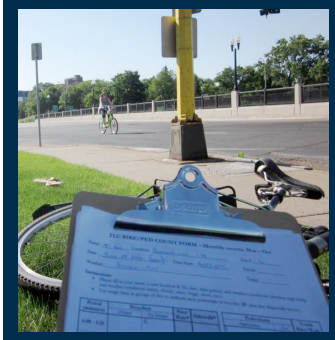
BICYCLE AND PEDESTRIAN DATA COLLECTION MANUAL

DEPARTMENT OF TRANSPORTATION



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The Minnesota Department of Transportation (MnDOT) launched the Minnesota Bicycle and Pedestrian Counting Initiative in 2011, a statewide, collaborative effort to encourage and support non-motorized traffic monitoring. One of the objectives of the Initiative was to provide guidance related to monitoring bicycle and pedestrian traffic. This manual is an introductory guide nonmotorized traffic monitoring. The manual describes general traffic monitoring principles; bicycle and pedestrian data collection sensors; how to perform counts; data management and analysis; and the next steps for bicycle and pedestrian traffic monitoring in Minnesota. The manual also includes several case studies that illustrate how bicycle and pedestrian traffic data can be used to support transportation planning and engineering.

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CHAPTER 1: INTRODUCTION

The Minnesota Department of Transportation's (MnDOT) bicycle and pedestrian data collection program is a collaborative program with state and local agencies to collect bicycle and pedestrian traffic counts throughout the State of Minnesota. The general goal is to inform transportation planning, engineering, and management. The data are being collected following the same principles and using approaches similar to those used in vehicular traffic data collection. State and local agencies, engineering consultants, and others can use these data for many purposes, including pre-post analysis of projects, performance management, evaluation of polices such as Complete Streets, and safety and crash analyses. The bicycle and pedestrian data collection program focuses on collection of traffic volume data, not turning movement data This document supports ongoing traffic monitoring programs and will be updated periodically as traffic analysts gain experience, new technologies become available, and new methods for analyzing and sharing data are developed.

This document supplements the 2013 Federal Highway Administration (FHWA) Traffic Monitoring Guide (TMG) and the 2014 National Cooperative Highway Research Program (NCHRP) Report 797 Guidebook on Pedestrian and Bicycle Data Collection. These documents present state-of-the-art practices and provide guidance on monitoring alternative modes of transportation. The FHWA established the first set of guidelines and practices for bicycle and pedestrian data collection in the 2013 TMG. Minnesota is putting these new guidelines to use in this manual.

Figure 1: Morning Commuters on the Midtown Greenway

1.1 PURPOSES

Collection of bicycle and pedestrian data is in its infancy in Minnesota and throughout the United States. However there is use for this data and much to be learned about these modes of transportation. Potential uses of bicycle and pedestrian count data include:

- Determine baseline volumes of bicycle and pedestrian activity
- Track changes in bicycle and pedestrian activity levels by time of day, day of week, season, and under various weather conditions
- Track bicycle and pedestrian related performance measures
- Inform the public about bicycle and pedestrian activity and trends
- Prioritize bicycle and pedestrian projects
- Conduct risk or exposure analysis
- Inform Road Safety Audits
- Inform Intersection Control Evaluations

- Evaluate the effects of new infrastructure on pedestrian and bicycle activity
- Measure facility usage
- Model transportation networks and estimate annual volumes
- Identify variations in activity based on location or facility type and calculate context-specific expansion factors
- Develop models to predict future bicycle and pedestrian volumes at different locations

MnDOT is implementing statewide bicycle and pedestrian monitoring throughout Minnesota. The approach is based on the bicycle and pedestrian counting methods in this manual and involves establishment of at least 25 permanent, continuous monitoring stations, including at least two stations in each of MnDOT's eight administrative districts. MnDOT also is collaborating with agencies to conduct and archive results from a larger number of short duration monitoring locations.

The purposes of the permanent monitoring stations are to track trends in traffic over time, to provide insight into exposure to risk for safety analyses, identify patterns in traffic that can be used to interpret and extrapolate short duration counts into annual traffic estimates, and develop performance indicators to track progress relative to MnDOT goals and objectives.

The specific purposes of short duration monitoring are to document variations in traffic volumes on different types of roads, to provide broad geographic coverage across the state, and assist with evaluation of transportation investments and innovative safety treatments.

MnDOT Central Office is managing the deployment and data collection from the permanent continuous monitoring installations. Local agencies and MnDOT District offices are conducting and managing short duration counts with technical assistance from MnDOT Central Office.

1.2 SCOPE

This manual describes methods by which bicycle and pedestrian data are collected and recorded. It provides information on count types, site selection, and basic calculation and analytic techniques.

The following subjects are addressed for several types of data collection technologies that have been used in Minnesota:

- Site Design
- System Installation
- System Calibration

- Data Collection
- Maintenance and Troubleshooting

None of these subjects is meant to be covered exhaustively, rather this manual provides an overview and a list of references that may be consulted for more in depth information. Additions and changes may be made to this manual as new equipment and methods for bicycle and pedestrian data collection become available.

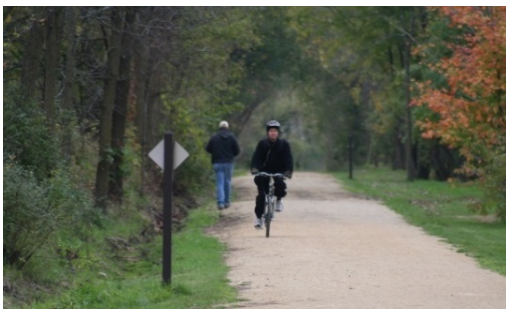


Figure 2: Rural Mixed-use Path

CHAPTER 2: GLOSSARY & ACRONYMS

2.1 GLOSSARY

Adjustment factor – Adjustment factors are used to estimate AADT from short duration counts. These actors are developed from representative data collected at continuous count stations (TMG 2013). The TMG includes an example using mixed-mode data from train monitoring in Minneapolis. This example uses day-of-week and month-of-year factors that are analogous to factors used to estimate AADT from short-duration counts for motorized traffic. Expansion factors and extrapolation factors are types of adjustment factors. This manual also illustrates the use of day-of-year factors to extrapolate short-duration counts. Day-of-year factoring has been shown to be more accurate than standard approaches to factors for non-motorized traffic (Hankey et al. 2014; Nosal et al., 2014; El Esawey 2014, 2016).

Automated count – collection of traffic data with automatic equipment which continuously records non-motorized traffic flow. Automated methods of data collection include both permanent and portable counters.

Average bicycle traffic volume – the amount of bicycle traffic passing a given point on an average daily basis computed over 180 days during the months of April through September. MINN STAT. 169.011 (2014). Although this definition remain in Minnesota statute, analysts increasing are using estimates of annual average daily traffic (AADT) analogous to meaures used for motorized traffic.

Annual Average Daily Traffic – the total volume of traffic on a given roadway for a year divided by 365 days. Many agencies use the terms ADT and AADT to define non-motorized volumes. When used for bicycle and pedestrian traffic, these terms often are reported as annual average daily bicyclists (AADB) and annual average daily pedestrians (AADP).

Average Daily Traffic – the total volume of traffic during a specified but arbitrary time period given in a whole day (24 hours), greater than one day, but less than one year divided by the number of days in the time period; abbreviated ADT. MINN STAT. 169.011 (2014).

Bicycle – (a) a device propelled by human power upon which a person or persons may ride, having two tandem wheels either of which is over 16 inches in diameter, and including any device generally recognized as a bicycle though equipped with two front or rear wheels. MINN STAT. 169.011 (2014).

(b) All pedal powered vehicles: including unicycles, tandem bicycles, recumbent bicycles, three-wheelers, tag-alongs, trailers, and pedicab. Each vehicle counts as one count (MnDOT Manual Count Program, 2014).

Bicycle lane – a portion of the roadway or shoulder designed for exclusive or preferential use by persons using bicycles. Bicycle lanes are to be distinguished from the portion of the roadway or shoulder used for motor vehicle traffic by physical barrier, striping, marking, or other similar device. MINN STAT. 169.011 (2014).

Bicycle path – a bicycle facility designed for exclusive or preferential use by persons using bicycles and constructed or developed separately from the roadway or shoulder. MINN STAT. 169.011 (2014).

Bicycle route – a roadway or shoulder signed to encourage bicycle use. MINN STAT. 169.011 (2014).

Bikeway – a bicycle lane, bicycle path, or bicycle route, regardless of whether it is designed for the exclusive use of bicycles or is to be shared with other transportation modes. MINN STAT. 169.011 (2014).

Commute-mixed traffic – a facility that has similar volumes of traffic on weekdays and weekends with morning and evening peaks that do not indicate typical commuting.

Commuter traffic – a facility that has morning and evening peaks Monday through Friday and typically has higher use on weekdays than weekends.

Complete Streets – roadway planning tool used to help maximize the use of public roadways and right-of-way in order to provide a comprehensive and connected multimodal transportation system. This includes development of fully integrated transportation networks that accommodate bicyclists and pedestrians.

Continuous – count sites equipped with permanently installed automated counting sensor that collects data 24 hours a day, 7 days a week, 365 days a year. Ideally these count locations collect data every day, but due to equipment failure or other unforeseen impacts such as weather, there can be gaps in the data.

Cordon – vehicle and person surveys that provide time series data of traffic flow across a given set of screen lines (Source: adapted from the website of the New York Department of transportation Cordon Count Program)

Coverage counts – short duration counts that cover many different areas in a region. This data may often supplement continuous traffic counts.

Index locations – index locations are permanent continuous count locations that are selected to be illustrative of the counts statewide. These sites are not fully representative or inclusive of every roadway nor are they a statistically random sample. MnDOT is using this approach for establishing statewide trends.

Intersection counts – counts conducted where non-motorized facilities cross another facility of interest.

Manual count – method of counting by observation of number, classification and direction of travel. This counting may be performed in person at the site or by analyzing video. Data are typically tracked using a tally sheet or an electronic counting board.

Mixed-mode Traffic – Undifferentiated non-motorized traffic (i.e., undifferentiated bicycle and pedestrian traffic). Automated sensors such as active or passive infrared sensors that do not distinguish between bicyclists and pedestrian produce estimates of mixed-mode traffic.

Multipurpose-mixed – a facility that experiences higher volumes on weekends, although weekday traffic patterns show typical commuting peaks.

Multipurpose traffic – a facility with traffic volumes that peak during the afternoon and evening hours and have similar weekday and weekend traffic patterns with a slightly higher usage on weekends.

Peak volume – refers to when the highest traffic volumes are generated.

Pedestrian – (a) any person afoot or assisted. MINN STAT. 169.011 (2014).

(b) Any person afoot or assisted including walkers, joggers, skaters, Segways, wheelchairs, strollers, crutches, scooters, children being carried, and person walking a bicycle. MN state statutes definition of pedestrian does not classify skaters (inline, traditional, board) as pedestrians, but they are placed in this category for the purpose of this manual (MnDOT Manual Count Program, 2014).

Project counts – these counts are taken before and after construction projects to support planning and forecasting efforts and/or to determine the effectiveness of new infrastructure.

Screen line - imaginary line typically drawn along features such as rivers or railways at mid-block. Since these areas have a minimum number of crossing points it is more manageable to count traffic going from one side to the other. Although these are spot counts they are often applied to the full segment length to calculate pedestrian – miles traveled and bicycle – miles traveled (TMG, 2013).

Shared use path - a multi-use trail or other path, physically separated from motorized vehicular traffic by an open space or barrier, either within a highway right-of-way or within an independent right-of-way, and usable for transportation or other purposes.

Short duration – count sites that are either manual or automated counting locations that collect data for a specific period of time. Count durations can be anywhere from several hours to several weeks.

Stanchion – a sturdy upright fixture that provides support for some other object.

Traffic – pedestrians, ridden or headed animals, vehicles, streetcars, and other conveyances, either singly or together for purposes of travel. MINN STAT. 169.011 (2014).

Trail – see shared use path.

Vehicle – every device in, upon, or by which any person or property is or may be transported or drawn upon excepting devices used exclusively by stationary rails or tracks. MINN STAT. 169.011 (2014).

2.2 ACRONYMS

ADT – Average Daily Traffic

AADT – Annual Average Daily Traffic (Motorized)

AADNT – Annual Average Daily Non-motorized Traffic

AADB – Annual Average Daily Bicyclists

AADP – Annual Average Daily Pedestrians

FHWA – Federal Highway Administration

MnDOT – Minnesota Department of Transportation

NBPD – National Bicycle and Pedestrian Documentation Project

NCHRP – National Cooperative Highway Research Program

TEM – Traffic Engineering Manual

TMG – Traffic Monitoring Guide

UMN – University of Minnesota

CHAPTER 3: GENERAL PRINCIPLES

3.1 BICYCLE AND PEDESTRIAN DATA COLLECTION INTENDED AUDIENCE

This manual provides guidance and methods for collecting bicycle and pedestrian data in Minnesota. This manual is for MnDOT staff and other transportation professionals, and was created for individuals who range from experienced to those new to bicycle and pedestrian data collection. The following transportation professionals and entities can benefit from the information presented in the manual.

- City Planners and Engineers
- County Planners and Engineers
- State Planners and Engineers
- Public Health Professionals
- Department of Natural Resources
- Parks and Recreation Departments
- Traffic data collection practitioners
- Traffic data collection managers and staff
- Traffic operations practitioners
- Transportation agencies
- Transportation researchers
- Traffic detector vendors

3.2 BICYCLE AND PEDESTRIAN DATA COLLECTION ATTRIBUTES

Bicycle and pedestrian data collection is founded on the principles of motor vehicle traffic data collection. However, there are some key differences, including:

- Non-motorized volumes are more variable than motor vehicle volumes
- Bicycle and pedestrian trips tend to be shorter
- Experience with bicycle and pedestrian counting technology is more limited than motorized vehicle detection technology
- The scale of data collection is typically smaller than for motorized vehicles
- Non-motorized traffic typically has higher use on lower functional class roads and streets as well as shared use paths and pedestrian facilities
- Motorized vehicles tend to be easier to detect than bicycle and pedestrians
- Non-motorized travel is less confined to a fixed lane or path and sometimes makes unpredictable movements
- Bicycles and pedestrians sometimes travel in closely spaced groups which can result in counting errors
- Bicycles and pedestrians travel patterns are affected by weather more than vehicular travel patterns

- Technologies for counting bicyclists and pedestrians are evolving

3.3 TYPES OF DATA COLLECTION

Annual average daily traffic (AADT) is traditionally one of the main parameters for measuring motorized vehicular traffic. Bicycle and pedestrian volume metrics such as average daily traffic (ADT), AADB, AADP and peak volume provide information for traffic pattern modeling and adjustment factor creation. Detailed volume data provides needed information on trails and other facilities to show variations in non-motorized traffic volume based on day, time of day, day of week and time of year. These data are valuable for prioritizing investments to the transportation system.

Determining which method and type of data collection to perform is the first step in facilitating the determination of ADB, AADB and peak volume. The remainder of this section summarizes methods of counting, type of counting and travel patterns associated with bicycle and pedestrian data collection.

Figure 4: Bicycle Crossing Railroad Tracks

3.3.1 Methods for Counting Bicycle and Pedestrian Traffic

Methods for bicycle and pedestrian data collection include manual vs. automated and short duration vs. continuous counting (see the glossary for the definition of terms). Facility type, time of year and reason for collection will assist in determining type of count, length of deployment and which data collection technology is a good fit for the data collection needs.

3.3.2 Types of Counts

The two principal types of bicycle and pedestrian counts are volume counts and turning movement counts. Generally, volume counts are a measure of the number of bicycles or pedestrians that pass a screen line. Volumes can be on trail or street segments, or at intersections. Turning movement counts, record the number of bicycles or pedestrians that turn right, left or continue straight for each approach leg of an intersection. A full count at a four-leg intersection would generate four volume counts (one for each leg) and 12 turning movement counts (three for each leg). This manual focuses on volume counts taken when bicyclists or pedestrians cross screen lines in the location of interest.

The need for bicycle counts, pedestrian counts, or mixed-mode non-motorized counts are determined by the specific data collection need and facility type. Both nationally and in Minnesota, bicycle count programs are more mature, more similar to motor vehicle counts, and have been studied and analyzed more than pedestrian counts. Both the Minnesota Bicycle and Pedestrian State System Plans recommend implementation of traffic monitoring. Bicycle counts are used for a variety of planning and design needs, similar to motorized traffic counts. Pedestrian counts are currently mostly used for warrants for crossings while mixed-mode non-motorized counts are used for trail usage.

3.4 SITE SELECTION

The count purpose will determine where, when and how data collection should be performed. See Section 1.1 for potential data collection purposes. Understanding why the data are being collected determines if short duration counts are sufficient or if continuous counting locations should be considered. Once the when and why have been determined items such as reviewing the facility type and selecting the data collection method can be performed. Defining the type of count location and determining if short duration or continuous counts are warranted is discussed in this section.

Count locations can be assigned to one of five categories. The data collection purpose will drive the selection of location type:

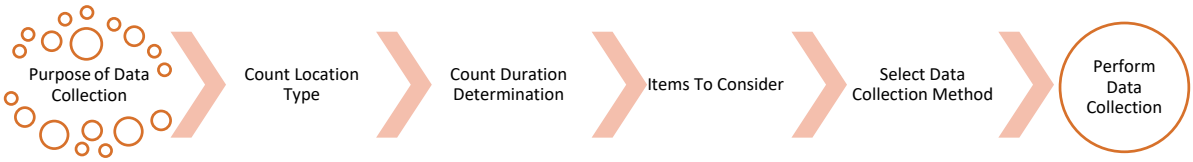
- **Targeted locations.** Targeted sites are associated with particular projects, facility types, or locations with particular characteristics. Target locations can be areas of safety concerns or areas with the highest expected volumes of bicycles and/or pedestrians. Target locations are often selected to support before and after studies. They are appropriate for either short duration or continuous counts.
- **Representative locations.** This approach balances available resources with spatial coverage. Identified sites, in aggregate, are representative of the traffic network as a whole. Representative locations are appropriate for short duration counts.
- **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. Control locations are appropriate for either short duration or continuous counts depending on the data usage.

- **Random locations**. This approach selects sites 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, but is not recommended for choosing count locations.
- **Index locations**. Index locations are illustrative of the counts statewide. These sites are not fully representative or inclusive of every roadway nor are they a statistically random sample. MnDOT is using this approach for establishing statewide trends.

Consider the following for all count locations:

- Facility type: roadway, bike lane, shoulder, protected bike lane, trail, protected trail
- Travel patterns (if known): commuter, commute- mixed, multipurpose, or multipurpose-mixed
- Facility area: urban, suburban, exurban, rural
- Land use: residential, commercial, school, green space
- Safety: of both data collection personnel and/or the data collection equipment
- Other agencies conducting short duration counts may be able to provide input on locations that are a good fit for continuous count site installations
- Exercise caution when working near traffic. Work with local traffic agencies to use traffic control devices if needed
- Avoid areas where people tend to gather such as areas near benches, drinking fountains, pedestrian crosswalk buttons or viewpoints/lookouts
- Observe the movements of bicycles and pedestrians in the area to develop a good understanding of the movements being made in the area before committing to installation

The graphic below illustrates the process to follow to select a count location and data collection plan. Short duration and continuous count location determination is discussed further in the remainder of this section.



3.4.1 Site Selection for Short Duration Counts

Short duration counts can be performed manually onsite, manually using video, or by using portable automated counting devices. In addition, researchers are developing methods for automated processing of video tape to produce bicycle and pedestrian counts, but these methods have not yet been widely deployed as part of ongoing programs run by transportation agencies.

Short duration counts can be performed for a few hours or up to several months. Guidance from research studies recommends that counts be conducted for a minimum of seven days so that weekend as well as weeday traffic patterns are observed. These recommendations assume automated counting.

In some situations, analysts may determine that two hour, peak hour counts or automated counts for different durations (e.g., 48 hours, five days) are sufficient to meet requirements for information.

The 2013 TMG recommends a combination of targeted and representative locations for short duration counts. Locations that meet this criteria include:

- Pedestrian and bicycle activity areas or corridors (downtowns, near schools, parks, etc.)
- Representative locations in urban, suburban, and rural locations
- Key corridors to gauge the impacts of future improvements
- Locations where counts have been conducted historically
- Locations where traffic is funneled to a certain throughway because of geographic constraints such as a bridge crossing a river
- Locations where ongoing counts are being conducted by other agencies through a variety of means, including video recording
- Gaps, pinch points, and locations that are operationally difficult for bicyclists and pedestrians to navigate (potential improvement areas)
- Locations where either bicyclist and/or pedestrian collision numbers are high
- Relatively flat locations where cyclist travel speeds are consistent
- Locations that meet multiple criterion

3.4.2 Site Selection for Continuous Counts

Continuous count sites are locations equipped with an automated counting technology that collects data 24 hours a day, 7 days a week. The following factors should be considered when looking at locations to install continuous count equipment.

- Locations where short duration counts have been conducted historically
- Locations where traffic is funneled to a certain throughway because of geographic constraints such as a bridge crossing a river
- Representative locations in urban, suburban, and rural locations
- Key corridors that can be used to gauge the impacts of future improvements
- Areas of high volume and/or well established bicycle and pedestrian facilities

CHAPTER 4: BICYCLE AND PEDESTRIAN DATA COLLECTION SENSORS

4.1 SENSOR OVERVIEW

Selecting the appropriate counting technology is dependent on factors such as budget, facility type, and duration of count. The chart in Figure 5 is a modified version of Figure 4-1 from the 2013 TMG. This chart helps determine which count technologies are best suited based on duration and facility user.

1. What Are You Counting?

	Technology	Bicyclists Only	Pedestrians Only	Pedestrian & Bicyclists Combined	Pedestrian & Bicyclists Separately	Cost
Permanent	Inductance Loops[1]	●			◐	$$
↑	Magnetometer[2]	○				$-$$
	Pressure Sensor[2]	○	○	○	○	$$
	Microwave Sensor	○	○	○		$-$$
	Seismic Sensor	○	○	○		$$
2. How long?	Video Imaging: Automated	○	○	○	○	$-$$
	Infrared Sensor (Active or Passive)	○	●	●	◐	$-$$
	Pneumatic Tubes[3]	●			◐	$-$$
↓	Multi-Technology			●	●	$$-$$$
	Video Imaging: Manual	○	○	○	○	$-$$$
Short Duration	Manual Observers	●	●	●	●	$-$$$[4]

○ Indicates what technology is possible.
● Indicates a common practice.
◐ Indicates a common practice, but must be combined with another technology to classify pedestrians and bicycles separately.
$, $$, $$$: Indicates relative cost per data point
[1] Typically requires a unique loop configuration separate from motor vehicle loops, especially in a traffic lane shared by bicycles and motor vehicles.
[2] Permanent installation is typical for asphalt or concrete pavements; temporary installation is possible for unpaved, natural surface trails.
[3] Requires specific mounting configuration to avoid counting cars in main traffic lanes or counting pedestrians on the sidewalk.
[4] Useful for short duration counts, however cost prohibitive for long term.

Figure 5: Simplified Flowchart for Selecting Non-Motorized Count Equipment (Adapted from FHWA TMG 2013)

Table 1 serves as a quick reference guide of the strengths and limitations of technologies commercially available and deployed through 2013. A more thorough overview of counting methods is located in Section 5.0. While specific technologies differentiate bicyclists from pedestrians, at this time, only manual counts are able to differentiate between pedestrians and skaters. Therefore if the area being monitored has a high occurrence of skaters, and it is important to differentiate them from pedestrians, steps should be taken to ensure they are counted appropriately. Additionally, automatic count

equipment is susceptible to vandalism. Care should be taken to properly secure all components left out in the field and check them regularly for signs of tampering.

Table 1: Commercially-Available Bicyclist and Pedestrian Counting Technologies (Adapted from FHWA TMG 2013)

Technology	Typical Applications	Strengths	Limitations
Inductive Loops	• Continuous Counts (saw cut or under pavement) • Short duration counts (tape down) • Bicycles only	• Accurate when properly installed and configured • Uses traditional motor vehicle counting technology	• Capable of counting bicyclists only • In-pavement installation requires professional installer to saw cut in existing pavement or to place pre-formed loops on sub-base prior to construction • May have higher error when detecting groups of bicycles • May be susceptible to electrical interference
Magnetometer	• Continuous Counts • Bicycles only	• May be possible to use existing motor vehicle sensors	• Commercially-available, off-the-shelf products for counting bicyclists are limited • May have higher error with groups
Pressure Sensor/ pressure mats	• Continuous Counts • Typically unpaved trail or paths	• Some equipment may be able to distinguish between bicyclists and pedestrians	• Expensive/disruptive for installation under asphalt or concrete pavement
Seismic Sensor	• Short-term counts on unpaved trails	• Equipment hidden from view	• Commercially-available, off the shelf products for counting are limited
Microwave Sensor	• Short-Term or continuous counts • Bicyclists and pedestrians combined	• Capable of counting bicyclists in dedicated bike lanes or bikeways	• Commercially-available, off the shelf products for counting are limited • Distance limitations
Automated Video Imaging -	• Short-term or continuous counts • Bicyclists and pedestrians separately	• Potential accuracy in dense, high-traffic areas over manual counts	• Typically more expensive for exclusive installations • Algorithm development still maturing

Technology	Typical Applications	Strengths	Limitations
Active Infrared	• Short-Term or continuous counts • Bicyclists and pedestrians combined	• Relatively portable • Low profile, unobtrusive appearance	• Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detection technology • Very difficult to use for bike lanes and shared lanes • May have higher errors with groups
Passive Infrared	• Short-Term or continuous counts • Bicyclists and pedestrians combined	• Very portable with easy setup • Low Profile, unobtrusive appearance	• Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detection technology • Very difficult to use for bike lanes and shared lanes, requires careful site selection and configuration • May have higher error when ambient air temperature approaches body temperature range • May have higher errors with groups • Direct sunlight on sensor may create false counts
Pneumatic Tube	• Short-Term counts Bicyclists only	• Relatively portable, low cost • May be possible to use existing motor vehicle counting technology and equipment	• Capable of counting bicyclists only • Tubes pose tripping hazard to trail users • Greater risk of vandalism • Not for use in winter
Video Imaging - Manual Analysis	• Short-term counts • Bicyclists and pedestrians separately	• Can be lower cost when existing video cameras are already installed	• Limited to short-term use • Manual video reduction is labor-intensive
Manual Counts	• Short-term counts • Bicyclists and pedestrians separately	• Can be used for automated equipment validation	• Useful for short duration counts, but cost prohibitive for long term unless volunteer supported

4.2 BICYCLE DETECTION SENSOR ACCURACY

The accuracy of available technologies varies and is dependent largely on proper installation and configuration. Table 2 summarizes the accuracy of several bicycle detection technologies. The average percentage deviation, or error relative to the totals counted manually from the video, ranged from 0.55% to more than 18%, depending on the technology unique characteristics of deployment. The averages of the absolute percentage differences were higher because false positives and false negatives do not offset each other.

Table 2: Accuracy and Precision Rates of Sensor Technologies (Adapted from: NCHRP Project 07-19, Table 4-1)

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%	.9991	30	328/822
Microwave	-18.18%	48.15%	.9503	95	129/563
Bicycle-specific pneumatic tubes	-17.89%	18.50%	.9864	160	218/963
Inductive loops (detection zone)*	0.55%	8.87%	.9938	108	128/355
Inductive loops (including bypass errors)*	-14.08%	17.62%	.9648	165	200/781
Piezoelectric strips	-1.46%	2.57%	.9966	51	129/283
Combination (pedestrian volume)	18.65%	43.78%	21.37%	47	176/594

Notes: APD = average percentage deviation, AADP= 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 bypass the detection zone.

4.3 SENSORS CURRENTLY IN USE IN MINNESOTA

The bicycle and pedestrian project team selected and deployed a variety of sensors in the summers of 2014 and 2015. Table 3 summarizes each of the seven sensors deployed, focusing on the level of difficulty to install.

Table 3: Sensors Currently in Use in Minnesota

Counter Type	Modes Counted	Level of Difficulty to Install	Agency	Vendor	Installation Instructions
Inductive Loops	Bikes	**DIFFICULT** - Equipment is saw-cut into road or trail surface by an experienced construction or consultant team. This install will require stringent safety protocols (truck with flashing lights, vests, spotters, etc.). Calibrate by biking across the sensor and checking detection with software. Download data with a Bluetooth enabled device or it can be sent through the cellular network and accessed remotely. Data can be analyzed using proprietary software or in Excel.	MnDOT	EcoCounter	Eco-Zelt
Multiple Technologies	Bikes and Peds Differentiated	**DIFFICULT** - Equipment is saw-cut into road or trail surface by an experienced construction or consultant team. This install will require more stringent safety protocols (truck with flashing lights, vests, spotters, etc.). Calibrate sensors by biking and walking across them and checking detection with software. Download data with a Bluetooth enabled device or it can be sent through the cellular network and accessed remotely. Data can be analyzed using proprietary software or in Excel.	MnDOT, Rails to Trails, and the City of Minneapolis	EcoCounter	Eco-Multi
Pneumatic Tubes	Bikes	**INTERMEDIATE** - Equipment secured to road or trail surface with road nails or stakes. Installation may require more stringent safety protocols (truck with flashing lights, vests, spotters). A computer and software needed to set up counters. Data post processing needed to classify traffic and identify bikes.	MnDOT, Hennepin County	TimeMark	
In Road Sensors	Bikes	**DIFFICULT –** Holes are drilled into road surface by an experienced construction or consultant team and round puck shaped equipment is dropped in and sealed over. This install will require more stringent safety protocols (truck with flashing lights, vests, spotters, etc.). Calibrate by biking across the sensor and checking detection with software. Data can be analyzed using proprietary software or in Excel.	Hennepin County	Sensys Networks	

Counter Type	Modes Counted	Level of Difficulty to Install	Agency	Vendor	Installation Instructions
Pneumatic Tubes	Bikes	**INTERMEDIATE** - Equipment secured to road or trail surface with road nails or stakes. Installation may require more stringent safety protocols (truck with flashing lights, vests, spotters). A computer and software needed to set up counters. Data post processing needed to classify traffic and identify bikes.	Hennepin County	MetroCount	MC5600 Operator Guide Installation Videos
Active Infrared	Bikes and Peds Undifferentiated	**EASY** - Equipment attached to posts or poles on both sides of a trail. Calibrate sensor by walking across IR beam. Download data with a special collector, process with proprietary software and export to Excel for analysis.	Minneapolis Park & Recreation Board, ARDC, and DNR	TrailMaster	TM 1550 Data sheet
Passive Infrared	Bikes and Peds Undifferentiated	**EASY** - Equipment attached to post or pole on one side of a trail. Calibrate sensor by walking within range of IR beam and checking detection with software. Download with a Bluetooth enabled device or it can be sent through the cellular network and accessed remotely. Data can be analyzed using proprietary software or in Excel.	MnDOT, and DNR	EcoCounter	Eco-Pyro
Microwave	Bikes and Peds Differentiated	**EASY** - Equipment attached to posts or poles on both sides of a trail. Calibrate sensor by walking and biking across microwave beam. Download data from integrated bike and pedestrian data loggers and process with Excel.	MnDOT	Chambers Electronics	RadioBeam People-Bicycle Counter (RBBP)

CHAPTER 5: HOW TO PERFORM COUNTS

In 2013 MnDOT partnered with UMN to assess the relative effectiveness of different, commercially available technologies for collecting bicycle and pedestrian volume data. Six approaches were selected for investigation and are described in this manual.

- Manual/Video
- Pneumatic tubes
- Microwave
- Inductive loop
- Infrared
- Inductive loop + Infrared

Appendix A provides a quick reference flow chart for sensor selection based on count duration and facility type.

The sections that follow present a general overview, and consult manufacturer documents for specific installations guidelines. Safety of installation personnel needs to be considered. Note that a professional installation is needed for some devices, particularly loops that are saw cut into pavement or preform loops that are installed in the sub base before paving.

5.1 MANUAL COUNTS

Manual counts are performed by personnel either positioned at the desired count location who tally the bicycle and/or pedestrian traffic, or via video recorded onsite and reviewed and tallied at a later time. These counts can be performed using the MnDOT Counting Form (see Appendix B) or an electronic counting pad. Counts are taken in 15 minute increments for a pre-determined amount of time with a separate tally recorded for bicyclists and/or pedestrians. Manual counts are a good way to capture data beyond volume including age (adult vs. child), gender, helmet use, and direction of travel. The use of video tools allow the counter to speed up or slow down the video playback for accurate manual counts and makes long duration manual counts possible.

Manual counts can be used as standalone count data or can be used as a baseline to identify errors and/or correction factors for automated counting devices.

MnDOT began the bicycle and pedestrian count research project by working with local partners to establish a consistent methodology for conducting manual counts. The City of Minneapolis, Transit for Livable Communities, and other agencies were using methods for manual counting based on those recommended by the National Bicycle and Pedestrian Documentation Project. The MnDOT methodology for manual counting incorporates procedures used by these partners.

Going forward the MnDOT program will focus on using automated technology. However, local jurisdictions may decide to conduct manual counts to better understand quantitative as well as qualitative information about their community, such as mode split and gender and age of people walking and biking.

Figure 6: Manual Count being Performed Along Roadway

MnDOT developed a training program for conducting manual bicycle and pedestrian counts as part of the MnDOT and MDH Bicycle and Pedestrian Counting initiative. Local communities can easily manage the collected data with spreadsheets.

5.1.1 Site Design

The person or camera collecting data should be located where viewing is minimally impeded by infrastructure or curves. Mid-block locations are suitable. If intersectioncounts are performed, it may be necessary to have more than one person or camera collecting data. If using video, consider the time of day and how the sunlight will affect the camera's view.

The count area should be considered a "transportation work zone." The person conducting the count should be out of the travel way and not interfere with traffic flow. Make sure field personnel understand safety is a primary concern and they should not take risks to collect the counts. Provide field personnel with the count manager's contact information for questions or onsite issues. Field personnel should wear approved high visibility clothing.

Once site locations for counts have been selected, visit the site to determine the best line of sight to perform the counts before the counts take place.

If utilizing cameras, the cameras must be attached to a pole, fence or other permanent structure that offers a place to secure the video monitoring device with chain and lock to prevent theft and tampering. Attach a sticker or tag stating who owns and operates the device and contact information for the device.

Good quality video requires appropriate lighting conditions and camera placement. Use a small video monitor or computer connected to the video recording device to verify the camera view is sufficient. Ensure the camera will not rotate or move by securing it with zip ties or hose clamps at several places along the camera pole. Verify all connections are made correctly and the data storage device is collecting the video data before leaving the site.

Figure 7: Mix of Bicycle and Pedestrians on a Path

5.1.2 Calibration

Train personnel with the methods contained in the MnDOT Manual Count Training Manual. A clear definition of bicycles and pedestrians ensures all counting personnel will perform counts in a uniform manner.

- Bicycle – all pedal powered vehicles including unicycles, tandem, recumbent, three wheelers, tag-alongs, trailers, pedicab. Each person counts as one count.
- Pedestrian – each person on foot or assisted including people using walkers, skates, Segways, wheelchairs, strollers, crutches, scooters, children being carried, person walking a bicycle.

5.1.3 Data Collection

Every pedestrian or vehicle that passes through the screen line or intersection are to be be counted. If directionality or any other data collection parameters are being collected, they should also be recorded for every tally. If multiple counts are conducted at the same area, the same location should be used for observation.

A MnDOT data collection form has been created for performing manual screen line or cordon counts (See Appendix B). MnDOT typically collects data in 15 minute increments for two hours. The form is to be completely filed out including the areas for name, date, and location ID. There is additional space at the bottom of the form to document any unusual occurrences impacting the count.

Items to provide in addition to training for personnel conducting manual counts:

- Instructions
- Location map
- Clipboard
- Data Collection Forms
- Pen/pencils and spares
- Watch/phone/timepiece
- Public information sheet or “Traffic Count in Progress” sign

- High visibility clothing

The public may interact with personnel onsite and distract them from counting. Providing professional and polite answers to the public's questions, and information sheets to people that stop for more information, is a useful tactic that allows the counter to stay focused (Figure 8). The person conducting the count is to note if and when any counts are interrupted for any reason. At the end of the shift provide the counter with clear direction on where to return the count forms and other materials.

Bicycle and Pedestrian Counting Program

We are participating in a research project to study bicyclist and pedestrian traffic volumes. For more information, you may contact *insert count manager contact information here*. I will be happy to answer your questions if possible, but I must keep focused on counting to ensure our counts are as accurate as possible. Thank you for your interest in our program.

Figure 8: Example Public Information Sheet for Counters

A traffic monitoring camera allows manual counts to be performed at a later time by viewing the video and tallying the information. The accuracy of the data depends on careful deployment and analysis.

Figure 9: Video Recorder, camera and recorded video

The manual tally of the video can be performed in three ways; using the MnDOT Data Collection Form, utilizing a mechanical/electronic count board, or a computer keyboard and the accompanying software.

At most two keystrokes are needed to record a passing bicycle or pedestrian. An example mechanical/electronic count board, COUNTpad, is shown in Figure 10.

Using the video playback for manual counts has advantages such as the ability to play back any recorded time. This allows an operator to return to the exact spot in the video they previously stopped working from, or allows others to review uncertainties by recording the time at which the subject in question passed. Another feature is the ability to speed up and slow down the video playback. This provides the opportunity to slow down the video to allow for accurate counting of bicycles and pedestrians passing by in quick succession or speed up the video during periods of little activity.

Figure 10: Electronic Count Board Used With Video Data Processing

5.1.4 Maintenance and Troubleshooting

Maintenance and troubleshooting for manual counts are minimal. Counts performed by personnel can be reviewed by the count manager. A few simple questions may give an indication of the quality of the count:

- Were you able to document everything you wanted?
- Were the traffic volumes overwhelming?
- Do you think your location onsite was at the best location for counting or do you have other suggestions?

Based on this information, the field observers could be re-positioned, additional staff could be added, or the count equipment could be changed to the use of a hand tally (click counter), video monitoring, or other automated technologies.

Maintenance and troubleshooting for traffic monitoring cameras includes ensuring the battery is charged, has the ability to hold a charge long enough to record video for the desired amount of time and has enough data storage for the data collection needs. If the camera battery or amount of storage available will not last for the desired amount of data collection time, make plans for personnel to visit the site and swap in new batteries or data storage until the data collection effort is complete.

5.2 PNEUMATIC TUBE COUNTERS

Pneumatic tube counters detect wheeled vehicles that pass over rubber tubes. As the wheel passes over the rubber tube, a pressure pulse is created and the pressure change is detected by the data recorder. Tubes for detecting bicycles are typically thinner than those used for motor vehicle detection for increased safety and detection accuracy.

Figure 11: Pneumatic Tube Installation on Roadway

5.2.1 Site Design

Pneumatic tube counters may be installed as either short duration or semi-continuous detectors on paved surfaces. They may be used on some gravel surfaces, however this installation is not recommended. Rubber tubes are stretched taught across the surface to be detected. Pneumatic tubes function in most weather conditions although snow or ice buildup around the tube may cause the tube to not compress and pressurize the air to record the detection. Winter deployment is not recommended as snowplows will rip up the tubes. Also be aware of street sweepers and their routes so they don't harm the tubes.

Various configurations of tubes can be used to capture different types of data. A common tube configuration is to place two tubes perpendicular to the travel direction spaced equidistance apart. As wheeled vehicles pass over the tubes, the direction can be determined by the sequence of the tube "hits." The speed of the vehicle can be determined by the timing of the tube hits and vehicle classification is determined by measuring axel spacing. Ideal locations are ones with only bicycle traffic, however in some cases it is necessary to include a roadway with motor vehicle traffic as well.

When selecting a location for pneumatic tubes:

- Stay away from signalized/stop-controlled intersections and from parking areas to minimize the chance of vehicles/bikes stopping on the equipment
- Avoid hilly areas where one direction of bikes travel uphill
- Avoid areas where vehicles/bikes are changing lanes, such as a "major intersection" where it is common for users to turn

Follow the manufacturer's installation instructions for placing the pneumatic tubes and data recorder. Be sure to plan your route to the locations and inventory equipment (hoses, counters, and installation tools) before leaving to set up the equipment.

Other installation items:

- Exercise caution when working near traffic. Work with appropriate traffic agencies to use traffic control devices if needed (e.g. traffic cones or signs, flashing lights, etc.)
- Document the relevant information: equipment number, travel direction, and sketch of the setup with north arrow
- Secure equipment on roadway to minimize chance of it being disturbed
- Apply tension to hoses (pull 10-15% of the slack tube length before anchoring the end closest to the counter)
- Knot ends of tubes or plug them to keep the dust out and to reduce bounce back signals
- If the tubes cross a parking lane, set out traffic control devices (usually traffic cones) to prevent vehicles from parking on top of the tubes

5.2.2 Calibration

Pneumatic tubes require calibration to determine if the air switch sensitivity needs to be adjusted. Tubes require precise installation in cases where dual tubes are used. It is important to set the tubes parallel to each other at a measured distance apart. This distance is programmed into the detector for speed determination.

Figure 12: Tube Calibration

After setup, monitor the detector for several activations to ensure detections for common vehicle types are properly recorded. To see the detector activated in real time, connect to the detector via Bluetooth on an Android device (e.g., tablet) or laptop, or plug the counter directly into a laptop or tablet. Once connected, bike over or step on the tubes to make sure the counts are registered correctly. Bring an extra battery or a car charger, especially if multiple sites and counters are to be set up in one day.

5.2.3 Data Collection

Data are automatically collected by the data recorder attached to the tubes. Depending on the manufacture, data can be automatically uploaded to a web server, or downloaded to a laptop or an Android device. Verify the data recorder has sufficient memory to store data throughout the desired data collection interval.

5.2.4 Maintenance and Troubleshooting

Pneumatic tubes require little maintenance although they should be checked periodically depending on the risk of the tubes detaching from the surface due to site conditions, traffic, or vandalism. If the tubes detach from the surface, they could become a safety hazard until they are fully removed. In semi-continuous tube installations, check the pneumatic tube setup frequently (roughly every three days) for proper performance.

Upon placement, check tubes for holes. Use an air compressor to blow air through hoses to check for holes and remove dust – this is a major problem as equipment is used over several installations. Over time and use, tubes wear out and need to be replaced, so keep a supply of spare tubes available.

5.3 MICROWAVE

Microwave detectors, which commonly are called radar detectors, use radio waves to detect bicycles and pedestrians. Depending on the detector selected, they may be able to count bicycles and pedestrians separately, together or configured to omit one or the other. They may be a single detector adjacent to the traveled way or a dual detector with a signal and receiver installed on each side of the facility being monitored.

Figure 13: Microwave Detector Installation using Stanchions

5.3.1 Site Design

Microwave detectors must be set up directly adjacent to a path or trail. Detectors are typically placed at a height of two to five feet. If there is no trailside infrastructure that can be used to mount the detector, a sturdy stanchion to support the detector may be installed.

In cases where unconventional modes of transportation are used, such as an equestrian trail, the detector should be placed at an appropriate height to detect only desired subjects. Be aware of the distance limitations stated by the manufacturer, and take those limitations into consideration when selecting a site. Follow the manufacturer's instructions for installing the detector.

5.3.2 Calibration

Microwave detectors require little calibration, but should be tested upon setup by verifying that several subjects are correctly detected. If the detector misses subjects, it may need to be installed at a different height, angle, or location.

5.3.3 Data Collection

Data are automatically collected by the detector. Data can be downloaded from the detector to a laptop.

5.3.4 Maintenance and Troubleshooting

Detectors require little maintenance. Refer to the product manual and perform basic maintenance and troubleshooting steps to verify battery level and/or electrical connections and check for signs of vandalism or tampering.

5.4 INDUCTIVE LOOP

Inductive loops are an induced current detection system that sense metal objects that pass over the in-ground "loop." Data are logged by a data collection unit nearby. This technology cannot be used for pedestrian detection as they do not induce a current in the loop wire.

Professional installation is required for saw cut loops and preform loops that are installed on a sub base before paving. Tape-down temporary loops do not require special training or equipment to install, but must be installed carefully to ensure proper recording of bicyclists.

Inductive loops are typically made by forming three to eight turns of loop wire that are installed in a channel that is saw cut into pavement, installed as preformed loops with new construction at the time of paving, or temporarily affixed on top of the paved traveled way with some sort of bonding agent. The specific number of turns of loop wire depends on the manufacturer. For example, a vendor selected by MnDOT for inductive loops (i.e., Eco-Counter) specified eight turns.

Figure 14: Installing an Inductive Loop in a Saw Cut on a Multi-purpose Path

Saw cutting is the preferred method of installation. The reason is that experience with inductive loops installed in the asphalt or concrete pavement shows that they may function for a decade or more in a variety of climates. This longevity results because the locations typically experience very little heavy vehicle traffic which reduces the wear and tear on the pavement.

Questions that commonly arise during installation concern the depth of cuts, insertion of the wires, and the resulting appearance of the cuts. It is crucial that wire not be installed too deeply. Because bicycles have a small magnetic signature, the wire loops (which form the detection zone) need to be close to the surface. According to some manufacturer's specifications, the bottom wire of the loop cannot be deeper

than roughly 2” below the pavement surface. If cuts are made in exsiting pavement, the depth can be monitored during the cutting process. However, if loops are installed during repaving or new construction, care must be taken to account for final layers of payvement. For example, if the final layer of pavement is to .5” to 1” thick, cuts for the loops should not be more than one inch.

Another common problem is that wires installed in cuts flex and pop out. Having two individuals present during installation can help minimize this problem. New saw cuts will mar pavement surfaces and may be unattractive. By using sealant colors that match the color of the road surface and by pumping sealants into the cuts using a hand gun or squeeze bottle, sealant splatter can be minimized, and the visibility of the cuts will be minimized.

5.4.1 Site Design

Inductive loops are placed in the roadway/trail spanning the traveled way. Loops can be placed in bike lanes, on road shoulders, or on multi-purpose paths. Finding locations where the loop will detect the entire path or bike lane is critical so bicycles cannot ride outside of the detection zone. Depending on the manufacturer, a source of power may be required which may limit deployment locations. Determine if the site is affected by electrical influence; such as adjacent to power lines or underground utilities as this can interfere with the loop current.

Installing these devices during construction or reconstruction of bicycle facilities is the most cost effective. When a trail is reconstructed any existing loops must be replaced but the data logger should be salvageable. Loops and conduit can be laid when the pavement is installed to avoid the need to saw cut the pavement. Follow the manufacturer’s instructions for installing the detector.

Figure 15: Eco Counter Zelt Loop (from Eco-Counter)

5.4.2 Calibration

Inductive loop detectors may need to be calibrated to detect bicycles and may have higher error when detecting groups of bicyclists. If installed in lanes adjacent to a motorized vehicle traveled roadway, further calibration and manual counts may be needed to determine the level of interference caused by vehicles. Alternatively, two loops stacked ontop of each other may be installed to help filter out vehicle interference and only count bicycles. Depending on the manufacture, this configuration may allow for directionality to be determined.

After calibration, monitor the detector for several activations to ensure bicycle detections are properly recorded.

Figure 16: Calibration Performed before Sealing the Saw Cut to Ensure Proper Performance

Data are automatically collected by the data recorder. Depending on the type of data collection device used, data can be uploaded to a web server remotely through a cellular connection or downloaded onsite via Bluetooth or a hardwire connection. Verify the data recorder has sufficient memory to store data throughout the desired data collection interval.

5.4.3 Maintenance and Troubleshooting

Inductive loops require little maintenance although check them periodically for deteriorating pavement and sealent around the loop. Over time the pavement around the loop may wear out and need to be replaced or resealed.

In a semi- permanent inductive loop installations, check the loop setup monthly for proper performance. Figure 18 shows the effects of two seasons of periodic plowing – exposed and cut wires.

Figure 18: Inductive Loop on Top of Road Surface Worn and Frayed from Exposure and Road Maintenance

5.5 INFRARED

Infrared detectors use invisible radiant energy to detect bicycles and pedestrians. Depending on detector selected it can be active infrared or passive infrared. Active infrared requires mounting a receiver and a transmitter on each side of the detection area and bicycles or pedestrians are detected when the infrared beam is broken. Passive infrared is a side-fire technology mounted on one side of the detection zone which identifies the changes in temperature as a bicycle or pedestrian move through the detection zone.This technology typically does not distinguish between user types; consider dual technology if using this technology on a multi-purpose path that needs separate pedestrian and bicycle counts.

5.5.1 Site Design

Infrared detectors must be set up directly adjacent the path or trail. Detectors are typically placed at a height of two to three feet. If there is no trailside infrastructure that can be used to mount the detector, a sturdy stanchion to support the detector may be installed.

In cases where unconventional modes of transportation are used, such as an equestrian trail, place the detector at a height for detection of that subject. Be aware of the distance limitations stated by the manufacturer and take those limitations into consideration when selecting a site.

Follow the manufacturer’s instructions for installing the detector. Also, allow room for snow storage and maintenance vehicles like lawnmowers, four-wheelers and tractors.

5.5.2 Calibration

Infrared detectors require little calibration, but test upon setup by verifying that several people are correctly detected. If the detector misses people, it may need to be installed at a different height, angle, or location.

5.5.3 Data Collection

Data are automatically collected by the data recorder attached to the infrared sensor. Depending on the manufacture, data can be automatically uploaded to a web server, or downloaded to a laptop or an Android device. Verify the data recorder has sufficient memory to store data throughout the desired data collection interval.

5.5.4 Maintenance and Troubleshooting

Detectors require little maintenance. Consult the product manual and perform basic maintenance and troubleshooting steps to verify battery level and/or electrical connections and check for signs of vandalism or tampering.

5.6 INDUCTIVE LOOP PAIRED WITH INFRARED DETECTOR

In this dual technology approach, a short duration or permanent loop is paired with infrared technology to detect both bicycles and pedestrians and in some cases snowmobiles and ATV's. Data are logged by a data collection unit nearby with a tally of differentiated modes.

5.6.1 Site Design

Inductive loops are placed in the shared use path spanning the traveled way. Finding locations where the loop will detect the entire path or bike lane is critical so bicyclists cannot ride outside of the detection zone. Depending on the manufacturer, a source of power may be required which may limit deployment locations. Infrared sensors must be set up directly adjacent the path or trail. The height of the infrared dectors varies by manuscturer (e.g., Eco-Counter Pyros are to be installed 3 feet above the surface). If there is no trailside infrastructure that can be used to mount the detector, a sturdy stanchion to support the detector may be installed.

Figure 19: Inductive Loop and Infrared on Urban Multi-purpose Path

In cases where unconventional modes of transportation are used, such as an equestrian trail, place the detector at a height for detection of that subject.

It is ideal to install these devices during construction or reconstruction of bicycle facilities. Loops and conduit can be laid when the pavement is installed to avoid the need to saw cut the pavement.

Follow the manufacturer's instructions for installing the detector.

5.6.2 Calibration

Inductive loop detectors may need to be calibrated to detect bicycles and may have higher error when detecting groups of riders. Infrared detectors require little calibration, but can be adjusted for sensitivity and tested upon setup by verifying that several people are correctly detected. If the detector misses subjects, it may need to be installed at a different height, angle, or location.

After calibration, monitor the detectors for several activations to ensure detections are properly recorded. Installation of a video recording device for a short time period such as 24 hours, or 48 hours for lower volume sites, for validation or error determination at a loop and infrared location is recommended.

Figure 20: Calibration after Installation

5.6.3 Data Collection

Data are automatically collected by the data recorder. Depending on the manufacture, data can be automatically uploaded to a web server, or downloaded to a laptop or an Android device. Verify the data recorder has sufficient memory to store data throughout the desired data collection interval.

5.6.4 Maintenance and Troubleshooting

Inductive loops require little maintenance although periodically check them for deteriorating pavement and sealent around the loop. Over time the pavement around the loop may wear out and need to be replaced or resealed.

In a semi-permanent inductive loop installations, check the loop setup monthly for proper performance and identify if wires are exposed or cut.

Infrared detectors require little maintenance. Basic maintenance and troubleshooting steps can verify battery level, electrical connections, and signs of vandalism or tampering. Make sure that the infrared sensor holes are free of debris (clean them out if clogged).

Figure 21: Infrared and Short Duration Inductive Loop Installation on Surface of a Shared-use Path

CHAPTER 6: DATA MANAGEMENT AND ANALYSIS

Key steps in management and analysis of bicycle and pedestrian counts include

- Site identification and description;
- Count validation;
- Data analysis, including computation of descriptive statistics and use of adjustment factors; and
- Data archiving and sharing.

Each step is essential to ensure the data used in planning, engineering and decision-making are valid and as informative as possible.

This chapter presents a general overview of these four elements of a data management and analysis program. Although each jurisdiction that establishes a count program will need to customize data management to integrate into its own existing systems, there are benefits to establishing common practices and structures for archiving data. MnDOT is establishing data management protocols that will enable integration of non-motorized traffic counts with motorized counts in the state's traffic databases and with the FHWA's Traffic Monitoring Analysis System (TMAS) database. The information in the sections that follows is designed to support integration of counts taken by local jurisdictions into MnDOT and FHWA databases.

6.1 SITE IDENTIFICATION AND DESCRIPTION

Site identification is the process of assigning a unique identifier or number to each counting location so that counts collected at each site can be maintained over time. Site description involves recording and archiving attributes of each location such as latitude-longitude, street address (if relevant), and number of traffic lanes.

MnDOT staff from Transportation Data Analysis (TDA), MnDOT Information Technologies (MnIT), Transportation System Management (OTSM) and the Office of Transit have identified a list of critical information to capture for each non-motorized count (Table 4). This list is based on FHWA's TMAS data submission requirements; each item represents a field in the TMAS database. MnDOT developed a master Excel © spreadsheet to track these data for all bicycle and pedestrian counts taken by MnDOT or submitted to MnDOT by local jurisdictions. The spreadsheet is compatible with MnDOT's motor vehicle databases and can be integrated into mapping programs used by MnDOT. Fields in the spreadsheet also enable users to track deployment and maintenance of equipment and record notes from counts and locations. Local jurisdictions in Minnesota that wish to duplicate or adapt this system should contact MnDOT's Office of Transit, Bicycle and Pedestrian Section.

Table 4: Data Fields for Bicycle and Pedestrian Counts to Ensure Compatibility with FHWA TMAS Databases

Data Field	Notes / Explanation
Jurisdiction	Where the count was performed
Location Description	Detailed description pinpointing count location
FIPS and GNIS	Federal location identifiers
Latitude and Longitude	
Road Address	Useful for finding the location on site
Facility Type	Sidewalk, shared use path, buffered bike lane, shoulder, etc.
Road Classification	Useful for determining how many counter we have on different types of roads
Sensor Type	Vendor and equipment name
Mode Counted	Bikes, pedestrians, both combined, or both separately
Start date and time	
End date and time	
Responsible Agency	Who is / was responsible for the count

6.2 COUNT VALIDATION

Count validation is the systematic process of ensuring the accuracy of the counts that are collected and recorded. This guide focuses on approaches for validation of continuous counts taken with automated sensors, although some of the procedures also are relevant for validation of manual counts.

Important steps in validation include (1) confirmation of counter operations; and (2) identification and correction for systematic counter error.

6.2.1 Confirmation of Sensor Operation

The first step in count validation is to ensure counters are operating properly and recording counts accurately. This step must be performed each time portable equipment is setup. Manufacturers of each type of automated sensor recommend specific procedures for ensuring proper operation. These procedures typically involve installation of the sensors and then observation of devices when bicyclists or pedestrians pass to ensure they are being counted. Manufacturers of some devices (e.g., Eco-counter) include software specifically designed for validation of sensors in the field. Field validation for some devices is more ad hoc. For example, with some devices (e.g., TrailMaster), counts are visible on a screen or the device itself, and the numbers of people passing can be compared to the count on the device in real time. For other devices (e.g., MetroCount pneumatic tube counters), icons can be observed that reflect axle base, which enable observers to differentiate bicycles from cars, but a running total of bicycles is not presented.

Figure 22: Validation of Microwave Sensor

Regardless of the type of sensor, have personnel responsible for installation plan for validation of counts in the field. The amount of time required for field validation depends on the device, the experience with installation and operations, and traffic flows. For example, if an individual is installing a device for the first time, more time will be required for validation than if an individual is responsible for a fleet of sensors and has years of experience operating them. In situations where volumes of bicycle traffic are low, a practical approach involves bringing a bicycle along to the the device. This approach, however, requires two individuals, one to ride and one observe the monitor.

Periodic field validation of permanent automated sensors also is important. The frequency of field validation required depends on the type of device and the duration for which the sensor will be installed. In a recent study, for example, field checks of sensor operations every three to six months or, at minimum, once per year were recommended (NCHRP 2014).

6.2.2 Quality Assurance / Quality Control for Non-motorized Traffic Counts

Quality assurance / quality control (QA/QC) is an essential element of all traffic data management programs. QA/QC is necessary because sensors occasionally malfunction or other factors contribute to erroneous measurements. Procedures for QA/QC for motorized traffic monitoring data are well established, but these cannot be applied directly to non-motorized data because non-motorized traffic volumes typically are lower and much more variable. For example, a common quality check for motorized traffic data is to identify and flag consecutive hours of zero traffic above some cutoff. The logic is that extended periods of zero traffic indicate potential data problems. The same logic cannot be

applied to non-motorized data because many consecutive hours of zero traffic may be common, especially in winter. Therefore, new procedures for QA/QC for non-motorized traffic are being developed.

Turner et al. (2013) advises the following steps in QA/QC for non-motorized traffic data:

- visual inspection of data,
- assessment of potential for outliers using a pre-specified cutoff criterion,
- assessment of zero counts, and
- use of professional judgment to make final decisions about counts to include or censor from a dataset.

The steps are straightforward, but in practice difficult to apply because they involve judgment and most decisions, particularly those that involve application of data cleaning rules, may simultaneously eliminate some valid counts while including some invalid counts. More simply, even with careful QA/QC, it is not always possible to differentiate valid and invalid counts. Appendix D is a detailed example of issues in QA/QC that illustrates Turner's basic approach. The example uses data from six of MnDOT's permanent monitoring stations, including data from three installations of inductive loops on roadways measuring bikes and three installations of integrated inductive loop and passive infrared devices on multiuse trails.

Regardless of the specific procedures used for QA/QC, it is important to both retain a copy of the original dataset and report all editing decisions so users can understand how data have been cleaned.

6.3 DATA ANALYSIS

Data analysis involves a variety of procedures used to inform planning, engineering, and decision-making. The most common of these procedures include computing standard statistics used in traffic engineering such as peak hourly volume and estimation of adjustment factors from continuous monitoring data for purposes of calculating measures such as annual average daily traffic. These procedures are well-developed for motorized traffic, and both the TEM and the TMG discuss standard approaches for comparing and computing data and establishing correction and extrapolation factors. These standard approaches can be adapted for analyses of non-motorized traffic, but because non-motorized traffic varies more in response to changes in weather, new procedures are being developed that take into consideration this daily and seasonal variation. For example, non-motorized traffic volumes tend to be highest on warm, dry and sunny days and lowest on cold and snowy days. If these weather effects are not reflected in methods of extrapolation, estimates of non-motorized traffic volumes may include greater error.

Because the field is still gaining experience in collection and analysis of non-motorized traffic data, standardized protocols for analysis have not been established, but progress is being made in developing them. Researchers at universities in the United States, Canada, and Egypt, among other nations,sare

collaborating with state and local agencies to develop new methods for analysis and factoring of non-motorized traffic data, and a number of important developments and case studies have been reported. The FHWA and some state and local agencies are institutionalizing procedures, and some vendors are incorporating basic analyses in data reporting software. In many cases, however, data analyses are specific to particular projects. The case studies at the end of this chapter from communities in Minnesota illustrate approaches to analysis and use of non-motorized traffic data.

6.3.1 Standard Descriptive Statistics

Standard descriptive statistics used in transportation planning and engineering include average daily traffic (ADT), annual average daily traffic (AADT) and peak hour volume. Statistics such as peak hour are often calculated for each day of the week in each month of the year, as averages for weekdays and weekends in each month of the year, or for seasons. For example, average weekday peak hour volumes during summer months may be useful in engineering analyses to determine traffic controls at intersections.

The steps in computing statistics such as these varies depending on several factors, including the duration of the count, the quality of the data, the type of reporting options available with specific devices, and the engineering application. Many devices include both standard reports and the option to export data into spreadsheets or databases for customized analyses. Because the procedures for computing basic statistics vary according to device and need, this manual does not attempt to address all potential applications. However, MnDOT developed spreadsheet templates for analyzing counts from several of the sensors currently used in Minnesota. As of 2016, bicycle and pedestrian counts collected in Minnesota use automated counters manufactured by at least six different vendors: Eco-Counter, Metrocount, Chambers, TrailMaster, TrafX, and Sensys. MnDOT developed Excel © spreadsheet templates for three of these sensors: Chambers radio beam monitors, Metrocount pneumatic tubes counters, and TrailMaster active infrared monitors. Each template is available from the MnDOT Office of Transit.

Figure 23 is a copy of a count summary for bicycle counts using the Metrocount pneumatic tube template. In addition to descriptive information about the monitoring location, the template summarizes average daily traffic volumes and a variety of other statistics. Appendix E is a copy of instructions for using the Metrocount Excel © template. At least two other agencies (i.e., Arrowhead Regional Development Commission in Duluth and the National Park Service in Minneapolis) are using MnDOT templates for analyzing data collected in their count programs.

Rollins Creek near Gitchee Gami Trail
in Grand Marais, MN

ARDC, UMN

8/4/2015

This summary report shows results from Rollins Creek near Gitchee Gami Trail (GGT) for complete days (full 24-hour periods) counted between 6/24/15 and 7/25/15 using MetroCount MC5600 sensors. Using rubber road tubes, this sensor only classified bikse and motor vehicles even though it potentially detected pedestrians, roller bladers, bike trailers and or strollers too.

- Table 1 summarizes many useful descriptive factors including Total Traffic Volume and Daily Average Volume
- Graph 1 depicts the total daily volumes of people biking and driving for all complete days during the sample period
- Graph 2 compares the average daily volumes of people driving and biking at at Rollins Creek near the GGT as well as the average distribution of total non-motorized traffic for each day of the week. It shows that bike traffic is highest on Saturday making up 19% of total traffic at that location per week.
- Graph 3 shows the average hourly traffic volumes for people walking and biking during weekdays
- Graph 4 shows the volumes for non-motorized traffic during weekend days

* The graphs and tables in this report may include extraordinary data as fluctuations caused by weather, holidays, and or other notable events such as organized races may not be addressed. Some recommended links for comparing this output to local weather are http://www.noaa.gov/ and http://weather.weatherbug.com/.

Table 1: Key Figures for Sample Period

	Bike Traffic		Motor Vehicle Traffic		Total Traffic	
First Complete Day of Data:					6/25/2015	
Last Complete Day of Data:					7/24/2015	
Number of Complete Days of Data:					30	
Number of Complete Weekdays:					22	
Number of Complete Weekend Days:					8	
Total Traffic Volume:	1772		474		2246	
Daily Average Volume:	59		16		75	
Weekday Daily Average Volume:	54		16		70	
Weekend Daily Average Volume:	72		16		88	
Ratio of Weekend vs. Weekday Traffic (WWI):	1.3		1.0		1.2	
Ratio of Morning (7-9am) to Midday (11am-1pm) Traffic (AMI):	0.3		0.2		0.3	
Weekday Maximum Average Hourly Traffic (Peak Hour):	10:00 AM	6	4:00 PM	2	10:00 AM	8
Weekend Maximum Average Hourly Traffic (Peak Hour):	11:00 AM	11	2:00 PM	2	11:00 AM	13
Day of Week with the Maximum Average Daily Traffic:	Saturday	92	Thursday	20	Saturday	109
Day of Sample with the Maximum Daily Traffic:	6/27/2015	132	7/21/2015	24	7/4/2015	144

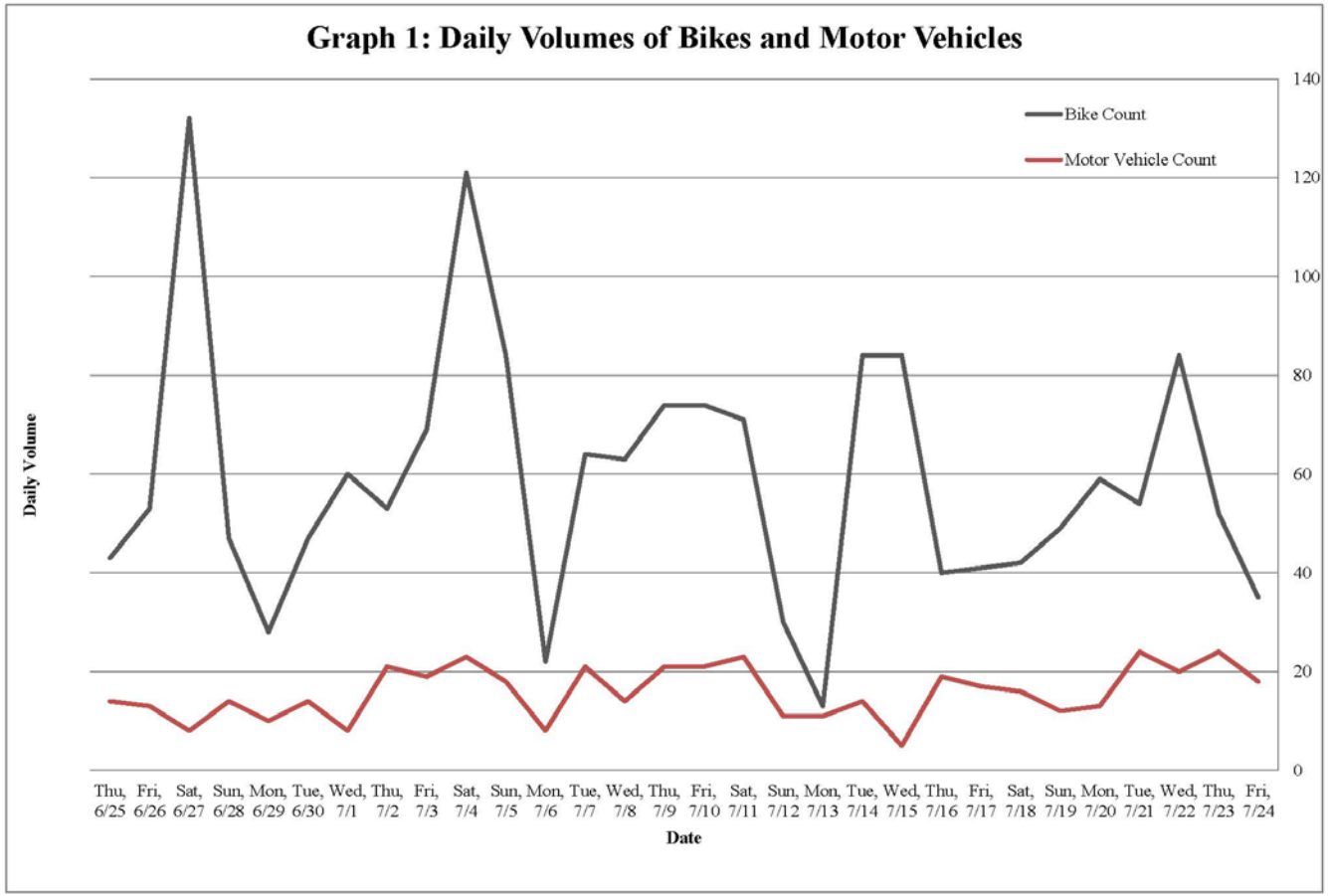
1

Figure 23a Spreadsheet Template for Managing and Analyzing Count Data from Metrocount Pneumatic Tubes

Rollins Creek near Gitchee Gami Trail
in Grand Marais, MN

ARDC, UMN

8/4/2015



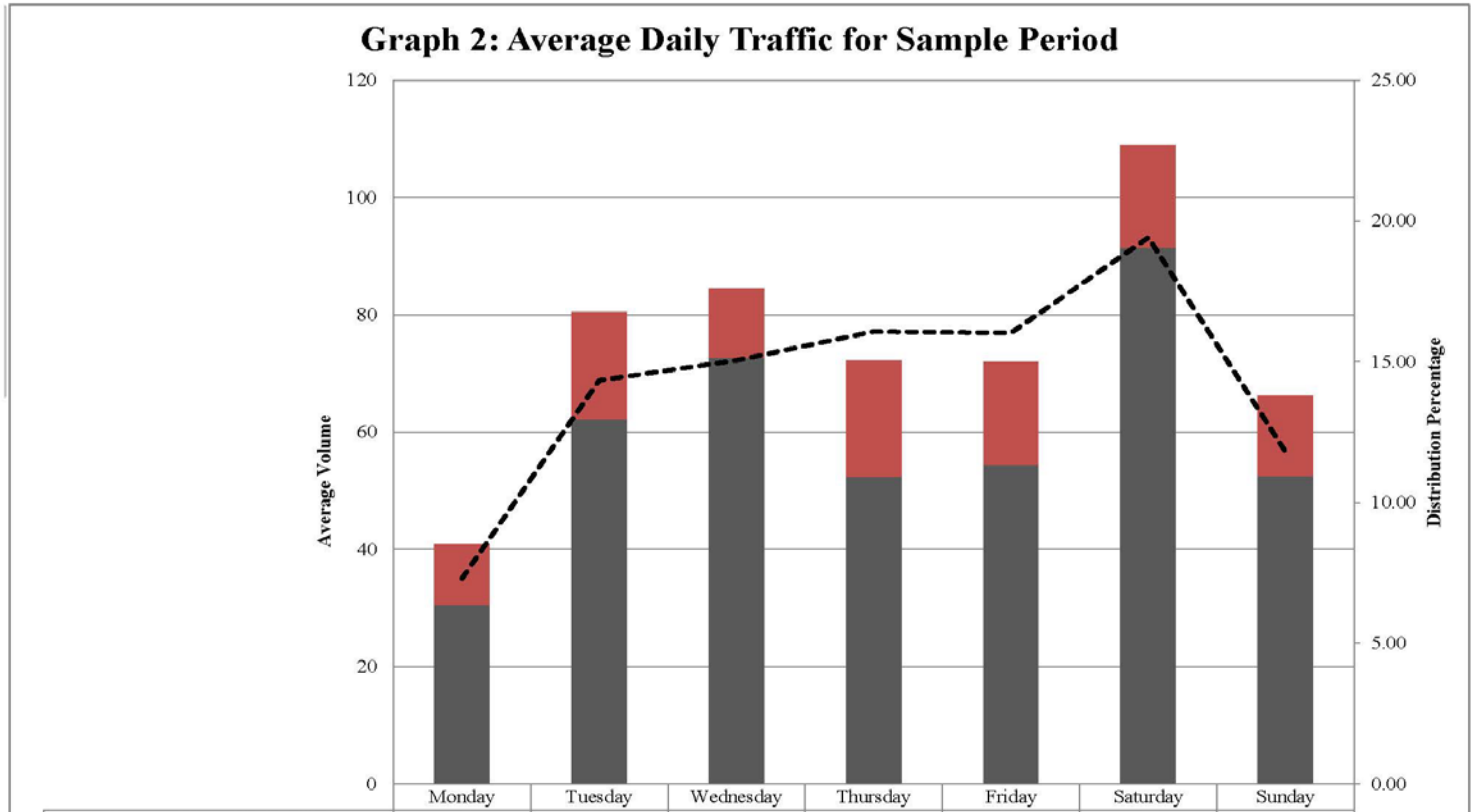
2

Figure 23b Spreadsheet Template for Managing and Analyzing Count Data from Metrocount Pneumatic Tubes

Rollins Creek near Gitchee Gami Trail
in Grand Marais, MN

ARDC, UMN

8/4/2015



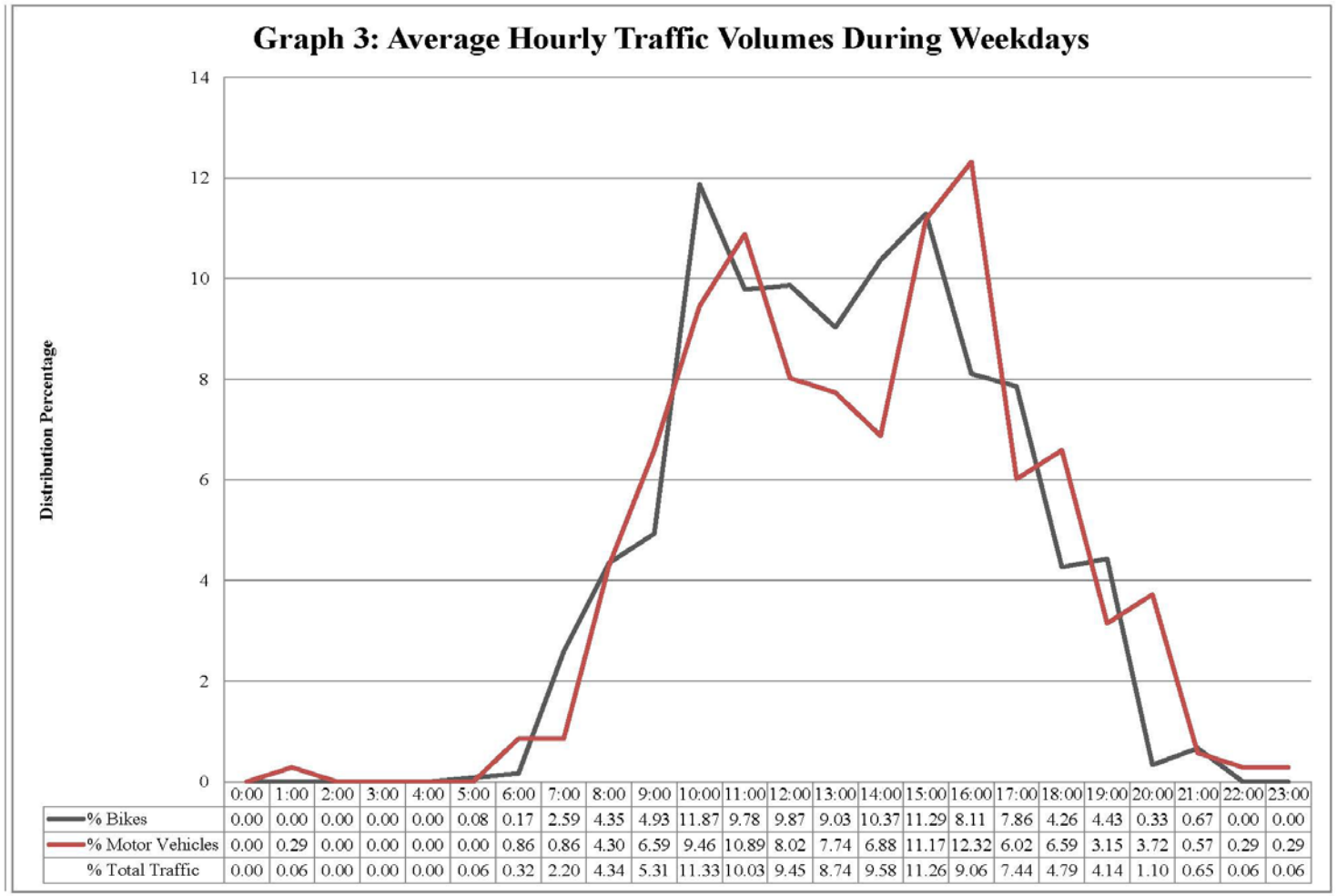
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average Motor Vehicle Volume	11	18	12	20	18	18	14
Average Bike Volume	31	62	73	52	54	92	53
# of Days in Sample	4	4	4	5	5	4	4
Total Distribution over Sample (%)	7.30	14.34	15.05	16.07	16.03	19.41	11.80

Figure 23c Spreadsheet Template for Managing and Analyzing Count Data from Metrocount Pneumatic Tubes

Rollins Creek near Gitchee Gami Trail
in Grand Marais, MN

ARDC, UMN

8/4/2015



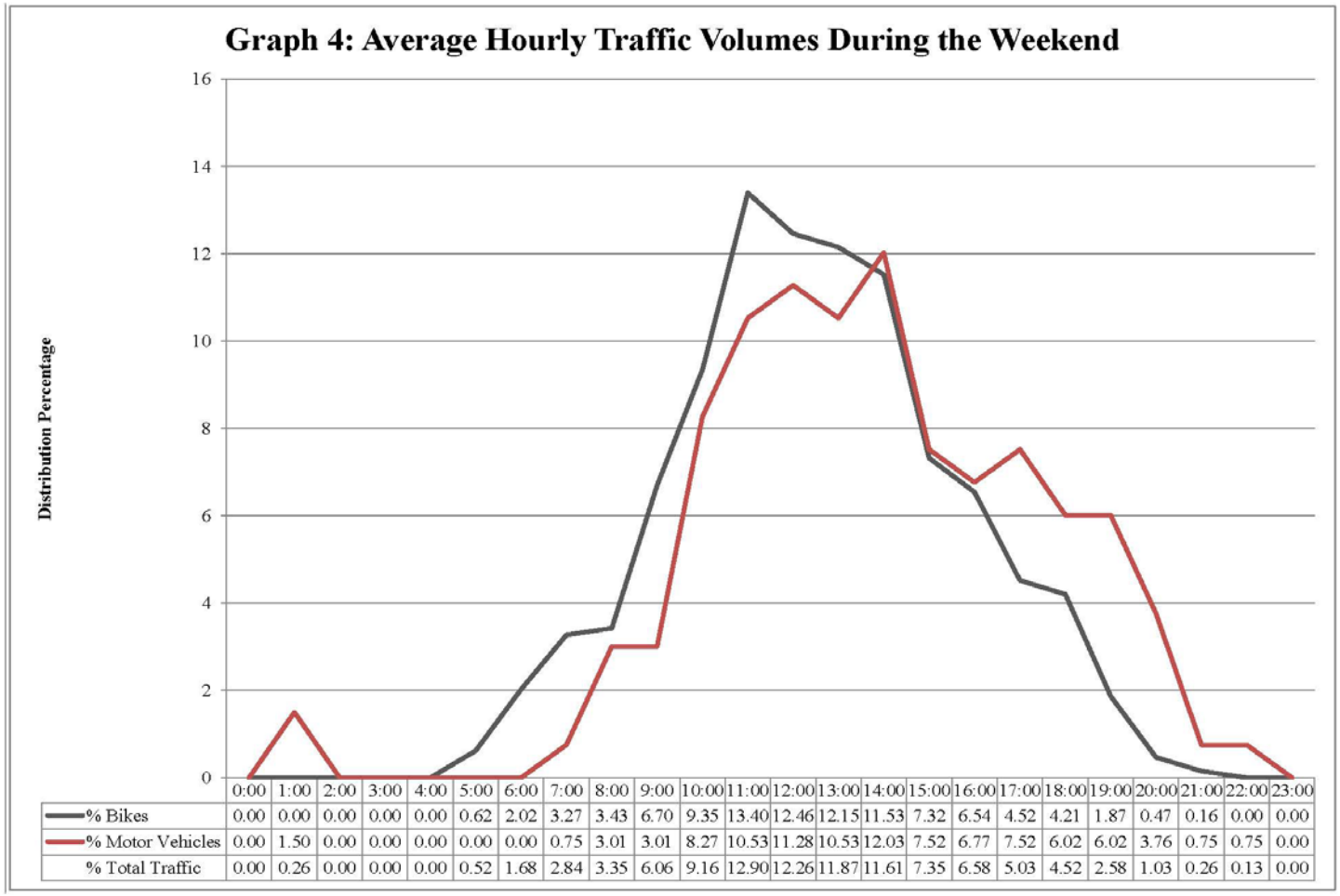
	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
% Bikes	0.00	0.00	0.00	0.00	0.00	0.08	0.17	2.59	4.35	4.93	11.87	9.78	9.87	9.03	10.37	11.29	8.11	7.86	4.26	4.43	0.33	0.67	0.00	0.00
% Motor Vehicles	0.00	0.29	0.00	0.00	0.00	0.00	0.86	0.86	4.30	6.59	9.46	10.89	8.02	7.74	6.88	11.17	12.32	6.02	6.59	3.15	3.72	0.57	0.29	0.29
% Total Traffic	0.00	0.06	0.00	0.00	0.00	0.06	0.32	2.20	4.34	5.31	11.33	10.03	9.45	8.74	9.58	11.26	9.06	7.44	4.79	4.14	1.10	0.65	0.06	0.06

Figure 23d Spreadsheet Template for Managing and Analyzing Count Data from Metrocount Pneumatic Tubes

Rollins Creek near Gitchee Gami Trail
in Grand Marais, MN

ARDC, UMN

8/4/2015

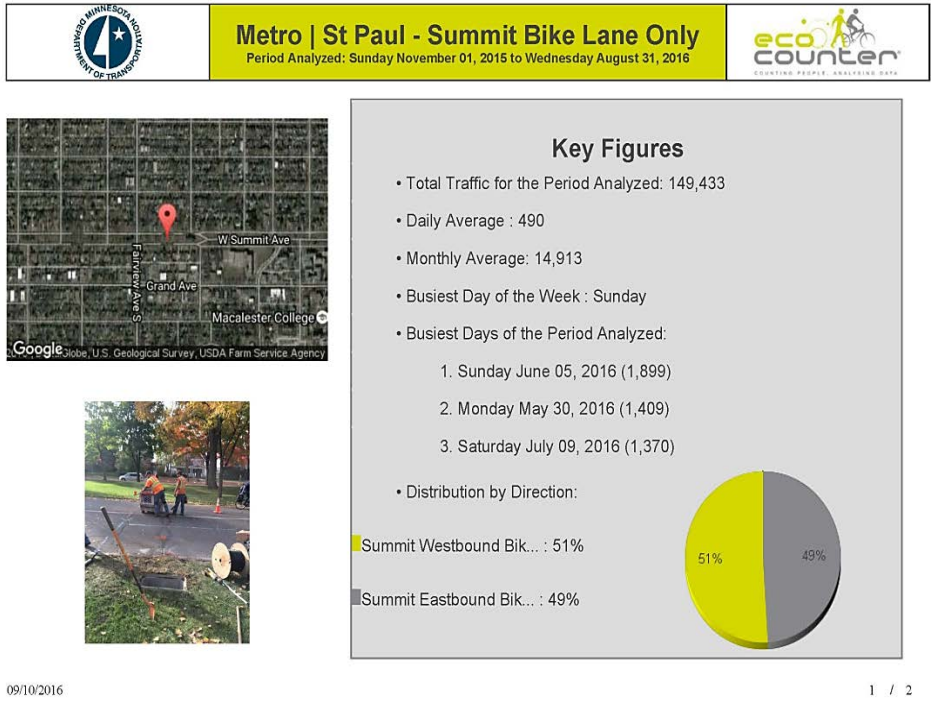


	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
% Bikes	0.00	0.00	0.00	0.00	0.00	0.62	2.02	3.27	3.43	6.70	9.35	13.40	12.46	12.15	11.53	7.32	6.54	4.52	4.21	1.87	0.47	0.16	0.00	0.00
% Motor Vehicles	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.75	3.01	3.01	8.27	10.53	11.28	10.53	12.03	7.52	6.77	7.52	6.02	6.02	3.76	0.75	0.75	0.00
% Total Traffic	0.00	0.26	0.00	0.00	0.00	0.52	1.68	2.84	3.35	6.06	9.16	12.90	12.26	11.87	11.61	7.35	6.58	5.03	4.52	2.58	1.03	0.26	0.13	0.00

Figure 23e Spreadsheet Template for Managing and Analyzing Count Data from Metrocount Pneumatic Tubes

MnDOT purchased Eco-Counter counters for permanent monitoring locations, short-duration monitoring, and the equipment loan program. Reasons for selecting Eco-Counter as the principal vendor for MnDOT bicycle and pedestrian counters include the capacity for remote data retrieval and the analytic capabilities of the accompanying software, Eco-Visio. MnDOT can access data from all its counters (both permanent and portable) through the same interface. Among other features, Eco-Visio allows users to analyze hourly, daily, weekly, monthly, or annual traffic patterns for any chosen time period. Figure 24 is a sample of an Eco-Counter standard report form for bicycle traffic on Summit Avenue in St. Paul. The same type of report is available for short-duration counts taken with portable Eco-counter devices.

MnDOT also has implemented administrative procedures for use of the Eco-Visio data retrieval software. These procedures involve accessing data through an FTP service provided by the vendor that typically is provided on a 'per-domain' basis so it can include all of the counters in a user's domain for a single fee. The Eco-Visio web-based data management system allows users to choose the data format (XML, TXT or CSV) and the data to identify the systems (i.e., specify the counting site identification number). This integration procedure enables MnDOT to secure all data in-house, thereby supporting larger analyses and making the creation of adjustment factors easier. To facilitate data-sharing, MnDOT has created a read-only access option and is sharing the Eco-Visio site with external partners, including local agencies collaborating in counting, and consulting engineers and planners who need data for project-related work.



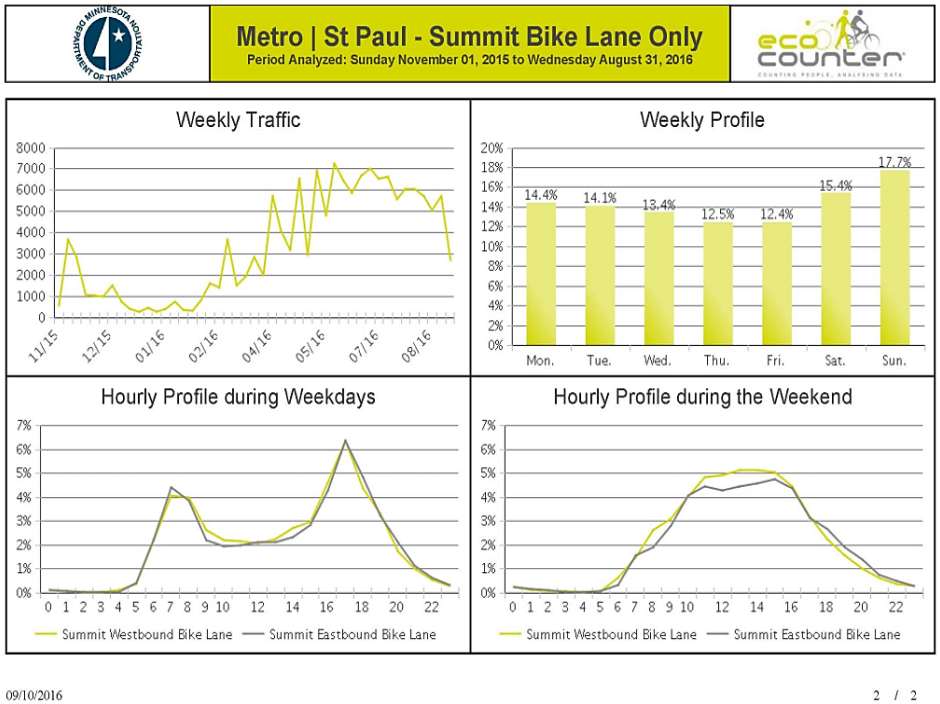


Figure 24: Eco-visio Standard Report from for Bicycle Traffic on Summit Avenue in St. Paul

6.3.2 Peak Volume Determination

Peak volume is the highest traffic volume generated at a specific location. Peak volumes can be determined for both hours and months or seasons and often vary by type of traffic and trip purpose.

The hour in which peak volume occurs varies based on primary user, type of facility and adjacent land use. Additionally, weather events and time of year impact bicycle and pedestrian traffic in ways not typical of motorized traffic. Peak volume varies by type of non-motorized travel and location.

To classify these patterns, practitioners are adapting methods first outlined by Miranda-Moreno et.al. (2013). Their methods involve construction of two traffic indices: (1) relative index of weekend vs. weekday traffic (WWI) and (2) relative index of morning (7-9am) to midday (11am-1pm) traffic (AMI) for weekdays only:

$$WWI = \frac{V_{we}}{V_{wd}} \tag{2}$$

$$AMI = \frac{V_{am}}{V_{mid}} \tag{3}$$

where V_{we} is mean daily weekend traffic volume, V_{wd} is mean daily weekday traffic volume, V_{am} is mean morning (7-9am) traffic volume, and V_{mid} is mean midday (11am-1pm) traffic volume.

MnDOT has adapted this approach and is using the following classification rules to analyze monitoring results and classify sites:

1. WWI < 1 and AMI > 1: *Commute*, because weekday traffic is higher than weekend traffic and weekday hourly patterns are commute-like.
2. WWI > 1 and AMI < 1: *Multipurpose*, because weekend traffic is higher and weekday hourly patterns are not commute-like.
3. WWI < 1 and AMI < 1: *Commute-mixed*, because weekday traffic is higher than weekend traffic but weekday hourly patterns do not indicate typical commuting
4. WWI > 1 and AMI > 1: *Multipurpose-mixed*, because weekend traffic is higher, although weekday hourly patterns are indicative of commuting.

Examples of these different patterns are shown in figures 25 - 28. Researchers are creating adjustment factors based on these patterns. The ultimate goal is to have enough continuous count locations to create adjustment factors based on pattern type that can be used to match extrapolation factors from continuous monitoring sites to short duration sites.

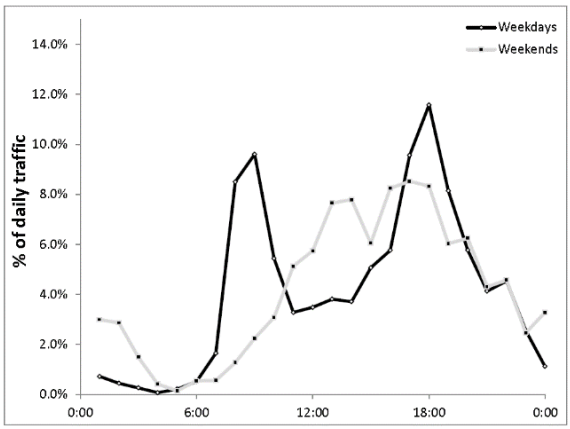


Figure 25: Commute Traffic Pattern

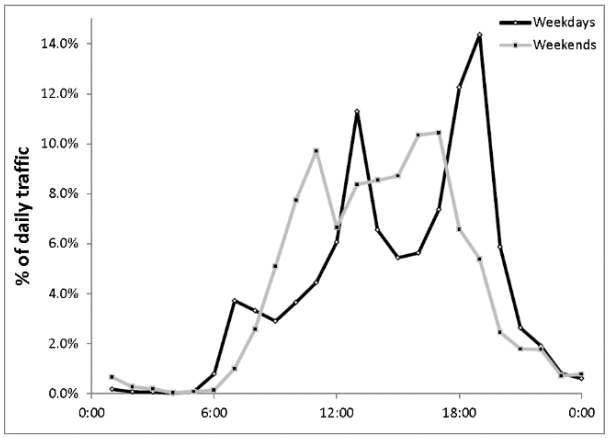


Figure 27: Commute-mixed Traffic Pattern

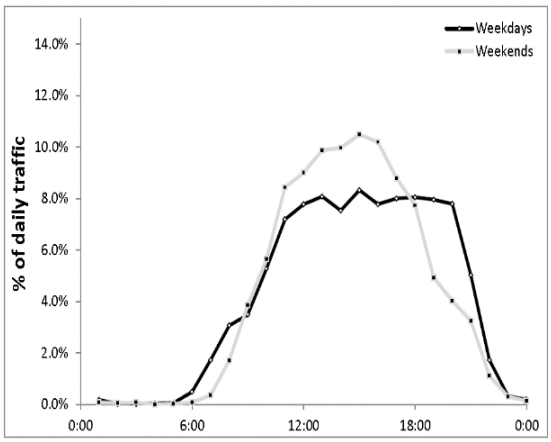


Figure 26: Multipurpose Traffic Pattern

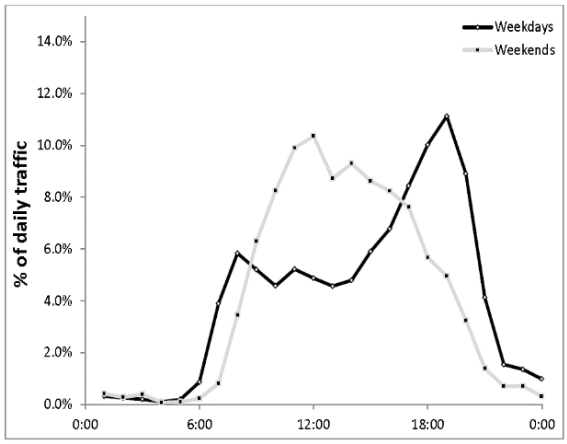


Figure 28: Multipurpose-mixed Traffic Pattern

Minnesota bicycle and pedestrian facilities experience highest use from May to September. An example of how average daily traffic changes based on time of year is shown in Figure 29. This figure illustrates the variation of volumes throughout the year at a variety of continuous monitoring sites in Minneapolis. The travel patterns at these sites range from multipurpose-mixed to commuter.

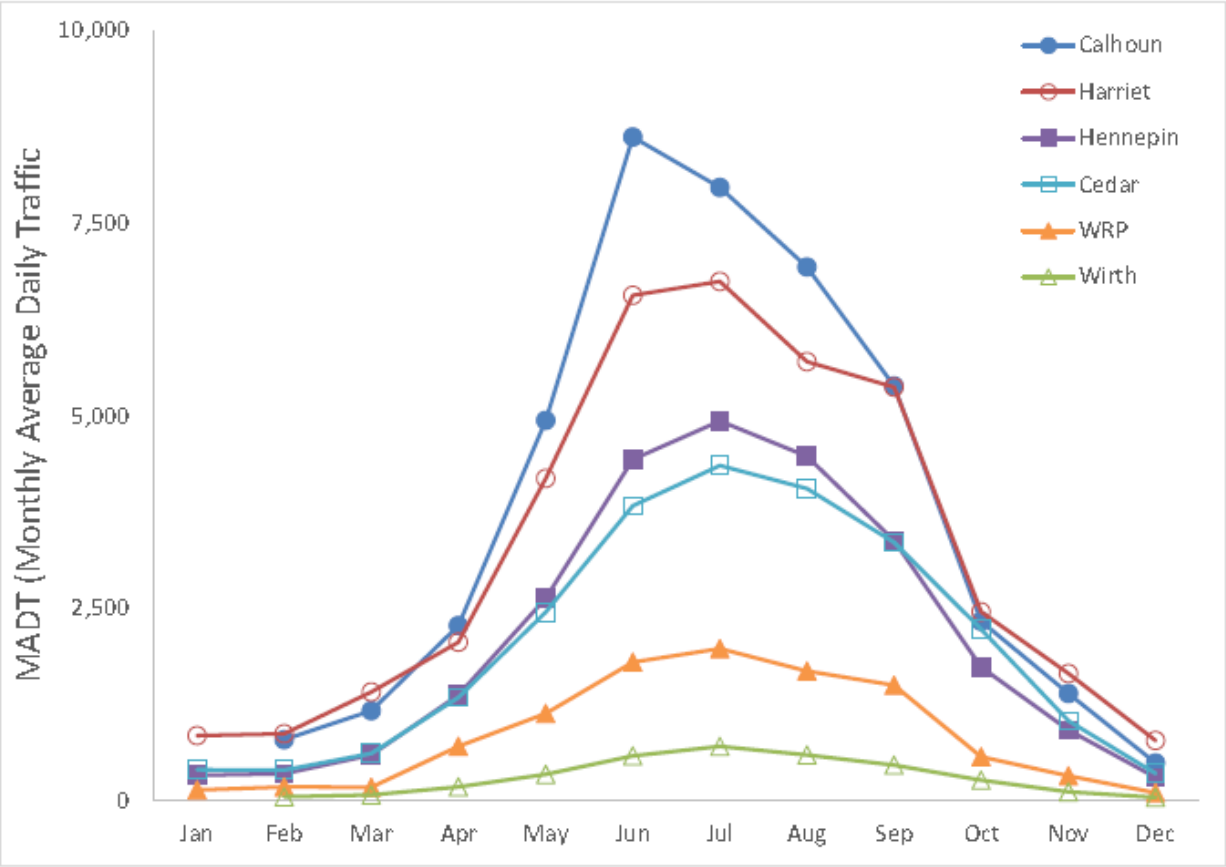


Figure 29: Average Daily Traffic by Month at Various Minneapolis Monitoring Sites

6.3.3 Adjustment Factors

Adjustment factors are statistics or ratios derived from continuous monitoring results to extrapolate short-term monitoring results into estimates of longer-term monitoring results. These factors can be computed from short duration counts of virtually any length (e.g., one-hour, two-hour, 48 hours, one-week, ten days). For motorized traffic, most short-duration samples are 48 hours long. