deviation (APD), representing the overall divergence from perfect accuracy across all data collected, was -17.9%. The average of the absolute percent difference (AAPD), representing the counter's consistency, was 18.5%. Figure 5-1 shows the accuracy and precision of the pneumatic tubes tested by NCHRP Project 07-19.

Research from a field test of bicycle counts using two pneumatic tube models in New Zealand found a range of accuracies for off-road locations from -15% to 0%, with the tubes typically undercounting bicyclists (ViaStrada 2009). Hjelkrem and Gjaever (2009) tested two models of pneumatic tubes in mixed traffic and found bicycle count accuracy rates of -27.5% and -1.9%.

Hyde-Wright, Graham, and Nordback (2014) compared the accuracy of BSCs to GPCs. They found that the BSC proved very reliable and accurate when counting bicyclists striking the pneumatic tubes up to 27 feet away from the counter (with an average accuracy between 94 and 95%). However, accuracy decreased for bicyclists at greater distances from the counter, with an accuracy of 57% for bicyclists riding 33 feet from the counter. The accuracy and reliability of GPCs proved variable based on the attachment method and classification scheme used. A custom classification



Source: NCHRP 07-19 testing.

Figure 5-1. Accuracy and precision of tested pneumatic tubes.

scheme was developed through the study to account for the systematic undercounting observed with the GPCs. Using this classification scheme, the GPCs proved accurate when bicyclists rode close to the counter, with an average accuracy of 95%. Accuracy declined significantly for bicyclists riding farther from the counter.

5.4.7 Usage

Of this project's practitioner survey respondents who performed counts, 27% used pneumatic tubes as part of their bicycle counting program. The survey did not distinguish between GPCs and BSCs.



Source: Katie Mencarini, Toole Design Group.

Technicians installing temporary inductive loop detectors.

5.5 Inductive Loop Detectors

5.5.1 Description

Wires are installed under the surface of the pavement (embedded) or on top of the pavement (temporary). Small electrical currents running through the wires that form the loops generate a magnetic field; the sensor detects changes in this magnetic field that occur when metal parts of a bicycle (e.g., frame, spokes, and pedals) pass over the loops.

5.5.2 Typical Application

Loop detectors are generally intended for permanent count locations (embedded loops), but can be used for shorter duration counts with temporary surface loops designed for bicycle counting (as shown in the picture to the right). Loop detectors are used to collect screenline counts and are typically used on paved facilities, although at least one vendor makes a product using pre-formed loops that can be buried in soil. Although inductive loop detectors can be used on exclusive bicycle facilities, on mixed-use paths, and in mixed traffic, they have shown to be more accurate in situations where bicycles are separated from motor vehicle traffic (Nordback et al. 2011). Inductive loops used to detect bicycles at traffic signals may also be a potential source of counts, but not all traffic signal controllers can process and store bicycle count data (Kothuri et al. 2012a).

5.5.3 Installation Considerations

Select a mid-segment, channelized location where bicyclists are unlikely to stop and will be more likely to ride single file. Locations where loops can cover all (or nearly all) of the bicycle facility are preferred, as are locations where bicyclists cannot easily bypass the detectors.

Embedded loop detectors require pavement sawcutting to install the loops. Depending on the situation, considerable lead time may be required to obtain necessary permits, hire a contractor, and schedule the installation. (This process may be simpler when the agency installing the counter also owns the roadway or facility, and when the agency has in-house sawcutting expertise.) The data logger is typically stored in a utility box adjacent to the facility, which may require some excavation.

Temporary loops are adhered to the pavement surface, typically using adhesive tape. It can be difficult to remove the tape at the end of the counting period. Temporary loops are meant to be discarded at the end of service, but the data logger and other hardware can be reused with new sets of loops at other sites.

With either type of loop, consideration will need to be given to managing bicycle (and perhaps other) traffic while the installation is occurring.

5.5.4 Level of Effort and Cost

Relative to other counting technologies, the cost and level of effort to install embedded loops is high (due to the need for sawcutting and traffic control). The relative cost and level of effort to install temporary loops is medium, given the need for traffic control and ensuring that the wiring is set up correctly. Installation costs for embedded loops can vary greatly, depending on whether the organization installing the counter has the in-house expertise to install loops (e.g., for traffic signals) or needs to hire a contractor.

Inductive Loops Summary

Maximum user volume: Provides consistent results up to 600 users per hour; counts can be corrected at higher volumes.

Detection zone width: <20 feet

Typical count duration: Embedded loops are designed for permanent installations, temporary loops can be used for shorter-term counts (<6 months)

Typical equipment cost (2013): \$1,000–3,000

Relative preparation cost: Moderate to high (potential need for permits and sawcutting/excavation, traffic control)

Typical installation time: >half day (embedded loops), several hours (temporary loops)

Typical data collector training time: <30 minutes

Relative hourly cost: Low, equipment costs are spread over a large number of data-collection hours

Mobility: Poor, embedded loops are designed for permanent installations; the data logger used for temporary loops can be moved

5.5.5 Strengths and Limitations

Strengths

- Most jurisdictions are familiar with embedded loop technology, because it is also used to detect vehicles at traffic signals.
- Can be used for on-street bicycle facilities.
- Can be battery powered.
- Long-lasting equipment.

Limitations

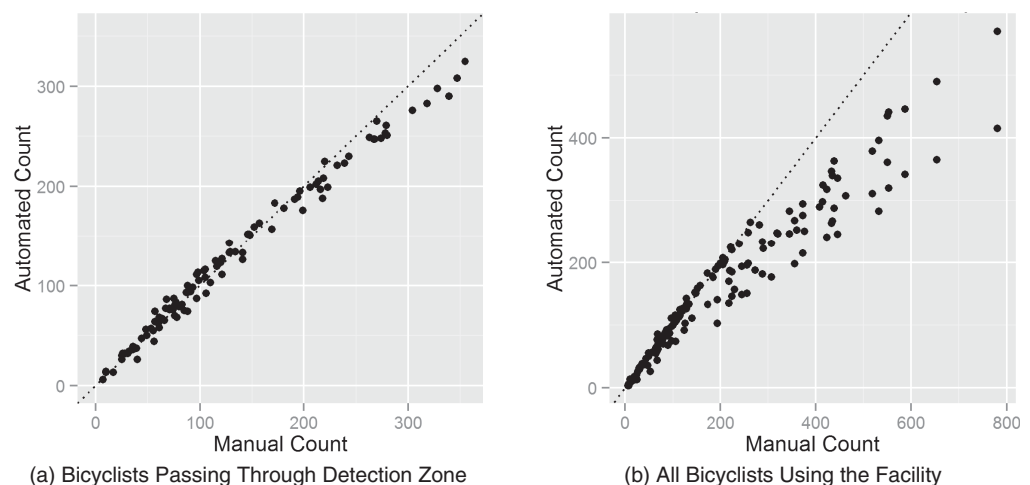
- Embedded loops require pavement saw cuts and a minimum pavement thickness.
- Electromagnetic interference can cause errors.
- May not detect side-by-side bicyclists.
- May experience inaccuracies with non-standard bicycles (e.g., bicycles with trailers or cargo boxes, tandem bicycles).
- If it is not possible to cover the entire facility width with the loops, bypass errors will occur when bicyclists ride outside the area covered by the loops.

5.5.6 Accuracy

NCHRP Project 07-19 tested one model of embedded loops and one model of temporary loops, primarily on off-street facilities. The two types of loops had similar accuracy rates when used off-street. Overall, the APD, representing the overall divergence from perfect accuracy across all data collected, was -0.6% . The AAPD, representing the counter's consistency, was 8.9% . Both of these values exclude bypass errors.

Figure 5-2 shows the accuracy and precision of the inductive loops tested by NCHRP Project 07-19, based both on (1) only the bicycles passing through the detection zone and (2) including bypass errors, where bicyclists were able to ride around the detection zone. The degree of miscounting because of bypass errors depends on the characteristics of the count site and the degree to which the loops cover the bicycle facility width. Consequently, site-specific correction values should be developed to account for bypass errors.

Tests of embedded loop detectors in Colorado showed an accuracy of -4% at off-road locations, -3% accuracy on separated paths, and $+4\%$ accuracy on shared roadways (Nordback et al. 2011; Nordback and Janson, 2010). Testing in New Zealand showed ranges of accuracy from



Source: NCHRP Project 07-19 testing.

Figure 5-2. Comparison of accuracy and precision of inductive loops.

–10% to +4% for on-road count sites and –10% to +25% for off-road sites (ViaStrada, 2009). At the time of writing, research was ongoing related to the accuracy of counts from traffic signal bicycle loop detectors (Nordback, Johnson, and Koonce 2014).

5.5.7 Usage

Embedded loop detectors have been more widely tested and used than temporary loops. Both types of loops are commercially available. Transportation agencies are familiar with embedded loop detectors given their use in vehicle and bicycle detection at signalized intersections.

Of those practitioner survey respondents who performed counts, 23% used inductive loops as part of their bicycle counting program.

5.6 Passive Infrared

5.6.1 Description

Passive infrared (IR) devices detect pedestrians and cyclists by comparing the temperature of the background to the infrared radiation (heat) patterns emitted by persons passing in front of the sensor. The passive infrared sensor is located on one side of the facility being counted. These devices are also known as “pyroelectric” counters, which refers to how the heat received by the sensor changes the sensor’s electrical properties.

5.6.2 Typical Application

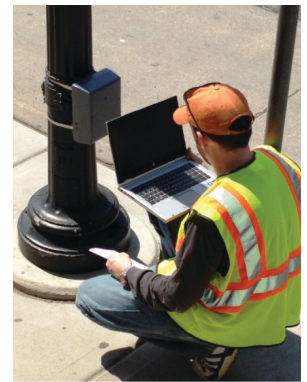
Passive IR devices are appropriate for collecting counts for several weeks or as permanent installations. They cannot differentiate between pedestrians and bicyclists, so are best for facilities with one user type or in conjunction with a bicycle-only counting technology to differentiate users. They collect screenline counts and can be used on multi-use paths or sidewalks. Integrated units that combine passive IR (to count all users) with either inductive loops or piezoelectric strips (to count bicyclists) are commercially available. When using a combination unit, the pedestrian count is obtained by subtracting the bicycle count from the total user count.

5.6.3 Installation Considerations

The placement of passive IR counters is critical to obtaining good results. IR counters are typically positioned on one side of the count corridor inside a post or placed on existing infrastructure. Passive IR sensors should be placed at the vendor-specified height (typically 2 to 3 feet) and work best when installed pointing toward a fixed object (e.g., a wall). Avoid locations where there is a likelihood that pedestrians will linger or congregate (e.g., doorways, bus stops, or street corners). Care should also be taken to avoid problems with reflection from heavy foliage, water, windows, or background traffic. Jones et al. (2010) found that the passive IR sensor model they tested produced the best results when positioned at a 45-degree angle to the pathway, to minimize occlusion.

5.6.4 Level of Effort and Cost

The level of effort to install a passive infrared detector is low, requiring mounting a single device on one side of the facility. The cost per device is medium, relative to other technologies.



Source: Ciara Schlichting, Toole Design Group.

Technicians setting up a passive infrared counter.

Passive Infrared Summary

Maximum user volume: Provides consistent results up to 600 users per hour; counts can be corrected at higher volumes.

Detection zone width: <20 feet

Typical count duration: Can be used for both short-term counts and permanent installations

Typical equipment cost (2013): \$1,000–3,000

Relative preparation cost: Medium (may require permitting)

Typical installation time: <30 minutes for temporary installations, longer for permanent installations involving installing posts

Typical data collector training time: <30 minutes

Relative hourly cost: Low, equipment costs are spread over a large number of data-collection hours

Mobility: Very good, equipment can be removed and taken to a new site

5.6.5 Strengths and Limitations**Strengths**

- Small, portable, and easy to install.
- Battery powered.
- May be used in combination with another technology to differentiate between bicyclists and pedestrians.

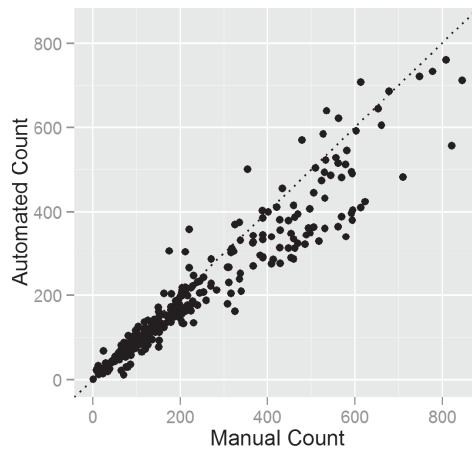
Limitations

- Cannot be used to count bicyclists in mixed traffic.
- Errors may arise because of occlusion with groups of pedestrians.
- Device performance can be affected by extreme temperatures.

5.6.6 Accuracy

NCHRP Project 07-19 tested two models of passive IR sensors at a total of nine locations (each model was tested at a subset of these locations). One model tested performed substantially better than the other model, with a correction factor of 1.037 versus 1.412 (a factor of 1.00 indicates that no correction is needed). The APD, representing the overall divergence from perfect accuracy across all data collected, was –3.1% for one product and –16.7% for the other product. The AAPD, representing the counter’s consistency, was 11.2% for one product and 33.1% for the other product. Figure 5-3 shows the testing results, combined for both products.

Previous research has shown that passive IR sensors undercount pedestrians, with the rate of undercounting increasing as pedestrian volumes increase (Schneider et al. 2012). Although there may be higher error rates when ambient air temperature approaches normal body temperature, “no conclusive evidence of this increased error exists, and the error may vary among different brands of passive infrared counters” (FHWA 2013). NCHRP Project 07-19 testing did not find any evidence of increased counting error when air temperatures exceeded 90°F.



Source: NCHRP 07-19 testing.

Figure 5-3. Accuracy and precision of passive infrared detectors.

5.6.7 Usage

Passive IR counters have been tested in research projects and are commercially available. These sensors are one of the primary automated technologies in practice in the United States for pedestrian counts. Of those practitioner survey respondents who performed counts, 22% used passive IR sensors as part of their pedestrian counting program and 19% used them as part of their bicycle counting program.

5.7 Active Infrared

5.7.1 Description

Active infrared (IR) devices count pedestrians and bicyclists using an infrared beam between an emitter and a receiver located on opposite sides of a traveled way (e.g., path or sidewalk). When the beam is broken for a set period of time by an object crossing it, a detection is recorded.

5.7.2 Typical Application

Active IR devices are most commonly used to collect bicycle or pedestrian screenline counts on multi-use paths. They can be installed temporarily or permanently. They cannot differentiate between pedestrians and bicyclists, so are best used on facilities with a single user type or in conjunction with a bicycle-only counting technology.

5.7.3 Installation Considerations

The receiver and transmitter need to be installed facing each other with a clear line of sight between them, at distances up to 90 feet apart for some products (vendor recommendations may vary). The need to find suitable mounting locations on both sides of the facility may pose a challenge when an active IR counter is used for a temporary count (a new post could be installed as part of a permanent installation). Avoid locations where pedestrians or bicyclists are likely to stop, linger, or congregate (e.g., doorways, bus stops, or street corners). Jones et al. (2010) found that an active IR device they tested was most accurate when oriented at a 45-degree angle to the facility.



Source: Tony Hull, Toole Design Group.

Active infrared counter installation at a test site.

Active Infrared Summary

Maximum user volume: Provides consistent results for over 600 users per hour

Detection zone width: >20 feet

Typical count duration: Can be used for both short-term counts and permanent installations

Typical equipment cost (2013): >\$3,000

Relative preparation cost: Medium (may require permitting, need to find suitable locations for both an emitter and a receiver)

Typical installation time: <1 hour for temporary installations

Typical data collector training time: <30 minutes

Relative hourly cost: Low, equipment costs are spread over a large number of data-collection hours

Mobility: Good, equipment can be removed and taken to a new site.

5.7.4 Level of Effort and Cost

The level of effort is medium relative to other technologies and requires setting up the emitter and the receiver in appropriate locations. The cost of the equipment is high, relative to other technologies, although overall installation costs are medium, relative to other technologies.

5.7.5 Strengths and Limitations**Strengths**

- Movable and easy to install.
- Battery powered.
- May be used in combination with another technology to differentiate between bicyclists and pedestrians.
- Very precise—error function is highly linear, so applying a multiplicative factor yields very accurate results.

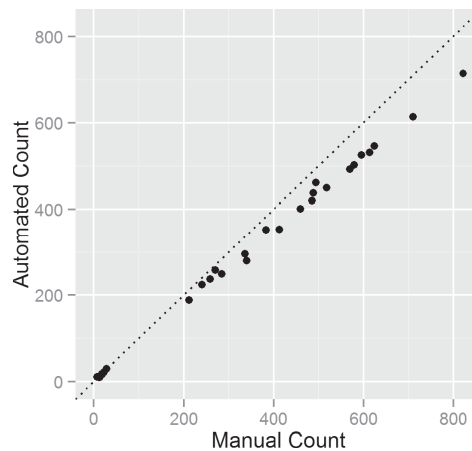
Limitations

- Cannot be used for on-street monitoring.
- Can count false positives from other objects (e.g. vehicles, insects, leaves, animals, and rain drops).
- Errors may arise due to occlusion with groups of pedestrians or side-by-side bicyclists.
- Requires mounting devices to fixed objects on each side of the trail or sidewalk.

5.7.6 Accuracy

NCHRP Project 07-19 tested a single active IR device at one location. The device had fairly high accuracy and very high precision. The APD, representing the overall divergence from perfect accuracy across all data collected, was -9.1%. The AAPD, representing the counter's consistency, was 11.6%. The relationship between the automated counts and ground truth counts is almost linear, as seen in Figure 5-4. The rate of undercounting gradually increases as volumes increase.

Jones et al. (2010) tested an active IR device. It was found to undercount travelers, with accuracy rates between -12% to -18% for all travelers, and -25% to -48% for pedestrians. An inverse relationship was found between accuracy and flow.



Source: NCHRP 07-19 testing.

Figure 5-4. Accuracy and precision of one active infrared detector.

5.7.7 Usage

Of those practitioner survey respondents who performed counts, 13% used active IR counters as part of their pedestrian counting program and 10% used them as part of their bicycle counting program.

5.8 Piezoelectric Strips

5.8.1 Description

Piezoelectric materials emit an electric signal when they are physically deformed. Counters using this technology consist of two strips embedded in pavement across the traveled way. The electric signal is detected by the data logger; the order in which the two strips emit a signal provides directionality, while the time interval between receiving the two strips' signals provides speed.

5.8.2 Typical Application

Piezoelectric strips are used for collecting bicycle counts at permanent count sites. They can be used on paved multi-use paths or cycle tracks.

5.8.3 Installation Considerations

These counters require pavement cuts to install the piezoelectric material. Depending on the situation, considerable lead time may be required to obtain necessary permits, hire a contractor, and schedule the installation. (This process may be simpler when the agency installing the counter also owns the roadway or facility.) The data logger is typically stored in a utility box next to the facility, which may require some excavation. Avoid placing the counter near intersections, to avoid overcounting bicyclists who must stop before crossing the intersection.

5.8.4 Level of Effort and Cost

The level of effort is high relative to other technologies and requires careful installation. The equipment cost is medium relative to other technologies, but the overall installation cost is high relative to other technologies.



Source: Tony Hull, Toole Design Group.

Bicyclist riding over piezoelectric strips.

Piezoelectric Strips Summary

Maximum user volume: The one counter tested by NCHRP 07-19 did not provide precise counts at any volume, although, on average, the counts were relatively accurate.

Detection zone width: <20 feet

Typical count duration: Used for permanent count stations.

Typical equipment cost (2013): \$1,000–3,000

Relative preparation cost: High (requires permitting, pavement cuts, specialized installation)

Typical installation time: >4 hours

Typical data collector training time: <30 minutes

Relative hourly cost: Low, equipment costs are spread over a long time period

Mobility: Poor, installations are typically permanent

5.8.5 Strengths and Limitations

Strengths

- Provides speed and directionality data.
- Discrete and not susceptible to tampering when embedded in pavement.
- Can be battery powered or externally powered.

Limitations

- Cannot be used in mixed-flow traffic.
- Specialized installation process.
- May introduce errors with groups of bicyclists.

5.8.6 Accuracy

NCHRP Project 07-19 tested one piezoelectric strip counter on a paved multi-use trail. The APD, representing the overall divergence from perfect accuracy across all data collected, was –11.4%. The AAPD, representing the counter’s consistency, was 26.6%. Figure 5-5 graphs the counter’s accuracy and precision. Piezoelectric strips have not been rigorously tested in the literature.

5.8.7 Usage

Of those practitioner survey respondents who performed counts, 4 out of 115 respondents (3%) used piezoelectric strips as part of their bicycle counting program.

5.9 Radio Beams

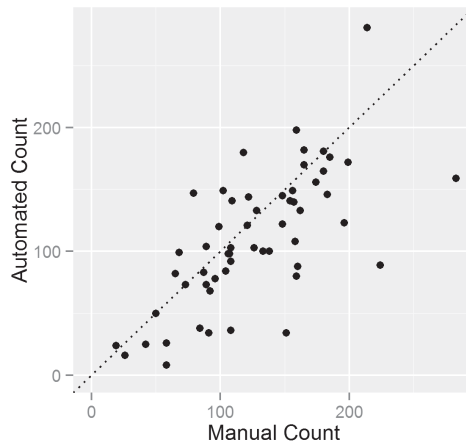
5.9.1 Description

Radio beam counters use a transmitter and receiver positioned on opposite sides of the facility. A radio signal is sent from the transmitter to receiver; when the beam is broken, a user



Source: Karla Kingsley,
Kittelson & Associates, Inc.

Completed radio beam counter installation.



Source: NCHRP Project 07-19 testing.

Figure 5-5. Accuracy and precision of one piezoelectric strip device.

is detected. Devices that use multiple radio frequencies can differentiate between pedestrians and bicyclists.

5.9.2 Typical Application

Radio beam counters are used for screenline counts on sidewalks, pathways, and cycle tracks and can be used in both short-term and permanent counting applications. As with other beam-type technologies, they are subject to occlusion errors.

5.9.3 Installation Considerations

The receiver and transmitter need to be installed facing each other with a clear line of sight between them. The multiple-frequency device tested by NCHRP Project 07-19 had a very narrow recommended maximum separation (10 feet), which made it challenging to find locations to apply it, given that many multiple-use paths are at least 10 feet wide. The radio beam can pass through thin wood and plastic, so the devices can be hidden behind certain types of objects. The devices can be mounted on existing infrastructure or installed in a post, so the device is completely hidden from sight. As with other beam-type technologies, locations where pedestrians or bicyclists are likely to linger should be avoided.

5.9.4 Level of Effort and Cost

The level of effort is medium relative to other technologies and requires finding suitable locations to mount a device on both sides of the facility. The equipment cost is high relative to other technologies, but the overall installation cost is medium.

5.9.5 Strengths and Limitations

Strengths

- Movable and easy to install.
- Can be hidden in post to discourage tampering or theft.
- Battery powered.

Limitations

- Errors with groups of pedestrians.
- Requires mounting devices to fixed objects on each side of the trail within limited distance.

Radio Beam Summary

Maximum user volume: Provides consistent results up to 200 users per hour; counts can be corrected at higher volumes

Detection zone width: <20 feet (single-frequency devices)
<13 feet (multiple-frequency devices)

Typical count duration: Can be used for both short-term counts and permanent installations

Typical equipment cost (2013): >\$3,000

Relative preparation cost: Medium (may require permitting, need to find suitable locations for both an emitter and a receiver)

Typical installation time: <1 hour for temporary installations

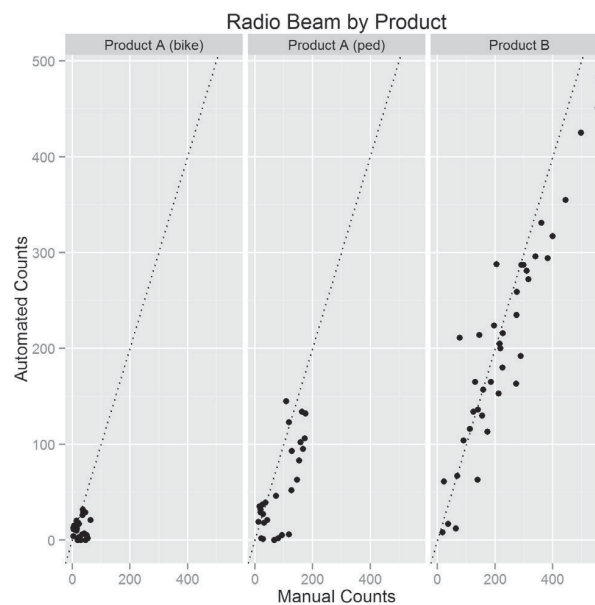
Typical data collector training time: <30 minutes

Relative hourly cost: Low, equipment costs are spread over a long time period

Mobility: Good, equipment can be removed and taken to a new site

5.9.6 Accuracy

NCHRP Project 07-19 tested two radio beam products. Product A counted pedestrians and bicyclists separately, using two radio frequencies, while Product B counted a combined total of pedestrians and bicyclists using a single radio frequency. The APD for Product A, representing the overall divergence from perfect accuracy across all data collected, was -31.2% for the bicycle count and -26.3% for the pedestrian count. The AAPD, representing the counter's consistency, was 72.6% for bicycles and 52.5% for pedestrians. The APD for Product B was -3.6% and the AAPD was 28.1% . Figure 5-6 graphs the counters' accuracy and precision.



Source: NCHRP Project 07-19 testing.

Figure 5-6. Accuracy and precision of radio beam detectors.

The researchers faced significant difficulties evaluating the accuracy of the radio beam sensors because of a specific detail of the products being tested: namely, the counters defaulted to beginning a count immediately when initiated, rather than aggregating into bins beginning on the hour. This setting could be altered in an “advanced settings” menu, but most of the installers did not realize this.

There has been no rigorous testing of radio beam technology in the literature, although one source anecdotally reports that a jurisdiction reported that it was the best technology they had used in 20 years of counting experience (ViaStrada 2009).

5.9.7 Usage

Radio beam devices are commercially available in the United States. None of the project’s practitioner survey respondents who performed counts (100 who performed pedestrian counts and 115 who performed bicycle counts) had experience with this technology.

5.10 Thermal

5.10.1 Description

Thermal devices generate infrared images by detecting body heat. They work similarly to passive infrared counters, but are mounted above the detection area. This positioning allows thermal devices to monitor the movement of persons and not just count the number of persons to pass the device. Thermal sensors are not affected by changes in ambient light.

5.10.2 Typical Application

At the time of writing, thermal sensors had primarily been used for presence-detection applications (e.g., traffic signal detectors and monitoring intrusions into restricted areas). One vendor was just entering the market with a device for performing bicycle and pedestrian counts. A thermal counter could perform screenline counts and could conceivably be used for pedestrian crossing counts within a defined area (e.g., a crosswalk). Thermal sensors would most likely be used for permanent count locations.

5.10.3 Installation Considerations

Thermal devices require an external power source and an overhead installation location.

5.10.4 Level of Effort and Cost

Unknown at the time of writing.

5.10.5 Strengths and Limitations

Unknown at the time of writing.

5.10.6 Accuracy

No rigorous testing has been performed on the accuracy of these devices.

5.10.7 Usage

Thermal devices are becoming commercially available in the United States, but none of the respondents to this project’s practitioner survey reported experience with them.

5.11 Laser Scanners

5.11.1 Description

Laser scanners emit laser pulses in a range of directions and analyze the reflections of the pulses to determine characteristics of the device's surroundings, including the presence of pedestrians or bicyclists. Two varieties of laser scanners exist: horizontal and vertical.

5.11.2 Typical Application

Non-motorized applications of laser scanners have primarily been indoors. One vendor states that the technology is best suited for locations with electrical power supplies. However, the technology can be used for short-term counts on battery power. Laser scanners can collect pedestrian and bicyclist screenline counts, but cannot differentiate between the two modes.

5.11.3 Installation Considerations

Permanent sites require an available electrical power supply. Horizontal scanners require locations with no obstructions. Vertical scanners are mounted above the detection area. Avoid locations where pedestrians or bicyclists are likely to stop, linger, or congregate (e.g., doorways, bus stops, or street corners).

5.11.4 Level of Effort and Cost

Insufficient U.S. experience with outdoor applications to judge.

5.11.5 Strengths and Limitations

Insufficient U.S. experience with outdoor applications to judge.

5.11.6 Accuracy

Bu et al. (2007) report that laser scanners face operational difficulties in inclement weather, (e.g., rain, snow, and fog) due to interference with the laser pulses.

5.11.7 Usage

Of the respondents to the project's practitioner survey who perform counts, only 2 of 100 used it for pedestrian counting and 1 out of 115 used it for bicycle counting.



Source: Linetop Ltd.

Installation of three pressure pads in a row to count side-by-side pedestrians and pedestrians traveling in opposite directions.

5.12 Pressure and Acoustic Pads

5.12.1 Description

Pressure and acoustic pads are installed in ground, either flush with or under the surface. Pressure pads detect a change in force (i.e., weight) on the pad. Acoustic pads detect the passage of energy waves through the ground caused by feet, bicycle tires, or other wheels (FHWA 2013).

5.12.2 Typical Application

Pressure and acoustic pads are primarily used to count pedestrians on unpaved trails. Pressure pads can also count bicyclists, while acoustic pads can only count pedestrians. Where pressure pads

are used on mixed pedestrian and bicyclist facilities, the software in the sensor can distinguish the pressure from bicyclists separate from pedestrians. These devices are most commonly used on unpaved multi-use paths and off-road trails where they can be buried and concealed. The pads require that pedestrians or bicyclists pass directly above them and are thus suited to situations where pedestrians or bicyclists would normally travel single file. If users are expected to travel side-by-side, multiple pads can be placed side-by-side and linked to detect multiple users. Given the required installation, pressure and acoustic pads are typically used for long-term or permanent installations, although pressure pads for temporary indoor applications are also available on the market.

5.12.3 Installation Considerations

Pads should be placed where users are expected to be moving. Locations near the start of a trail, benches, or notice boards should be avoided, because users may stop at those locations. The number of pads installed should match the facility width, to the extent possible, to minimize bypass errors. Consideration should be given to travelers' anticipated behavior and "desire lines" that show where users are traveling. For example, locations where users may cut corners or stray off the path are not ideal. Pads may be able to be installed in paved locations, but this will require the pavement to be removed and replaced. Pads are not appropriate for locations with ground freezes, because counts will typically not register in a hard frost.

5.12.4 Level of Effort and Cost

The level of effort is high and requires installing the pads in the ground. Information about equipment cost was insufficient, but overall installation cost would be expected to be high relative to other counting technologies, given the need to install the pads in the ground.

5.12.5 Strengths and Limitations

Strengths

- Battery powered.
- In-ground installation resists vandalism and theft.

Limitations

- Require users to pass directly above the sensor.
- Most commonly used on unpaved trails.
- Acoustic pads can only count pedestrians.

5.12.6 Accuracy

The accuracy of these technologies has not been rigorously tested.

5.12.7 Usage

The use of pressure and acoustic pads in the United States is uncommon. Of those responding to this project's practitioner survey who performed counts, none reported using pressure sensors to collect pedestrian and bicycle data. However, parks and recreation-focused agencies were not well-represented in the practitioner survey sample. The use of pressure and acoustic pads may be more common in other countries, as suggested by a review of available literature on the sensors.



Source: TRAFx.

5.13 Magnetometers

5.13.1 Description

Magnetometers detect bicycle activity through changes in the normal magnetic field as a bicycle's metal parts pass by. Magnetometers are more commonly used as part of vehicle detection systems to detect the presence and movement of vehicles. While it may be possible to use existing motorized traffic magnetometers for counting bicyclists, the installation and configuration may not be optimal, and they are not designed for this purpose (FHWA 2013).

5.13.2 Typical Application

Magnetometers are best suited to rural locations because the device is highly sensitive to ferrous objects. Due to the magnetometer's limited detection range, they are preferably installed where bicyclists will travel single file. Therefore, they are typically used to count bicyclists on rural bike paths or mountain bike trails.

5.13.3 Installation Considerations

Installation requires excavating an unpaved area or removing pavement from a bicycle facility, followed by replacement. They are not appropriate for locations with ground freezes.

5.13.4 Level of Effort and Cost

The level of effort is high and requires installing the device in the ground. Insufficient information was available about equipment cost, although overall installation cost would be expected to be high relative to other counting technologies, given the in-ground installation.

5.13.5 Strengths and Limitations

Strengths

- Battery powered.
- In-ground installation resists vandalism and theft.

Limitations

- Relatively small detection area.
- Limited application.

5.13.6 Accuracy

The accuracy of this technology has not been rigorously tested.

5.13.7 Usage

Magnetometers have been used to count and detect vehicles, but have not been widely applied to bicycle data collection. Magnetometers specifically designed for bicycle collection are commercially available in the United States. Of those responding to this project's practitioner survey who performed counts, none reported using magnetometers to collect bicycle data.

5.14 Fiberoptic Pressure Sensors

5.14.1 Description

Fiberoptic pressure sensors detect changes in the amount of light transmitted through an embedded fiberoptic cable, based on the amount of pressure (weight) applied to the cable. The sensitivity of the device can be adjusted to reflect the minimum or maximum weight desired to

be counted. A European vendor states that the technology can be used on mixed-traffic roadways to count bicycles separately from motor vehicles.

5.14.2 Typical Application

Fiberoptic pressure sensors can be used for permanent count stations. The technology could be applied to exclusive bicycle facilities, pathways, mixed-traffic roadways, and sidewalks.

5.14.3 Installation Considerations

Installation requires excavating a slot in the pavement and placing a fiberoptic cable in the slot. Avoid locations where users would be likely to congregate or linger, to avoid multiple detections of the same user.

5.14.4 Level of Effort and Cost

The level of effort is high and requires installing a fiberoptic cable in the pavement and associated traffic control. As no commercial system was available in the U.S. market at the time of writing, no equipment cost information was available, although overall installation cost would be expected to be high relative to other counting technologies, given the in-ground installation.

5.14.5 Strengths and Limitations

Strengths

- Can classify users/vehicles based on their weight.
- Can be used in mixed-flow traffic.
- Discrete and not susceptible to tampering when embedded in pavement.

Limitations

- Specialized installation process.
- Potential sources of error have not been rigorously tested.

5.14.6 Accuracy

The accuracy of this technology has not been rigorously tested.

5.14.7 Usage

Bicycle counters using fiberoptic pressure sensor technology are commercially available in Europe. At the time of writing, some of the components (e.g., fiberoptic cables and receivers) were available on the U.S. market, but a complete bicycle counting system was not marketed.



CHAPTER 6

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Case Studies

Case Study 1: Alameda County

Use of Continuous Count Patterns to Compare Short Pedestrian Counts

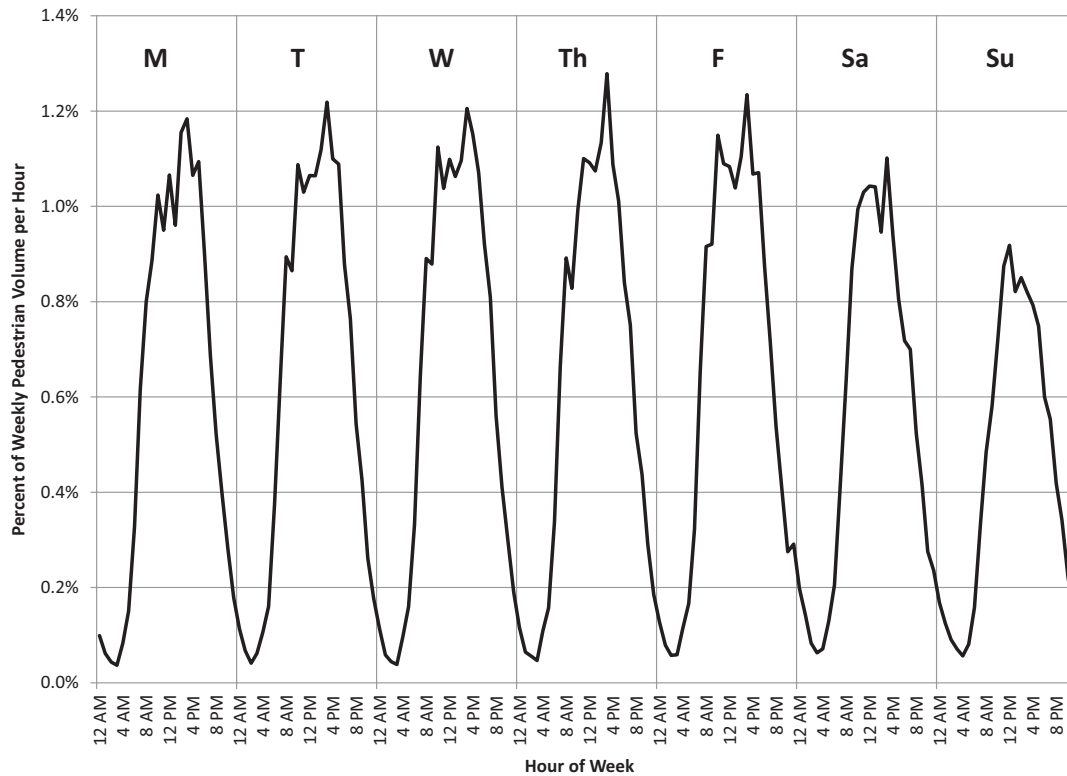
Alameda County, California, used approximately 1 month of automated count data to identify patterns of pedestrian activity at 13 sidewalk locations in 2008. Having continuous pedestrian activity pattern data helped address common challenges faced when comparing short (e.g., 2-hour) counts collected at different times of the week. These challenges include accounting for differences in activity level volumes by time of day, differences in activity patterns by land use, and differences in volumes by weather condition.

With the help of the UC Berkeley Safe Transportation Research and Education Center (SafeTREC), Alameda County identified relationships among activity levels occurring during different time periods. The percentages of pedestrian volume represented by each hour of the week at all 13 automated pedestrian counter locations in Alameda County were averaged to create a composite weekly pedestrian volume profile (see Figure A-1). For example, SafeTREC estimated that 1.07% of the weekly pedestrian volume occurred between 12 p.m. and 1 p.m. on Wednesday.

If analysis of these data over time proved this volume ratio to be relatively consistent and predictable based on observations at all locations, one could use the number of pedestrians counted between 12 p.m. and 1 p.m. on a Wednesday at another location to estimate that location's weekly pedestrian volume. If 100 pedestrians were counted during this hour at a particular location, the weekly volume estimate would be about 9,300 pedestrians ($100/0.0107 = 9,346$). Using this same weekly pattern, a count of 100 pedestrians at a different location on Saturday afternoon would give a comparable weekly volume estimate of about 12,000 pedestrians ($100/0.0084 = 11,905$). Similar activity profiles can be developed for seasons of the year, allowing the weekly estimate to be projected to an annual volume based on the time of the sample and seasonal adjustment factor.

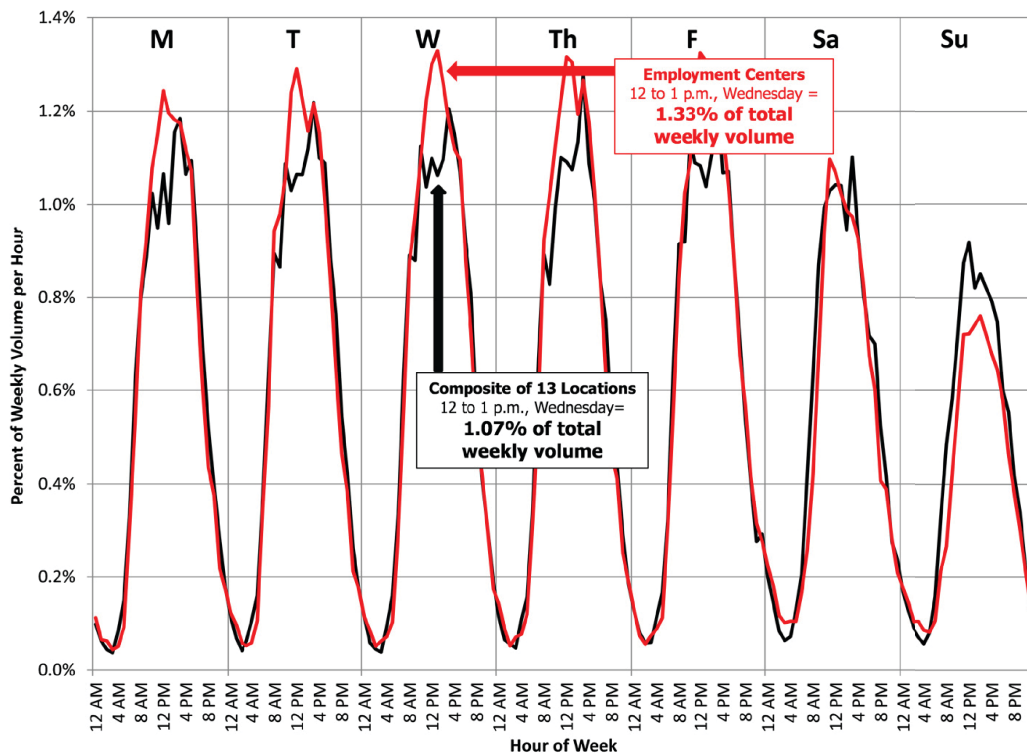
However, Alameda County and SafeTREC recognized that pedestrian patterns are not consistent at all locations. Patterns vary depending on land uses around a count location.

For example, compared to other automated counter locations in Alameda County, the locations in employment centers (defined as locations with more than 2,000 jobs within 0.25 miles) had a greater proportion of their weekly pedestrian volumes during mid-day hours on weekdays (see Figure A-2). Employees in these areas may go out to lunch or to business meetings during the middle of the day. Therefore, counts taken at locations in employment centers should be extrapolated based on the typical employment center pattern rather than the general county pattern. In an employment center, if 100 pedestrians were counted between 12 p.m. and 1 p.m.



Source: Robert Schneider, UC Berkeley SafeTREC.

Figure A-1. Alameda County typical weekly pedestrian volume pattern.



Source: Robert Schneider, UC Berkeley SafeTREC.

Figure A-2. Alameda County employment center vs. typical pedestrian volume pattern.

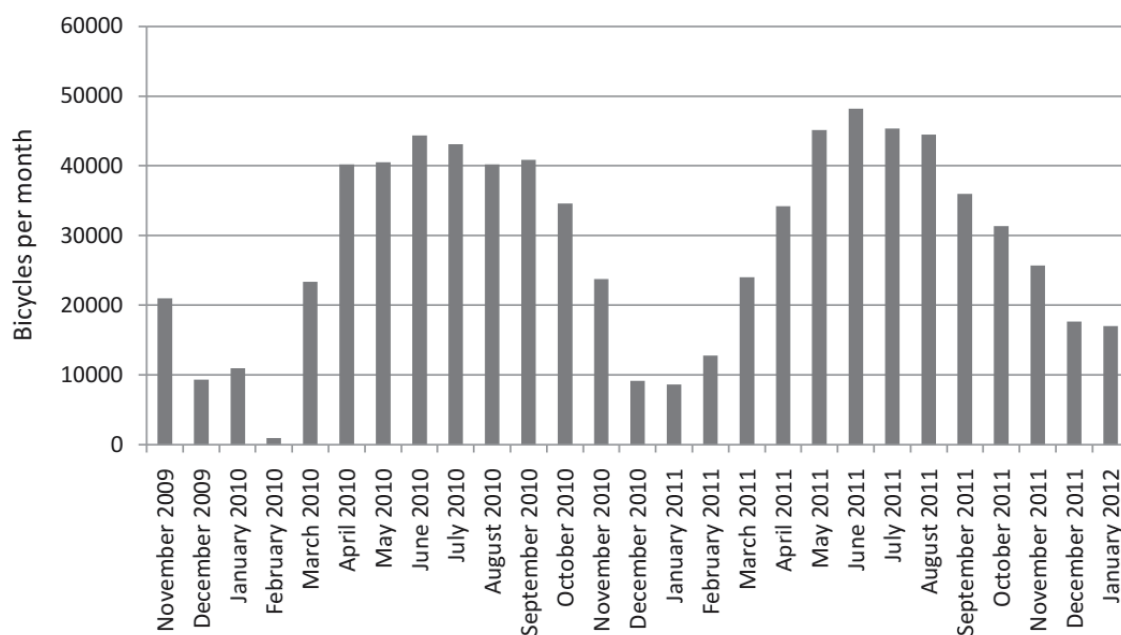
on a Wednesday, the weekly volume estimate would be about 7,500 pedestrians ($100/0.0133 = 7,519$), a difference of about 1,800 pedestrians compared to the weekly estimate produced by the unadjusted factor using the general county pattern.

Continuous data from automated counters also showed that pedestrian volume patterns are affected by weather conditions. For example, compared to the average count for a particular hour of the week, pedestrian volumes were approximately 5% lower when it was cloudy (i.e., they were about 0.95 times as high as a typical count). Therefore, to make short counts taken by manual data collectors on cloudy days comparable to counts taken on sunny days, Alameda County and SafeTREC divided the count by 0.95. For example, a volume of 100 pedestrians on a cloudy day would be equivalent to an average-day volume of 105 pedestrians ($100/0.95 = 105$). For additional information, see Schneider, Arnold, and Ragland (2009b). This example adjustment does not account for how people may respond to weather conditions at different times of day. In actuality, weather adjustments may be lower during commute times and higher at times of day when there are more discretionary walking and bicycling trips (e.g., people may walk to lunch on a warm, sunny day but eat in the building cafeteria on a cold, rainy day).

Case Study 2: Arlington County, Virginia

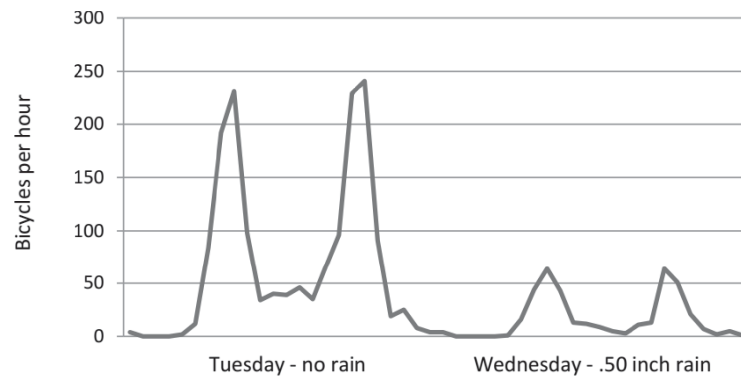
Using Continuous Count Data to Achieve Multiple Purposes

Arlington County, Virginia, started its pedestrian and bicycle counting program in 2009 with a single automated counter on a popular multi-use trail. The program expanded to include counters at more than 30 locations by 2012. The initial purpose of the program was to provide a baseline of pedestrian and bicycle volume data that could be considered along with volumes from other modes. Continuous data from the counter have shown expected seasonal patterns in bicycle use as well as overall growth in bicycle activity. For example, most monthly bicycle counts in 2011 were higher than the same monthly counts in 2010 (see Figure A-3).



Source: Arlington County, VA (2012).

Figure A-3. Custis Trail bicycle volume pattern.



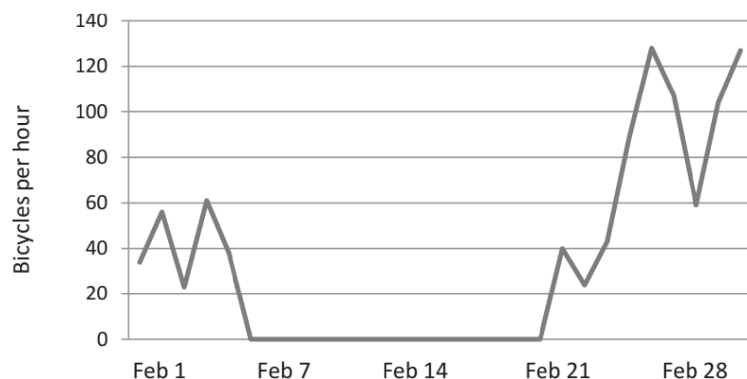
Effect of rainy weather suppressing bicycle transportation,
Tuesday, October 18 - Wednesday, October 19, 2011

Source: Arlington County, VA (2012).

Figure A-4. Illustrative impact of rain on bicycle volume.

Although the initial purpose was to provide baseline data on pedestrian and bicycle volumes, the Arlington County counting program has served additional purposes. For example, the measured activity patterns show that bicycles are used for various reasons. Many counters in Arlington County document regular weekday morning and evening peaks, suggesting that people use bicycles to commute to and from work. Counters also show a single, mid-day peak on weekends and holidays, suggesting that bicycles may also be used regularly for recreation, shopping, and other social activities.

In addition, Arlington County's automated counts show the influence of weather on bicycling. Comparing a normal weekday with a rainy weekday showed that rain may reduce bicycle commuting to just 25% of normal levels (see Figure A-4). Snow also has significant effects on bicycling levels. In particular, when several feet of snow were not cleared from the Custis Trail for 2 weeks, regular bicycle commuting levels were reduced to zero (Figure A-5). Arlington County pedestrian and bicycle program staff were able to use these data to illustrate the effect of poor winter maintenance and to show that many bicyclists could benefit from maintaining the trail year-round. For additional information, see Arlington County (2012).



Saturday, February 6 - Friday, February 19, 2010, zero bicycle
transportation on Custis Trail due to uncleared heavy snow

Source: Arlington County, VA (2012).

Figure A-5. Illustrative impact of uncleared snow on bicycle volume.

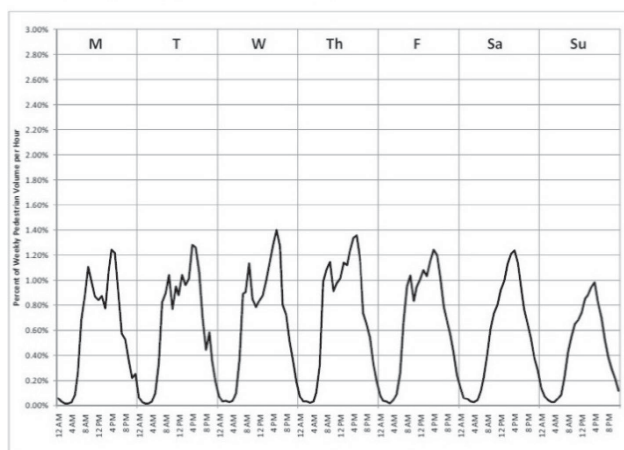
Case Study 3: San Francisco, California

Pedestrian Volume Patterns Provide Data for a Community-Wide Demand Model

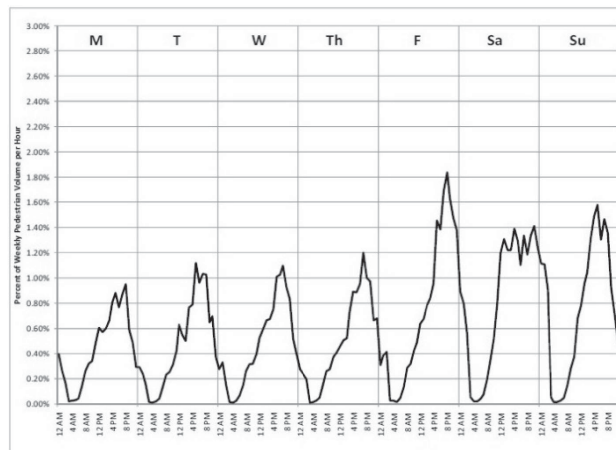
The San Francisco Municipal Transportation Agency (SFMTA) and San Francisco County Transportation Authority (SFCTA) used continuous automated count patterns to estimate annual pedestrian volumes at 50 intersections throughout the city. These annual volumes were used as the basis for an intersection pedestrian volume model developed by SafeTREC and Fehr & Peers Transportation Consultants. Accurate annual estimates were critical for developing the best possible model. Although the researchers could have applied the same expansion factors to 2-hour counts at all locations, they based their annual volume estimates on more than 20 different automated count patterns (see Figure A-6). The pedestrian volume patterns at the intersection crossings were assumed to match the overall pedestrian volume patterns on adjacent sidewalks where the automated counters were located (because automated technologies were not available to detect pedestrians crossing the street).

Statistical modeling showed that annual pedestrian volumes at San Francisco intersections were positively associated with household density, job density, high-activity zones with parking

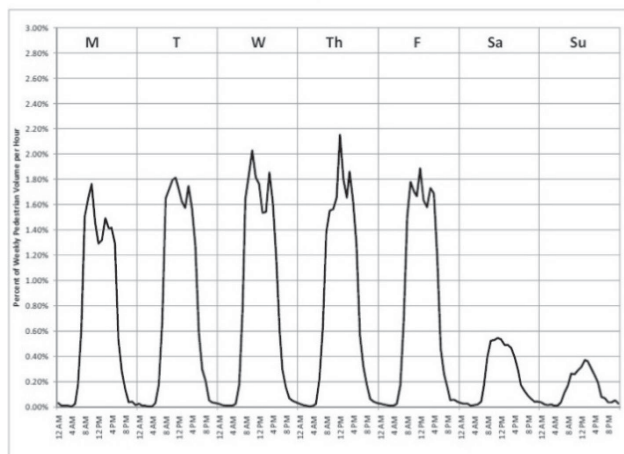
4th Street & Market Weekly Pedestrian Volume Pattern



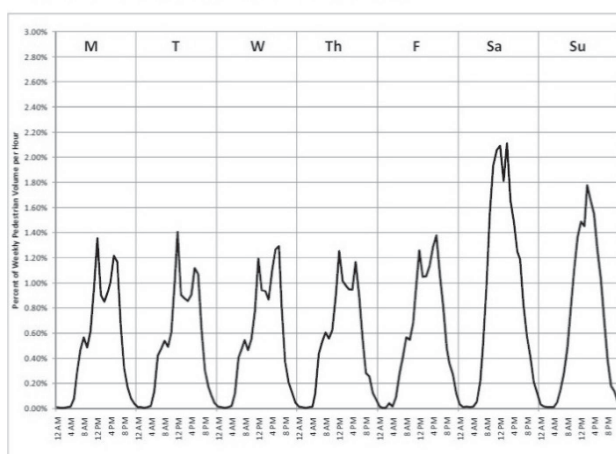
18th Street & Castro Weekly Pedestrian Volume Pattern



Divisadero & Geary Weekly Pedestrian Volume Pattern

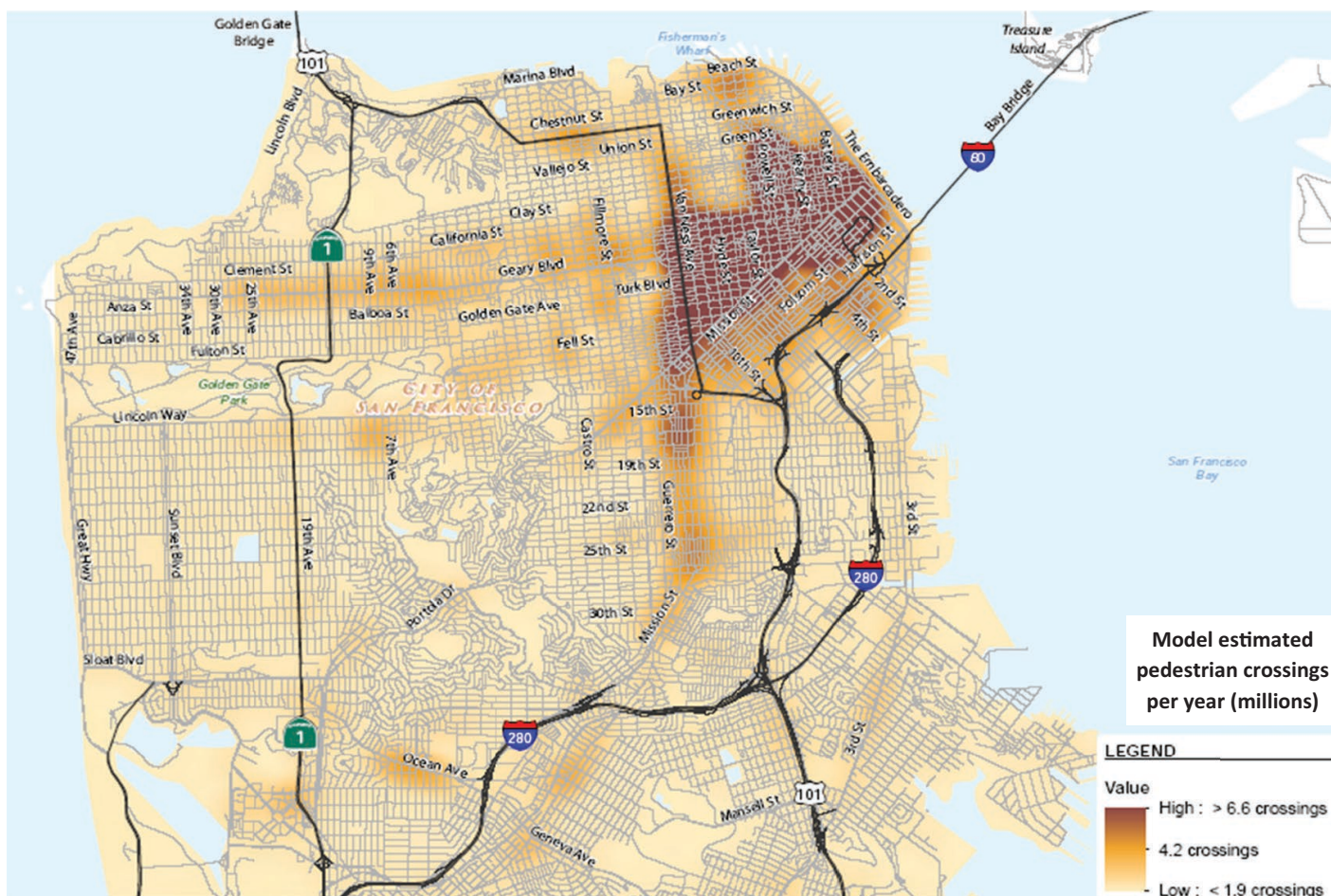


Embarcadero & Washington Weekly Pedestrian Volume Pattern



Source: Fehr & Peers Transportation Consultants and UC Berkeley SafeTREC (2011).

Figure A-6. Example pedestrian volume patterns near San Francisco intersections.



Source: Fehr & Peers Transportation Consultants and UC Berkeley SafeTREC (2011).

Figure A-7. Estimated San Francisco intersection pedestrian volumes.

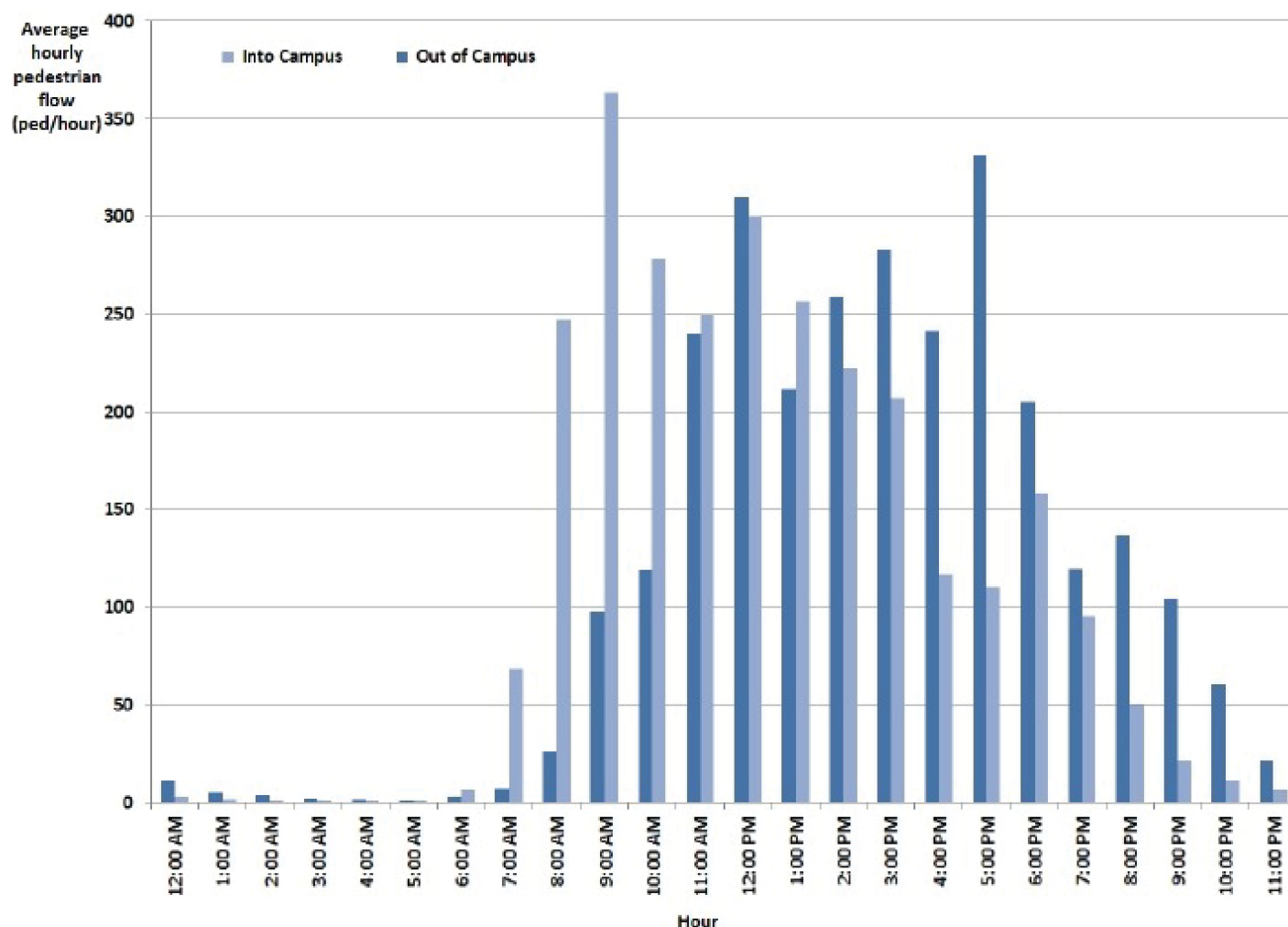
meters, proximity to a university campus, and traffic signals, and were negatively associated with steep slopes. The model equation was then used to estimate pedestrian volumes at all 8,100 intersections in San Francisco (see Figure A-7). The model results are being used by SFMTA and SFCTA to support the following policy goals: (1) reduce the absolute number of severe injuries and fatalities; (2) improve walking conditions in areas with elevated crash risk; and (3) implement effective safety measures. For additional information, see Schneider et al. (2012).

Case Study 4: University of California, Berkeley

Pedestrian Volume Patterns Provide Exposure Data for Safety Analysis

SafeTREC used long-term pedestrian volume patterns to control for pedestrian exposure and estimate pedestrian crash risk at 22 intersections along the campus boundary during typical spring and fall semester weekdays.

Continuous count patterns were collected at three locations on campus (counts from one of the locations are shown in Figure A-8). Two-hour manual counts at each of the 22 intersections were extrapolated to a 10-year volume estimate based on the pedestrian activity pattern from the closest automated counter. Estimated 10-year volumes were then compared with the number of



Source: UC Berkeley SafeTREC (2012).

Figure A-8. Pedestrian volume patterns at one UC Berkeley campus entrance.

reported crashes at each intersection during a 10-year period. Crash rates were also calculated by hour of the day.

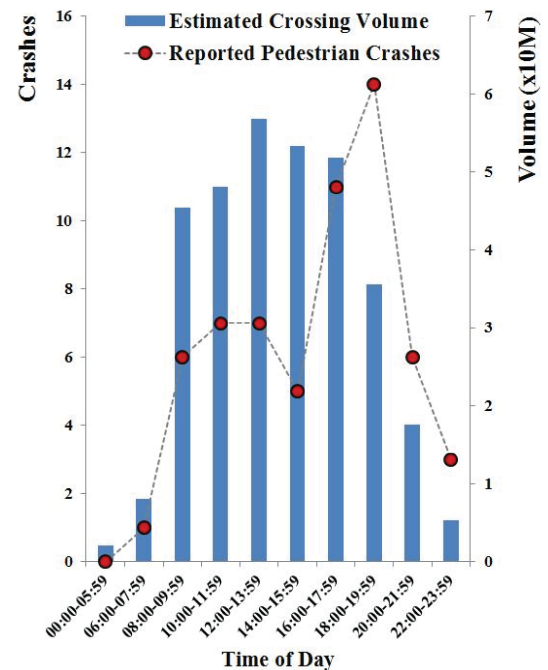
Results showed that pedestrian crash risk was generally higher at intersections along the boundary roadways with the lower pedestrian volumes. In addition, pedestrian risk in the evening (6 p.m. to midnight) was estimated to be more than three times higher than in the daytime (10 a.m. to 4 p.m.) (see Figure A-9). For additional information, see Schneider, Grembek, and Braughton (2013).

Case Study 5: Washington State Department of Transportation

Volunteers Collect Annual Pedestrian and Bicycle Counts

The Washington State Department of Transportation (WSDOT) has worked with the Cascade Bicycle Club (CBC) since 2008 to implement an annual volunteer-based statewide pedestrian and bicycle count program. In 2012, nearly 400 volunteers collected manual counts at more than 200 locations in 38 different cities. This level of coverage would not be possible for the

All 22 Boundary Roadway Intersections			
Time Period	Reported Pedestrian Crashes	Estimated Crossing Volume	Crashes/10M Crossings
00:00-05:59	0	2,025,899	0
06:00-07:59	1	8,025,759	1.25
08:00-09:59	6	45,451,089	1.32
10:00-11:59	7	48,181,827	1.45
12:00-13:59	7	56,791,023	1.23
14:00-15:59	5	53,333,999	0.94
16:00-17:59	11	51,804,940	2.12
18:00-19:59	14	35,643,980	3.93
20:00-21:59	6	17,638,689	3.40
22:00-23:59	3	5,345,865	5.61
Total	60	324,243,069	1.85



Source: Schneider, Grembek, and Braughton (2013).

Figure A-9. Pedestrian crash risk at campus boundary intersections by time of day.

state without volunteer resources. Each community has a Local Count Coordinator (often from a local transportation agency) who is responsible for organizing the local counts and reporting to WSDOT.

Each year, volunteers conduct 2-hour counts from 7 a.m. to 9 a.m. and from 4 p.m. to 6 p.m. on a Tuesday, Wednesday, or Thursday in late September. Most counts are at intersections, but some are along multi-use trail, roadway, and sidewalk segments. Volunteers are given counting instructions and data collection forms prior to the count dates—this approach helps data collectors prepare and likely helps reduce counting errors.

Although the counts are still tallied on paper forms and can be sent to WSDOT for database entry, WSDOT now offers a webpage where volunteers can enter their count data directly. In addition, CBC created an online system to help count volunteers register and select count times and locations.

Results from 83 locations that have been counted consistently in the morning and 64 locations that have been counted consistently in the afternoon each year since 2009 have shown overall increases in walking and bicycling (see Figure A-10). In addition, the manual counting approach has made it possible to document helmet use as well as pedestrian and bicyclist gender in different communities throughout the state. For more information, see Washington State DOT (2012).

Case Study 6: Columbus, Ohio

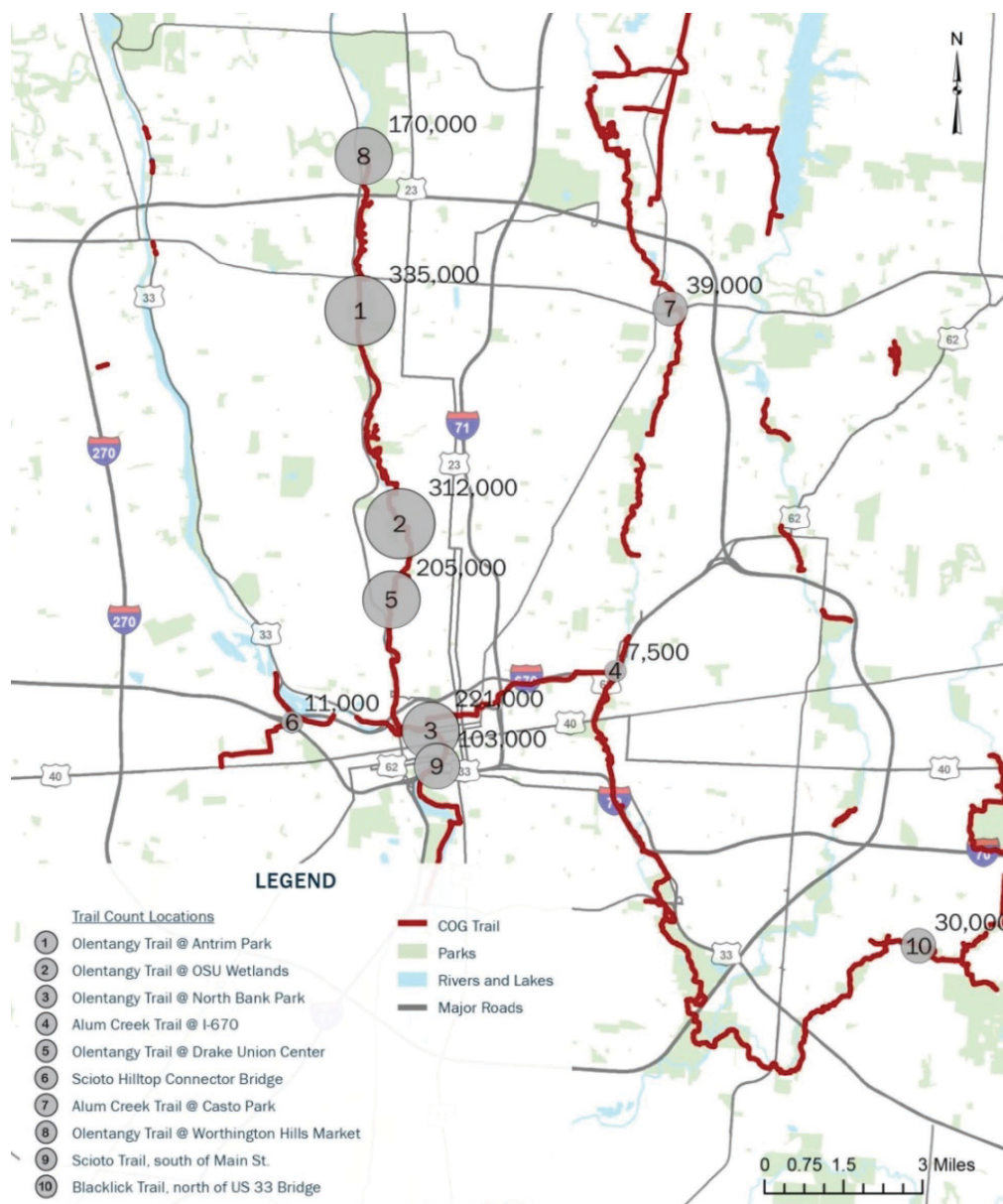
Three Organizations Coordinate to Collect Trail Counts

The City of Columbus, Ohio, partnered with the Mid-Ohio Regional Planning Commission (MORPC) and the Rails-to-Trails Conservancy (RTC) in 2010 to document trail use (pedestrians plus bicyclists) along several major corridors (see Figure A-11). Although none of the three organizations had an extensive budget for counting, their partnership made it possible to collect

	2009	2010	2011	2012	% change (2009 to 2012)
AM (comparing 83 locations)					
Bicycle	2,390	2,797	2,851	3,246	35.8%
Pedestrian	5,421	6,427	5,779	6,604	21.8%
Total	7,843	9,248	8,672	9,941	26.7%
PM (comparing 64 locations)					
Bicycle	3,206	4,631	4,345	4,683	46.1%
Pedestrian	8,313	9,828	9,130	9,528	14.6%
Total	11,643	14,569	13,514	14,389	23.6%

Source: Cascade Bicycle Club (2013).

Figure A-10. Washington State pedestrian and bicycle counts, 2009 to 2012.



Source: Mid-Ohio Regional Planning Commission (2012).

Figure A-11. Estimated annual trail volume by location.

LOCATION	2010	2011	2012
1: Olentangy Trail @ Antrim Park	321,000	335,000	350,000
2: Olentangy Trail @ OSU Wetlands	427,000	312,000	261,000
3: Olentangy Trail @ North Bank Park	202,000	221,000	271,000
4: Alum Creek Trail @ I-670	7,100	7,500	8,400
5: Olentangy Trail @ Drake Union Center	193,000	205,000	229,000
6: Scioto Hilltop Connector Bridge	10,000	11,000	12,000
7: Alum Creek Trail @ Casto Park	37,000	39,000	44,000
8: Olentangy Trail @ Worthington Hills Market	160,000	170,000	190,000
9: Scioto Trail, south of Main St.	97,000	103,000	115,000
10: Blacklick Trail, north of US33 Bridge	28,000	30,000	33,000

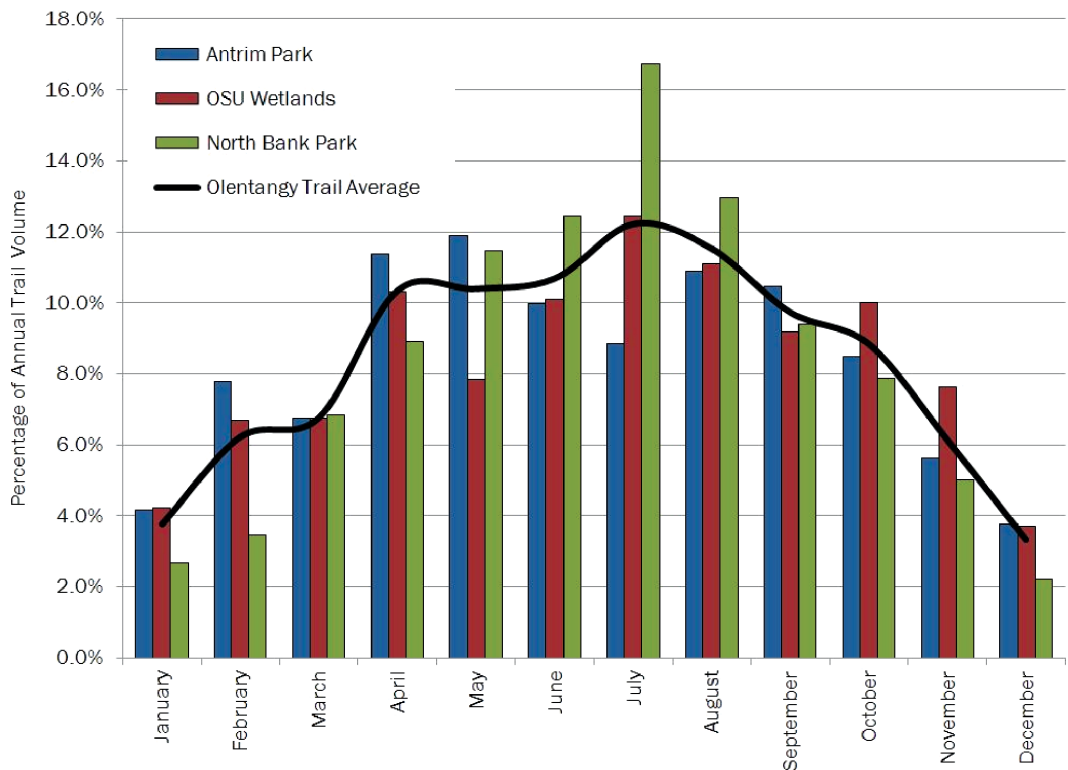
Notes: (1) Count values below 10,000 rounded to nearest hundred; values above 10,000 rounded to nearest thousand. (2) Values shown in *light blue italics* indicate that annual estimates for those locations and years are based on the trend from locations 1 and 3, as no actual counts were taken in those years.

Source: Mid-Ohio Regional Planning Commission (2012).

Figure A-12. Estimated annual trail volume by location, 2010–2012.

a rich set of information about trail use patterns. The City of Columbus funded the study, purchasing three passive infrared counters and installing them permanently at three locations. RTC rotated several temporary counters to collect 2 months' worth of data at seven other locations. MORPC organized and analyzed the data. The 2-month counts were extrapolated using seasonal volume patterns from two of the locations that had continuous 2-year data.

The data were used to create a report with useful information about changes in trail activity patterns by time of day, day of week, and season of year (see Figures A-12 and A-13). According



Source: Mid-Ohio Regional Planning Commission (2012).

Figure A-13. Estimated Olentangy Trail annual volume by month.

to MORPC, “The counts are meant to serve as a baseline to document changes over time, while also assisting with grant applications, providing information to elected officials, and supporting/justifying budget decisions. The trail counts inform the process of evaluating whether to widen selected trails.”

Case Study 7: San Diego County

Systematic Process Used to Select Permanent Count Sites

The County of San Diego Health and Human Services Agency, San Diego Association of Governments, and San Diego State University have partnered to install automated pedestrian and bicycle counters throughout the region. Funding was provided by a Centers for Disease Control and Prevention Community Putting Prevention to Work (CPPW) grant. Once completed, this system is likely to become the largest set of permanent counters used for pedestrian and bicycle traffic monitoring in the United States.

The first set of more than 30 automated count locations was selected using four criteria:

1. Locations along the existing or planned regional bicycle network;
2. Locations with a Smart Growth Opportunity Area (i.e., mixed-use, high-density infill development consistent with SANDAG’s Regional Comprehensive Plan);
3. Geographic variety (i.e., covering areas throughout the region); and
4. Demographic variety (i.e., covering a range of population and employment densities and median household incomes).

A stratified sampling approach was used to achieve the fourth criterion. This approach used census data to define high, medium, and low categories of population density, employment density, and median household income. The 27 sampling strata and their geographic distribution are shown in Figure A-14. For additional information, see Ryan (2013).

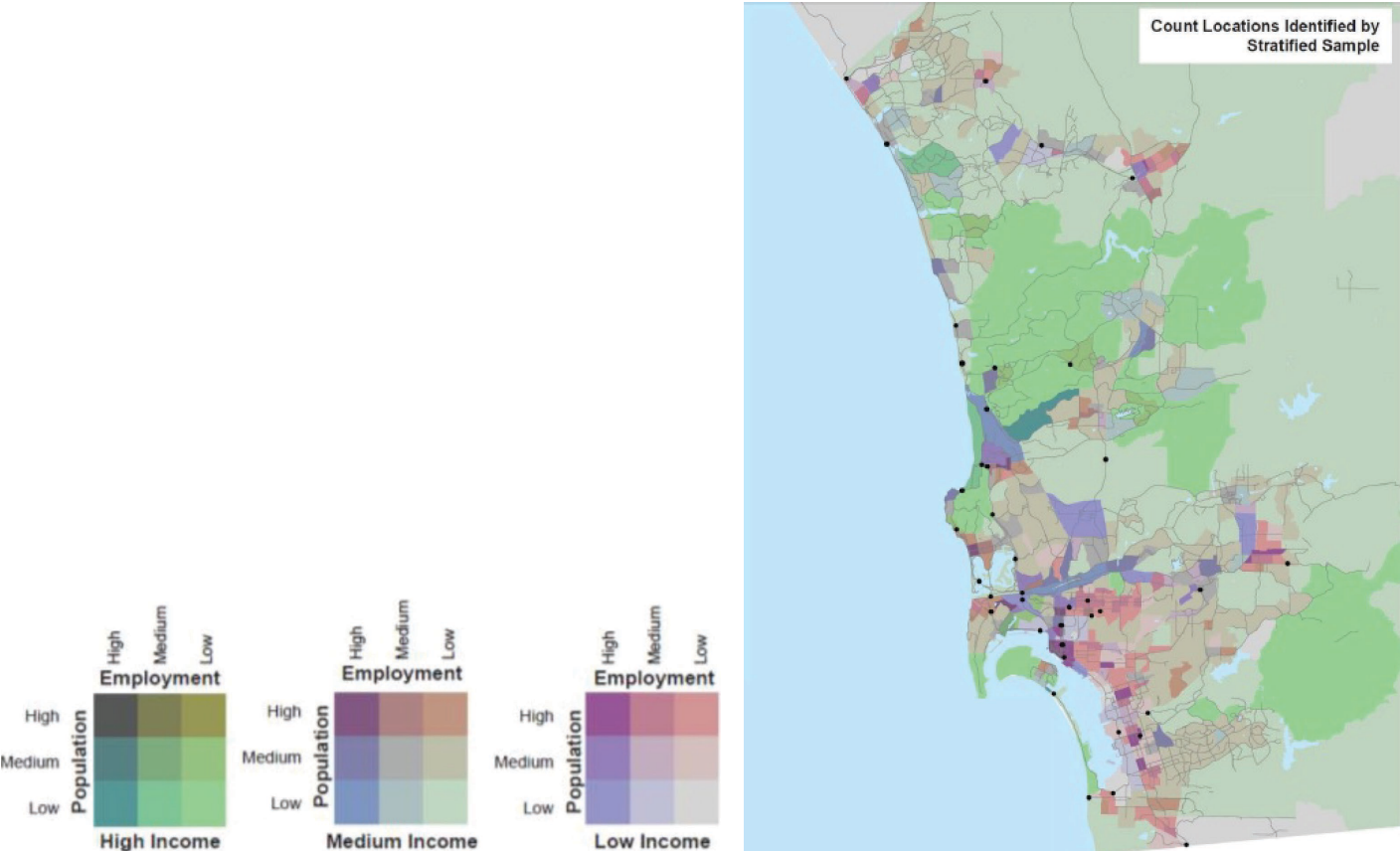
Case Study 8: Colorado Department of Transportation

Automated Counters Are Used to Identify Common Bicycle Volume Patterns

The Colorado Department of Transportation used automated counters to identify specific types of pedestrian and bicycle activity patterns on multi-use trails. Counts were collected on more than 20 trails. Three distinct trail usage patterns, or factor groups, were identified using cluster analysis:

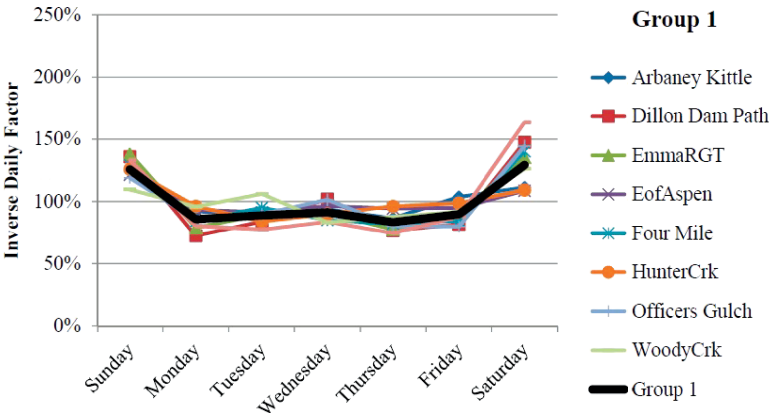
- Mountain Non-Commute. This pattern was typically observed in rural, mountainous areas (see Figure A-15). There was often a high level of weekend and monthly variation in volumes.
- Front-Range Non-Commute. This pattern was typically observed in the Front-Range (more urbanized) region and was associated with bicycling for recreational or non-commuting trip purposes. Some rural mountain locations with higher utilitarian bicycling were also included. This pattern tended to have high weekend variation and low monthly variation.
- Commute. This pattern was typically observed in the urban and suburban Front Range region and in urban Mountain communities (see Figure A-16). There were often distinct morning and afternoon peaks in activity. This pattern often had relatively low weekend and monthly variation.

These patterns are used to extrapolate short-duration counts to represent longer time periods, such as annual trail user volumes. For additional information, see Nordback, Michael, and Janson (2013).



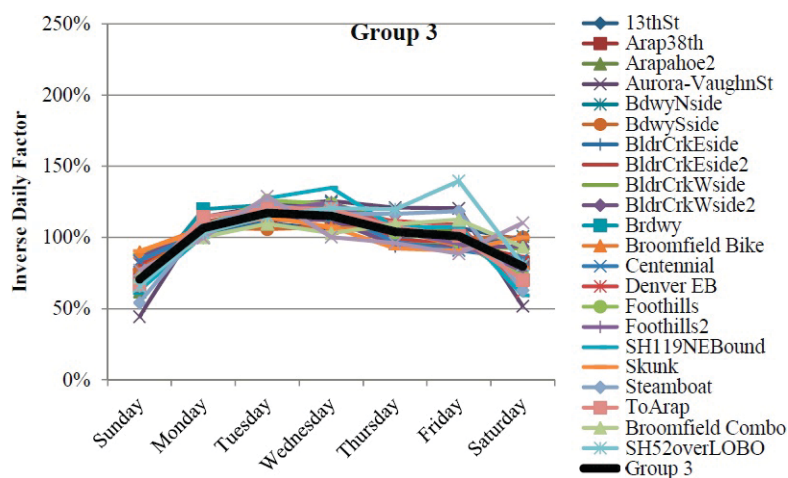
Source: Nordback, Michael, and Janson (2013).

Figure A-14. San Diego automated counter locations.



Source: Nordback, Michael, and Janson (2013).
Note: Inverse daily factor is the percentage of the average daily volume observed on each specific day. Each legend item represents a different bicycle monitoring location. The bold line is the average of all locations.

Figure A-15. Mountain non-commute trail usage pattern.



Source: Colorado Department of Transportation (2013).

Figure A-16. Commute trail usage pattern.

Case Study 9: Minneapolis

Counts Are Used to Map Pedestrian and Bicycle Volumes Throughout the Community

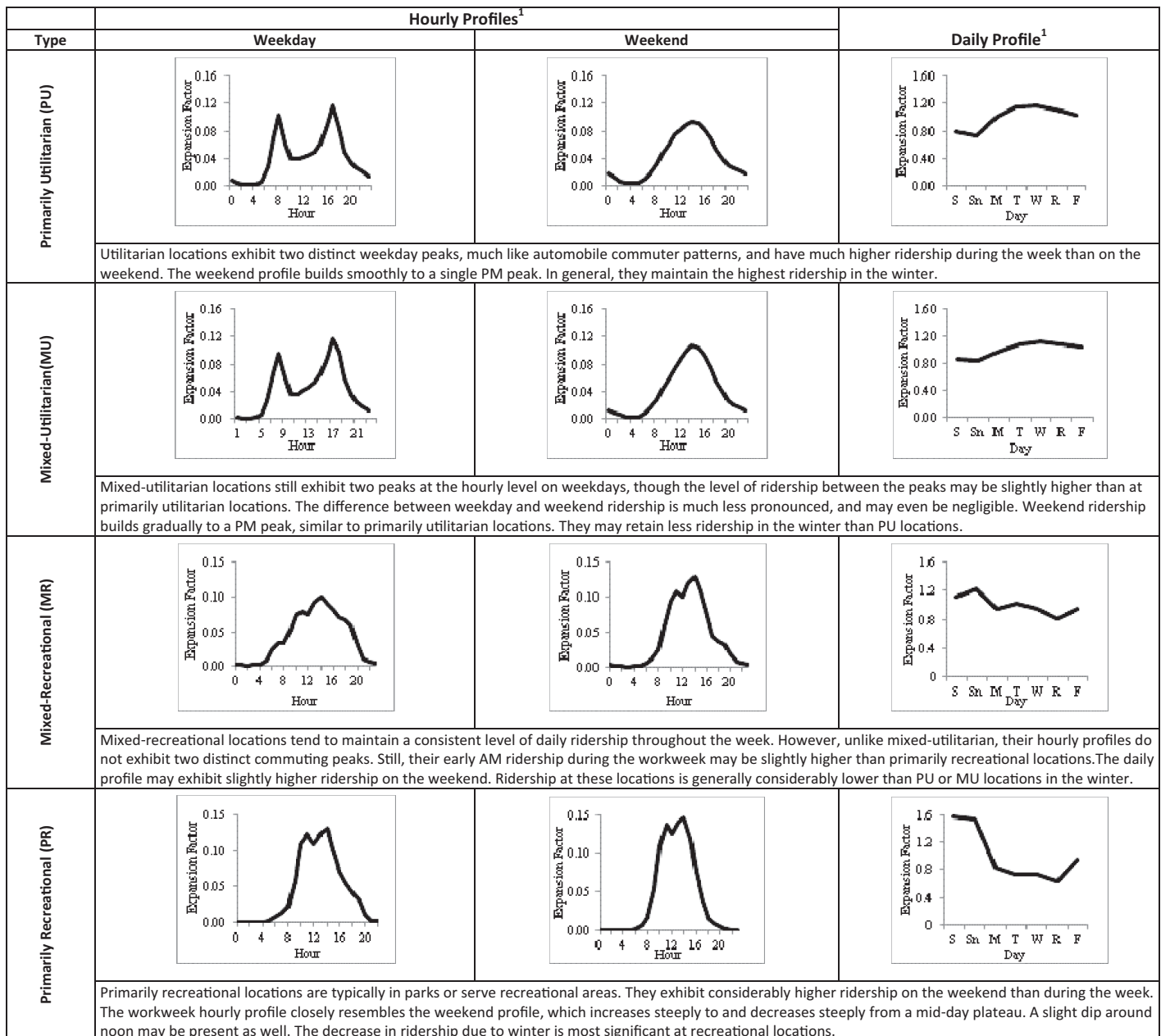
The City of Minneapolis, Minnesota, began collecting annual pedestrian and bicycle counts in 2007. With the assistance of Transit for Livable Communities (TLC), the City has collected counts each September at 23 consistent locations for pedestrians and 30 consistent locations for bicyclists. These consistent count locations have documented increases in walking and bicycling. However, the City also has more than 300 additional non-motorized count locations counted once every 3 years. Most counts are conducted from 4:00 p.m. to 6:00 p.m. or from 6:30 a.m. to 6:30 p.m., and models are used to extrapolate these counts to 24-hour volumes for a typical September weekday. Data from the 300 count locations are used to create maps of estimated daily pedestrian and bicyclist volumes on a typical September weekday (see Figure 3-5 in Chapter 3). For additional information, see Minneapolis Department of Public Works (2013).

Case Study 10: Five North American Cities

Classifying Bicycle Traffic Patterns in Five North American Cities

Researchers from McGill University and the UC Berkeley Safe Transportation Research and Education Center analyzed continuous count data to identify similarities between bicycle ridership patterns across different North American communities. Long-term bicycle counts were gathered from 38 locations in five cities (Montreal, Ottawa, Portland, San Francisco, and Vancouver) and along the Green Route in Quebec.

This study introduced a classification scheme for analyzing bicycle traffic patterns. Among other findings, the analysis showed that the bicycle volume patterns fell into one of the following classifications: utilitarian, mixed-utilitarian, mixed-recreational, and recreational (see Figure A-17). Study locations classified into each of these categories were found to have consistent hourly and weekly traffic patterns across cities, despite differences between these cities in terms of factors such as weather, size, and urban form. Seasonal patterns across the four categories and in the different cities were also identified. The study presents expansion factors for each category by hour and day of the week. Monthly expansion factors are also presented for each city. Finally, traffic volume characteristics are presented for comparison purposes.



¹The pictured profiles are the mean values of the facilities belonging to each classification.

Source: Miranda-Moreno et al. (2013).

Figure A-17. Summary of classification of bike traffic patterns.

Manual Pedestrian and Bicyclist Counts: Example Data Collector Instructions

About These Example Instructions

These instructions describe how to count pedestrians and bicyclists at intersections. There are many other ways that pedestrians and bicyclists can be counted at intersections, but this method is designed to gather counts in the most accurate, efficient, and consistent manner possible.

Gender is captured using this method, but age, helmet use, jaywalking, wrong-way riding, and other characteristics are not included so that data collectors can focus on counting accurately.

In addition, it is also possible to count pedestrians and bicyclists at locations such as trail, sidewalk, and bicycle lane segments and at building entrances. However, different methods are used to capture counts at these other locations.

This document describes the procedure that you will use to count pedestrians and bicyclists at intersections. Review this document before visiting the field, and refer to it when you have questions in the field. Ideally, you will be trained on the counting methods described below before taking counts. However, it is not necessary to have formal training to follow these procedures.

SAFETY FIRST: You will be standing near roadway intersections to take counts. Use caution traveling to the count locations, including crossing roadways near the sites. Follow traffic laws at all times. Maintain a constant awareness of your surroundings, including traffic conditions and social situations, and ensure that data collection does not interfere with your attention to safety. If you feel unsafe, uncomfortable, or threatened, stop data collection and move to a safer location.

BRING COUNT MATERIALS:

- Data Collection Sheets (8 total sheets; 1 for each 15-minute period)
- Pencil or Pen
- Clipboard (or something to write on)
- Watch (or other timing device that can identify 15-minute periods)
- Short letter from the agency sponsoring the counts. This letter should have the name, email, and phone number of someone at the agency so that you can tell people with questions about the counting effort who they can contact (See attached Example Agency Letter).

FILL IN GENERAL INFORMATION ON FIRST SHEET (See top of attached Data Collection Sheet):

- Arrive at the count intersection at least 15 minutes before the count period is scheduled to find a location where you can see all of the intersection crossings and to fill in general information.
- Record the name of the mainline roadway (roadway with more traffic) and intersecting roadway.
- Label the intersection diagram with the names of each roadway.
- Add an arrow to indicate which direction is NORTH.
- Record your name as the observer.
- Record the date and time period of the count.
- Estimate the current temperature (°F) and weather (sunny, cloudy, rainy, etc.).
- Describe the intersection, including surrounding buildings (e.g., restaurants, single-family houses, and offices) and roadway characteristics (e.g., traffic signals, median islands, and fast traffic).
- Record the appropriate 15-minute time period in the upper left corner of each sheet.

FOLLOW PEDESTRIAN COUNTING PROCEDURE (See Side 1 of Data Collection Sheet):

- Tally each time a pedestrian crosses each leg of the intersection from either direction.
- Pedestrians should be counted whenever they cross within the crosswalk or when they cross an intersection leg within 50 feet of the intersection.
- Do NOT count pedestrians who do not cross the street (e.g., turn the corner on the sidewalk without crossing the street).
- If the pedestrian is female, mark an “O”; if male, mark an “X”; if unknown, mark a “+”. If the pedestrian volume is so high that it is difficult to count by gender, use standard line tally marks.
- If the pedestrian is using a wheelchair or other assistive device, underline the “O”, “X”, or “+”.
- Count for 2 hours. Use a new sheet for each 15-minute period.
- If the intersection is a “T” intersection with only three legs, you should still count four sides of the intersection. Pedestrians using the “sidewalk side” of the intersection should be counted when they travel along the sidewalk for at least half of the width of the intersection. Label the “sidewalk side” on the intersection diagram.
- Pedestrians include people in wheelchairs, people using canes and other assistive devices, children being carried by their parents, children in strollers, runners, skateboarders, people walking with a bicycle, etc., but do NOT include people riding bicycles, people in cars, etc.

FOLLOW BICYCLIST COUNTING PROCEDURE (See Side 2 of Data Collection Sheet):

- Tally each time a bicyclist approaches from each leg of the intersection and arrives at the intersection (this includes turning left, going straight, or turning right).
- Count bicyclists who may be riding on the wrong side of the street (against traffic).
- Count bicyclists who ride on the sidewalk (i.e., if a bicyclist on the sidewalk turns right without crossing the street, they should still be counted as turning right).
- If the bicyclist is female, mark an “O”; if male, mark an “X”; if unknown, mark a “+”. If the bicycle volume is so high that it is difficult to count by gender, use standard line tally marks.
- If the bicyclist is wearing a helmet, underline the “O”, “X”, or “+”.
- Count for 2 hours. Enter tally marks in a new row after each 15-minute period. Record totals at the bottom of the sheet after the 2 hours are completed.
- Bicyclists include people riding bicycles. They do NOT include people who are walking their bicycles across the intersection.

UNDERSTAND DATA PRIORITY:

If you do not feel you (or you and your fellow data collectors at the intersection) can keep up with all observations at a location, collect the data according to the following priority ranking:

1. Count of Pedestrians
2. Count of Bicyclists
3. Gender
4. Helmet Use
5. Pedestrian Crossing Direction
6. Bicyclist Turning Movement

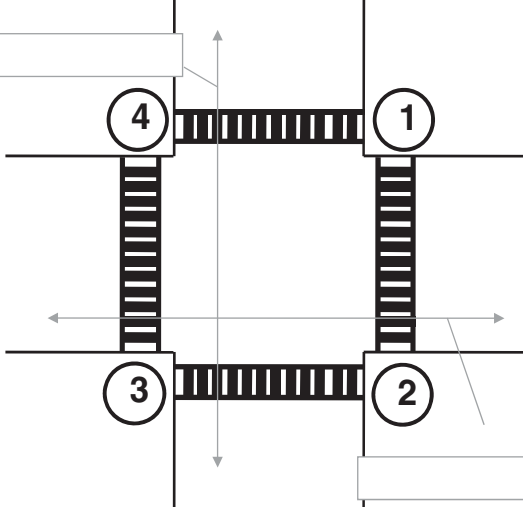
GIVE DATA COLLECTION SHEET TO THE COUNT MANAGER:

- Give your data sheets to the count manager as soon as possible after completing the counts.
- Keep the completed data collection sheet in a safe place until you can turn it in.

15-Minute Period:

4 to 1 OR 1 to 4

4 to 3 OR 3 to 4



2 to 1 OR 1 to 2

3 to 2 OR 2 to 3

Side1: Intersection Pedestrian Count Sheet

Mainline Roadway: _____

Intersecting Roadway: _____

Observer Name (s): _____

Date: _____ Observation Time: (Start) _____ (End) _____

Temp. (°F): _____ Sunny, cloudy, rainy, etc.: _____

Description of Specific Observation Location: _____

Tally each time a pedestrian crosses each leg of the intersection (count all crossings within 50 ft. of the crosswalk). If the pedestrian is female, mark an "O"; if male, mark an "X"; unknown, mark a "+".

15-Minute Period:

A to B OR A to C OR A to D

(Right) ← (Straight) ↓ (Left) →

Side 2: Intersection Bicyclist Count Sheet

Mainline Roadway: _____

Intersecting Roadway: _____

Observer Name(s): _____

Date: _____ Observation Time: (Start) _____ (End) _____

Temp. (°F): _____ Sunny, cloudy, rainy, etc.: _____

Description of Specific Observation Location: _____

B to A OR B to D OR B to C

(Left) ↖ (Straight) ↓ (Right) ↘

D to C OR D to B OR D to A

(Right) ↗ (Straight) ↑ (Left) ↖

C to B OR C to A OR C to D

(Left) ↖ (Straight) ↑ (Right) ↗

Tally each time a bicyclist arrives at the intersection from each leg (include bicyclists on sidewalks). If the bicyclist is female, mark an "O"; if male, mark an "X"; unknown, mark a "+".

Example Pedestrian & Bicycle Counting Information Letter for Field Data Collectors

[INSERT DATE]

The University of Wisconsin-Milwaukee is collecting pedestrian and bicycle counts in the Milwaukee region as part of research to track how local roadway, trail, and sidewalk systems are used by all types of transportation modes. Locations for counts have been selected by Dr. Robert Schneider in coordination with the City of Milwaukee. Student data collectors are being used to count pedestrians and bicyclists in the field.

If you have any questions about the count procedures or how the count data will be used by the University, please feel free to contact [INSERT NAME]. You can reach [FIRST NAME] by email at [E-MAIL ADDRESS] or by phone at [PHONE NUMBER].

Thank you.

Count Protocol Used for NCHRP Project 07-19

About This Count Protocol

These instructions reproduce the instructions given to the project staff who developed the project's ground-truth counts by performing manual counts from video. They are intended to provide a template for others who may wish to perform similar types of counts. In these instructions, "I" refers to the data collection supervisor and "you" refers to the staff performing the counts.

Introduction

This booklet will serve as a guide for Research Assistants working on NCHRP 07-19: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection. According to the NCHRP website, "the objective of this research is to assess existing, new, and innovative technologies and methods and provide guidance for transportation practitioners on how to best collect pedestrian and bicycle volume data. The assessment should consider, among other factors, feasibility, availability, quality, reliability, cost, and compatibility. The guidance should include methods to (a) efficiently mine and manage existing data sources; (b) acquire and use data from new and innovative technologies; and (c) summarize and disseminate pedestrian and bicycle volume data for site-specific, local, and system wide needs assessments, project development, and safety management."

The bulk of the research entails installing automated bicycle and pedestrian counting devices in the field and evaluating the accuracy of these technologies under a variety of conditions. We are installing counters at 13 sites spread across Davis (CA), San Francisco (CA), Portland (OR), Minneapolis (MN), and Washington (DC)/Arlington (VA). Additionally, we will use some pre-existing counters located in Montreal (QC, CAN). The accuracy evaluation involves recording video footage of the installation sites on a short-term basis and selecting 15-minute intervals of the video to conduct manual counts of bicyclists and pedestrians. These manual counts will then be compared to the automated counts gathered by our equipment in the field.

This is where you come in! Performing manual counts of bicyclists and pedestrians is a vital component of this research, and will enable us to determine how well the equipment is working. If you have any questions on any items in this process, please do not hesitate to ask. It will be far better to work out any issues as they arise than to try and troubleshoot in hindsight.

Key Points

1. Thank you for your help! Your work on this project will help to advance the state of the art of bicycle and pedestrian data collection, which in turn has great implications for roadway safety analysis, project prioritization, and bicycle/pedestrian planning in general.
2. **Accuracy is of the utmost importance.** Please take your time and try not to stress. It's completely normal to make occasional mistakes, get stressed out, get sleepy, etc. If you feel any of these things happening, take a short break, go drink some coffee, do some push-ups, whatever you need to stay alert.
3. Please do not work on this for more than 3 hours at a time. If you would like to work for more than 3 hours in a day, schedule it around your other obligations or take a break in the middle for at least 30 minutes. Do some homework, go get something to eat, do whatever you would like to do other than count bicyclists and pedestrians.
4. You will undoubtedly find situations where you have to make a judgment call as to how to count a particular event. I've done my best to write everything out very clearly in this guidebook, but you never know exactly what you're going to find. Whenever you run into a gray area, make your best guess, and jot down a note of what the situation was, when it occurred, and in which video file. Either send me an email or hold onto it for our weekly meeting so we can decide on an "official ruling." However, it's important to not get bogged down with these details.
5. Before performing any official counts, please read this guidebook at least twice. We will also do an in-person training. This will give you an opportunity to perform practice counts and will allow us to perform a test for inter-rater reliability (i.e., how accurate are your counts relative to the counts recorded by another student?).
6. Please follow all directions in the guide closely—I know there are a lot, but the more consistent that we can be, the stronger our results will be.
7. I will print out a copy of this guide for each RA, as well as a couple to keep in the office. Keep a copy handy when you're working in case you need to look anything up.

How to Count Bicycles and Pedestrians

What Counts in Each Category

The first thing to consider is how to classify any events that occur. Generally, you will record a count every single time a pedestrian or bicyclist passes through the detection zone (explained below) of each piece of equipment. There is a certain degree of nuance associated with what qualifies as a "pedestrian" and what qualifies as a "bicyclist." Below are lists of particular cases and where they fit within the schema of pedestrians/bicyclists for the purposes of this project.

Pedestrians

- Pedestrians
- Pedestrians walking dogs (count as one pedestrian, but write this down in the notes field any time you see it)
- People walking with walkers
- Pedestrian carrying a child in arms or wheeling a baby in a stroller (count as a single pedestrian but write this down in the notes field any time you see it)
- People rollerblading or skateboarding
- People in wheelchairs
- People riding on scooters (e.g. razor scooters—also, make a note of this in the notes field)

Bicyclists

- People riding bicycles
- Pedestrian walking a bicycle (according to the law, a person walking a bicycle is typically characterized as a pedestrian, but we are interested in how well the counting devices detect bicycles, so this should be counted as one bicycle)
- Children riding bicycles or tricycles
- People on Segways (write this down in the notes any time you see it)

Special Case

- People riding a tandem bicycle (record this as one bicycle count for an inductive loop, piezo-electric sensor, or pneumatic tube; record this as two people for an infrared or radio beam counter; write this down in the notes field any time you see it)
- Bicycles with trailers (record this as one bicycle for an inductive loop, two bicycles for piezo-electric sensor or pneumatic tube, and as however many people go by for an infrared or radio beam counter; write this down in the notes field any time you see it)
- Anybody loitering in the detection zone (Make a note of this—this type of behavior can give false counts. Record as a single count, and note roughly how long people loitered in total for the 15 minutes)

Detection Zones (by location)

In this project, we are testing the following detector/counter types: passive infrared, radio beam, pneumatic tubes, inductive loops, piezoelectric sensors, as well as combinations of these devices. For the purposes of performing manual counts, however, these can be thought of as either being screenline detection zones (i.e., when a pedestrian or bicyclist crosses an imaginary line) or areal detection zones (i.e., when a pedestrian or bicyclist travels through any part of an area). Passive infrared is an example of a screenline—these devices work by detecting body heat in front of them, within a fairly constrained band of space. A count is recorded any time a person crosses this “screenline.” Inductive loops, on the other hand, have an areal detection zone. These devices are installed in or on top of the pavement, and detect the metal in bicycles passing above them. Hence, a count is recorded any time a bicycle passes within the area defined by the bounds of the loop (or maybe slightly more or less).

To help with understanding what should be considered a count, a summary of the equipment types being tested and how they operate is provided in Table C-1.

Each count site’s video frame has been divided into numbered zones. The coded numbers for each zone correspond with specific data fields where you should enter the individual counts. This is done to determine whether people counted in the video are within the specified detection zones for each piece of counting equipment. Images depicting these numbered zones have been prepared and are provided later in this booklet. Keep these on hand for reference while performing counts in case of uncertainty with whether or not a count should be recorded.

Table C-1. Equipment types tested in NCHRP 07-19.

Technology	Bikes/Peds	How it works	Detection Zone
Inductive Loops	Bikes	Detects metal in the detection zone	Area above loop
Passive Infrared	Both	Detects body heat	Screenline
Radio Beam	Both	Radio beam between transponder and receiver records a count when broken	Screenline
Pneumatic Tubes	Bikes	Rubber tubes record counts when compressed	Screenline
Piezoelectric Sensor	Bikes	Strips on ground record counts when deformed by bikes passing over	Screenline

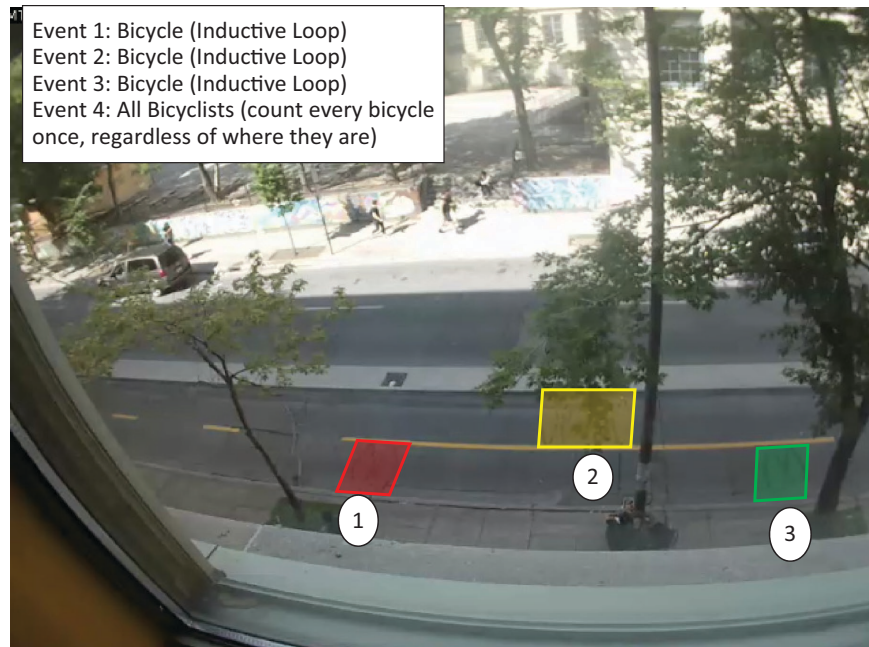


Figure C-1. Montreal University video zone.

At the site in Montreal shown in Figure C-1, we have three numbered detection zones in a cycletrack. Any time a bicyclist passes through any part of detection zone 1 (the red zone), they should be counted under “Initial Event 1.” The “Initial Event” field numbers are indicated in the box in the upper left-hand corner. For example, if the same bicyclist rode through Box 1 and Box 3, then that bicyclist would be counted under Event 1 and Event 3.

We will now get into the more technical aspects of the counting process.

Key Software and Files

The following are the key pieces of software/files that you will be using for this project, and where you can find them on the SafeTREC Network.

- **KeyCounter**
(W:\Grants\G2012_NCHRP_DataCollection\Task5_DataCollection\KeyCounter)—This software counts the number of times you press whatever set of keys you tell it to watch. Copy this over to your local hard drive. KeyCounter can be downloaded from <http://skwire.dcmembers.com/wb/pages/software/keycounter.php>
- **VLC Media Player**
(W:\Grants\G2012_NCHRP_DataCollection\Task5_DataCollection\VideoLAN\VLC)—This is a media player that includes speedup/slowdown options, as well as it works well with the video data formats that we’re receiving. Copy this to your local hard drive as well. Alternatively, VLC Media Player can be downloaded from <http://www.videolan.org/vlc/index.html>
- **Count Database**
(W:\Grants\G2012_NCHRP_DataCollection\Task5_DataCollection\NCHRP0719Count Database.accdb)—This database is where all data pertaining to the study will be stored. This includes manual counts (your input), automated counts, weather data, and site information.
- **External Hard Drives**—These contain all of the video files. They are kept in the SafeTREC office—ask if you don’t know where to find them.

Selecting Video

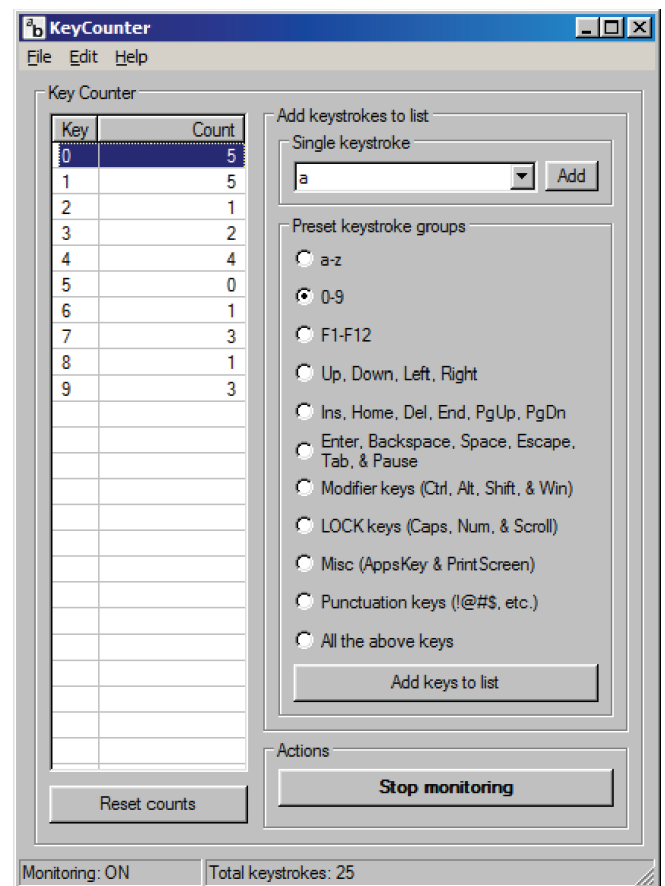
All of the video data will arrive to SafeTREC on DVDs shipped from project team members or contractors. Video that needs to be reduced will be stored on the external hard drives. Each external drive has a folder called “NCHRP0719Videos” that contains all of the video files. At the top of this folder is also an Excel file detailing what video clips are on the drive. Video is stored in .vob format, with videos sorted by site/time period. They are grouped into 6 hour blocks. A list of video segments to be reduced will be kept in the file W:\Grants\G2012_NCHRP_DataCollection\Task5_DataCollection\ManualCounts\VideoList.xlsx.

Should you need them for any purpose, the original DVDs are stored on the bookcase in the SafeTREC Office Room #107.

Performing Counts

And now, for the fun part: how to conduct counts.

- First, plug in the external hard drive (to the wall and a USB port on your computer). Open up the external hard drive in Windows Explorer and navigate to the folder of videos.
- Navigate to the folder corresponding to the time period that you are planning to conduct counts on. Within each folder, the video files are broken up into smaller chunks (1-2 hours), labeled along the lines of “VIDEO_TS-1-01.vob.” Take a guess as to which one your time period should be in (based on location within the 6 hour period) and open up the file. If you just double click on it, Windows might have trouble figuring out what to use—direct it to the VLC media player software. If you got the video wrong, select one before or after to find the correct time period. Navigate using the timestamp at the bottom of the video frame.
- Open your printed count protocol manual (this book!) to the Appendix Page corresponding to the site that you are analyzing.
- Open up KeyCounter as well. Under “Preset keystroke groups,” select “0-9” and press “Add keys to list.” If you click “Start monitoring,” the program will record how many times you press the numeric buttons (even if KeyCounter isn’t your active window). If you want to temporarily stop it from counting (like if you go to a web browser or a word document), hit “Stop monitoring.” This will keep your counts active without recording more (until you press “start monitoring” again). “Reset counts” will delete all counts.
- Play the video. Whenever a pedestrian or bicyclist crosses a screenline or passes through a detection area, press the corresponding number button. **Be very careful to *only* press the numbered keys when you are recording a count.**
- VLC media player has hotkey options to control the video—it is highly recommended to use these for pausing, speeding up, or slowing down videos. The hotkey options can be customized in the VLC media player by clicking Tools ≥ Preferences. Navigate to the “Hotkeys” tab at the bottom of the left-hand panel. You can use whatever keys you would like, although don’t



use any number keys as you should only be pressing these to record counts. The default settings for keys you may want include:

Play/Pause	Space
Faster (fine)]
Slower (fine)	[
Normal rate	=
Very short backwards jump	Shift+Left
Short backwards jump	Alt+Left

- As you perform the count, note the following information. These will be recorded as binary (yes/no) characteristics, so give a general assessment across the count period:
 - **Cloudy:** It is completely overcast (not partly cloudy)
 - **Foggy:** There is visible fog between the camera and background objects
 - **Raining:** Enough rain drops can be seen falling to make the pavement wet
 - **Wet Pavement:** The pavement is wet
 - **Snowing:** Frozen precipitation can be seen falling from the sky
 - **Snow on the Pavement:** Frozen precipitation has collected on the pavement
 - **Shade:** The detection zone(s) have a shadow falling across them
 - **Daylight:** It is fully daylight
 - **Darkness:** It is fully dark
- Count for the specified time period, being careful to count for exactly 15 minutes. Pay attention to the timestamp at the top of the video to get the number of seconds correct (and the timestamp at the bottom to ensure that you have the right hour and minute!).
- After you have finished the 15 minute period, switch to the KeyCounter window and note the number of key strokes for each numbered key. Press “Stop Monitoring” so you don’t accidentally alter your counts when entering data into the database. Move to the “Data Entry” step.

What to Do if You’re Having Trouble Counting

There might be situations where you have trouble counting everything going on. This is likely to occur when there are many detection zones (3+), mixing of modes, and/or high volumes. Do not despair, there are some good tricks to try and smooth out the process. When you get to a period where this seems to be the case, try the following:

- Focus on 1-3 detection zones at a time, which can be chosen however you would like to make things easier to count. Note the timestamp when you start using this technique (to avoid miscounting). Run through the difficult period counting on one set of detection zones (again note the ending timestamp), then move the video back to the point where you started and run through again, this time counting the other detection zones. The PATH software will save all of your counts with their timestamps, so the counts will get coded approximately the same as if they had been conducted simultaneously.
- Slow down the video (I find $\times \frac{1}{8}$ time is best).
- Scroll through the video with the slider bar under the playback pane—this is particularly helpful if you’re having trouble seeing the path taken by a bicyclist.

What to Do if a Count Period Runs Across Two or More Video Files

If a specified count period runs across the end of a single video file, this will be noted in the Video List. This is not likely to occur, because videos will generally be merged to encompass entire count intervals. However, if a count period spans multiple video clips, follow this procedure:

- Ensure that the timestamps in the video pane match up for the two video files
- Perform the count across the first video file

- Process the data output and make a note of the count results
- Perform counts on the second video clip up to the end of the count interval
- Add the count results for the two time periods together

Data Entry

Once you have calculated values for your 15-minute block of video, open up the count database. Open the form “ManualCountsDataEntry”—this will be your primary interaction with the count database. Figure C-2 is a screenshot of this form.

For every 15-minute interval that you reduce, fill out this form. This will create a record in the database for each interval. A description of each field follows:

- **Date:** Date the video was taken.
- **Time:** Beginning time of the 15 minutes being reduced.
- **Video ID:** The ID number given to the video, as found in the Video List document.
- **Student Name:** Your name. This is a dropdown menu with all of the Student RAs’ names in it—just find yours.
- **Count Site:** This is another dropdown menu, with an option for each of the count sites. These are all in coded forms, which are summarized later in this document.

Manual Count Data Entry

Date: 1/24/2012 Video ID: 221

Time: 2:00:00 PM Student Name: FrankTEST

Beginning Timestamp: 21.00 Count Site: DCA_FourMile

☒ Cloudy ☐ Raining ☒ Snowing ☐ Shade ☐ Darkness
☐ Foggy ☒ WetPavement ☐ SnowPavement ☒ Daylight

Count for Event 1: 30320 Count for Event 4:

Count for Event 2: 11 Count for Event 5:

Count for Event 3:

Notes: Clearly there weren't actually 30320 pedestrians in the detection zone in a 15 minute time period.

Figure C-2. Manual count data entry form.

Each of the following are checkboxes—check them if the given criterion is satisfied for the count interval, based on the instructions outlined previously in this document.

- Cloudy
- Foggy
- Raining
- Wet Pavement
- Snowing
- Snow on the Pavement
- Shade
- Daylight
- Darkness
- **Count for Event #:** These should be reported exactly as they are in the KeyCounter pane.
- **Notes:** Any notes about the data reduction period. For example, anything that you weren't sure of, odd occurrences, or reasons we might want to look more closely at this period.

After you have entered all of this data, save the form (Ctrl-s). If you have more count intervals to enter, use the record navigator at the bottom of the pane.



The rightmost button (“New (blank) record”) is the one to click. Otherwise, you can close the database. Finally, don't forget to check off the video as “complete” in the list of videos, to avoid duplicating efforts. Now you can start all over with a new video, or else go do something else.

Count Site Overviews & Event Definitions

Berkeley



Davis (Loyola)



Davis (Sycamore)



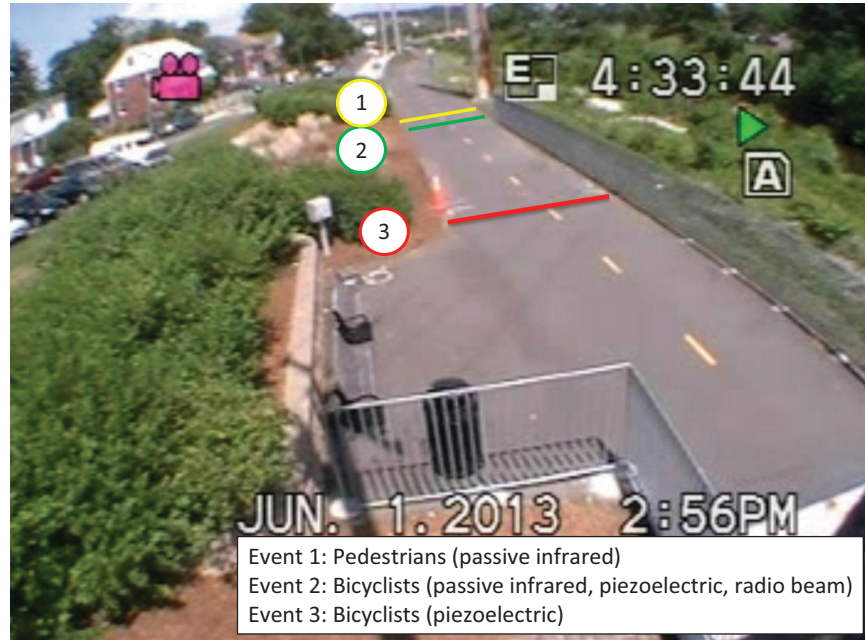
Arlington (Clarendon)



Arlington (Key Bridge)



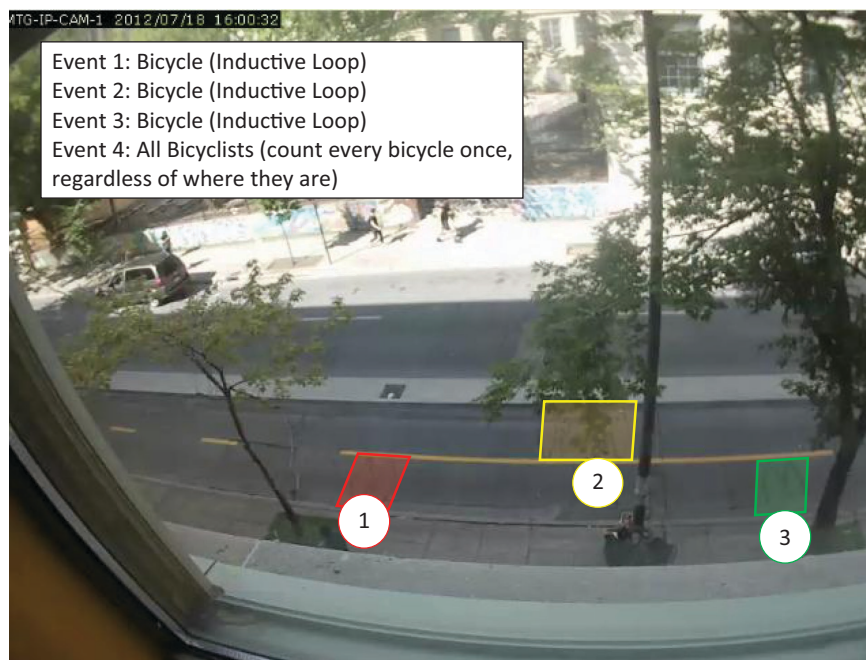
Arlington (Four Mile Run)



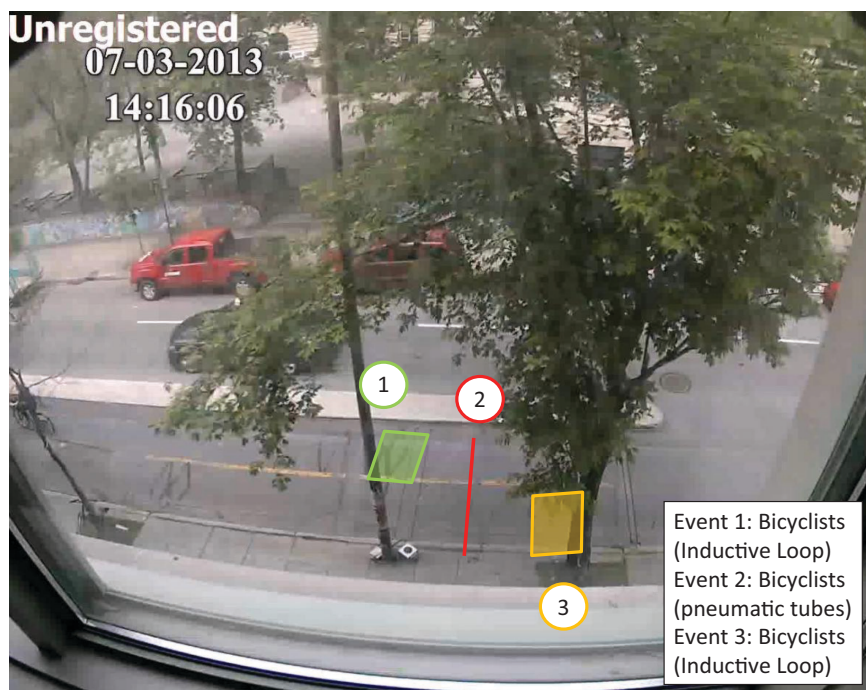
Washington, DC (L Street)



Montreal (University, for video from 07/2012)



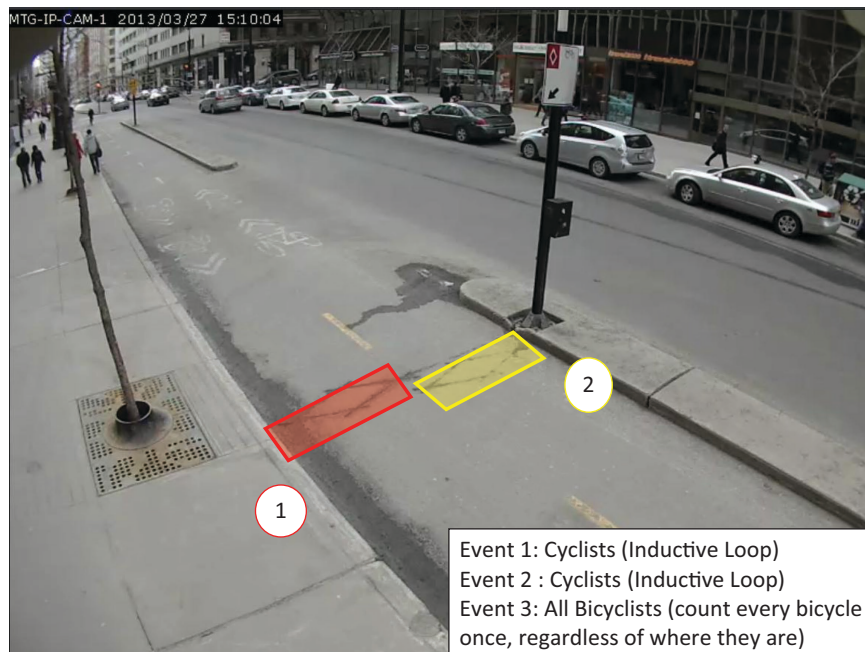
Montreal (University, for video from 07/2013)



Montreal (Milton)



Montreal (Maison)



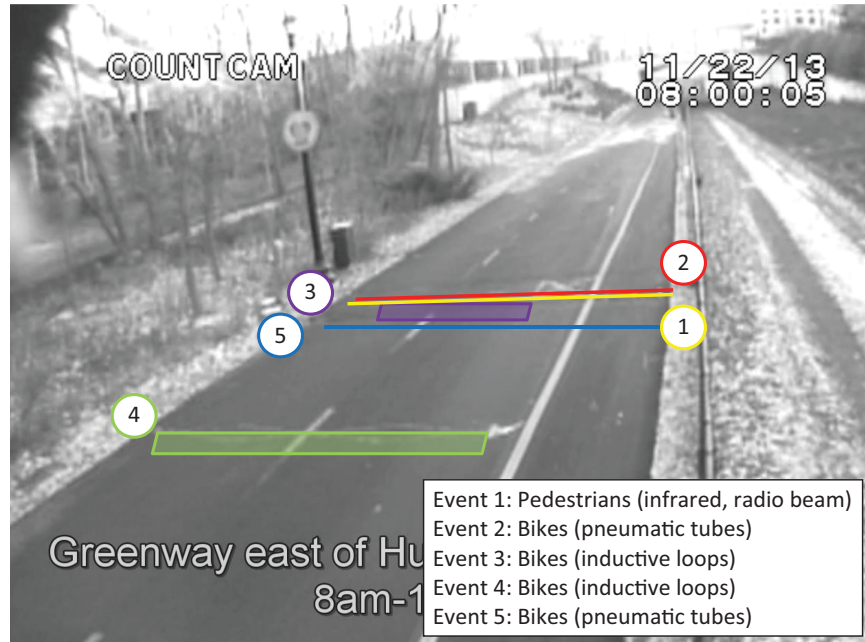
Montreal (Parc)



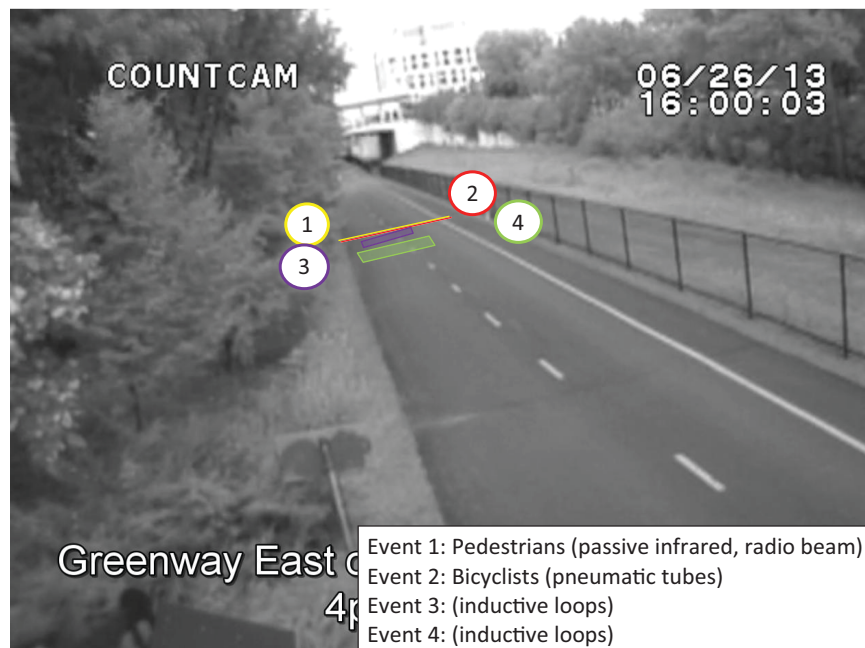
Minneapolis (15th Street)



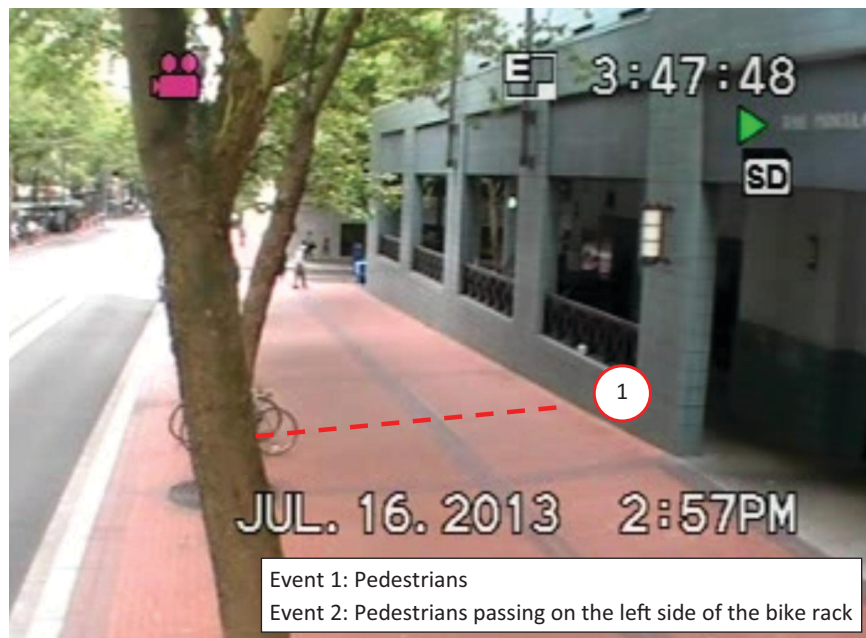
Minneapolis (Midtown, video from 11/2013)



Minneapolis (Midtown, video from 06/2013)



Portland (5th Avenue)



Portland (Eastbank Esplanade)



San Francisco (Fell Street)



Codes for Database

SiteID	Location Name	City
Berk	Bridge near VLSB	Berkeley
Dav_Loyola	Loyola Path (West of Pole Line Road)	Davis
Dav_Villanova	Villanova Path (West of Sycamore Street)	Davis
DCA_L	L Street (exact location TBD)	Washington
DCA_Clarendon	Clarendon Boulevard (E of Danville Street)	Arlington Co
DCA_FourMile	Four Mile Run Trail (E of I-395 Underpass)	Arlington Co
DCA_Key	South End of Key Bridge (Lee Highway and Lynn Street)	Arlington Co
Min_15th	15th Avenue SE (N of University Avenue SE)	Minneapolis
Min_Midtown	Midtown Greenway (E of Humboldt)	Minneapolis
Mon_Parc	Avenue du Parc (N of Avenue des Pins)	Montreal
Mon_University	Rue University (E of Milton)	Montreal
Mon_Maison	Boulevard de Maisonneuve	Montreal
Mon_Rachel	Rue Rachel	Montreal
Mon_Milton	Milton Street	Montreal
PDX_5th	5th/6th Avenue Transit Mall	Portland
PDX_Eastbank	Eastbank Esplanade	Portland
SF_Fell	Fell Street (W of Scott Street)	San Francisco



APPENDIX D

Day-of-Year Factoring Approach

A day-of-year expansion factor can be applied in lieu of the traditional combination of day-of-week and month-of-year factors. This approach has been shown to substantially outperform the traditional approach in both bicycle-only monitoring situations and in mixed bicycle and pedestrian situations (Hankey et al. 2014, Nosal et al. 2014). A separate adjustment factor is generated for every day of the year for each factor group of interest. Short-term counts conducted within a given factor group can then be expanded to estimate AABT or AAPT.

Expansions based on just 1 day of short-term count data were found to have a mean error of 14 to 21% with the day-of-year approach, compared to 24 to 40% with the traditional approach, as shown in Figure D-1. This range of error rates can likely be attributed to differences in the data collection sites—the low end comes from sites very near to each other, whereas the high end comes from sites dispersed over a larger area. As the number of days of data used for the short-term count is increased, the error rate further decreases, finally approaching a value of about 12% after 7 days. The traditional approach approaches a similar error rate, but only after 14 to 21 days of data collection. *Whenever possible, short-term counts should be taken for 1-week periods to ensure accurate long-term volume estimates.* (Hankey et al. 2014, Nosal et al. 2014).

The day-of-year approach has one substantial advantage over the traditional factoring approach when it comes to weather. In the traditional approach, weather is not taken into account unless the count estimate is multiplied by an additional “weather factor.” However, assuming that weather patterns are fairly consistent between the continuous count site and the short-term count site, weather effects are implicitly accounted for with the day-of-year patterns because every day of short-term data is matched to continuous count data from the exact same day.

To implement the day-of-year factoring method, a full year’s worth of continuous count data has to exist for at least one site in each factor group within the count study area, and this full year must include the days on which short-term counts were conducted. As stated before, at least 1 week of short-term counts should be available if possible, but as little as 1 day’s worth of data can be used. Calculate the proportion of the total annual traffic that each day of the year represents—this is the day-of-year factor:

$$DOY_{k,i} = \frac{VOL_{k,i}}{\sum_{j=1}^{365} VOL_{k,j}}$$

where $VOL_{k,i}$ is the volume at site k on day i .

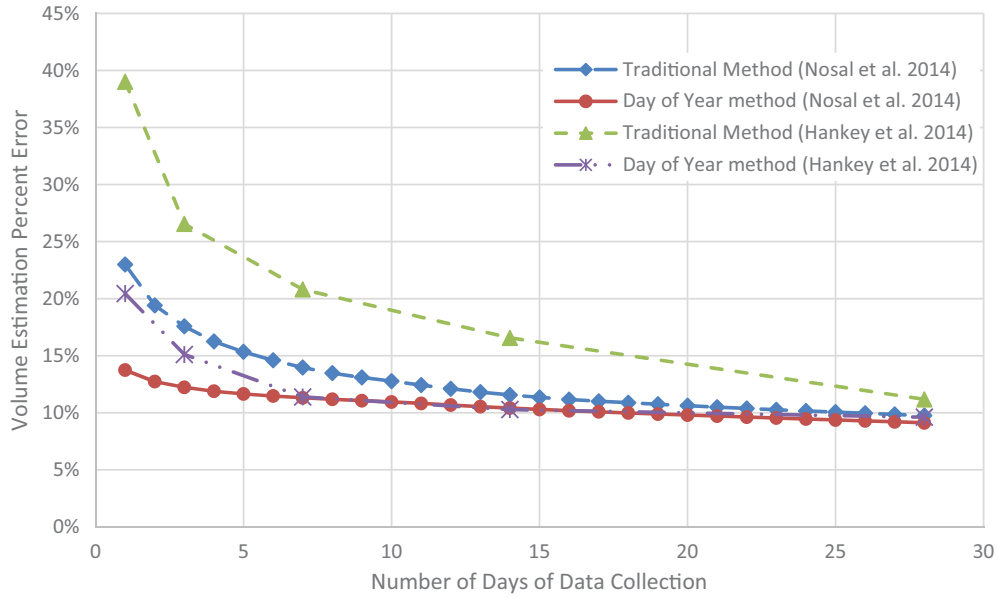


Figure D-1. Plot of AADT prediction by count duration and count expansion approach.

To apply these factors at a short-term count site l , where data has been collected for m full days, use the following (where SDT is the Short-Duration Total, VOL is the volume for a given site and day, and AADT is the annual average daily traffic):

$$SDT_{l,m} = \sum_{d=1}^m VOL_{l,d}$$

$$\widehat{AADT}_{l,m} = \frac{SDT_{l,m}}{\sum_d DOY_{l,d}}$$

If multiple continuous count sites are available for a specific factor group within the region, some discretion is needed in estimating the day-of-year factors. One approach is to average the factors from each of the sites in the group. Alternatively, the geographically closest continuous count site in the factor group could be used. These methods have not been rigorously tested, so local experimentation is encouraged.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation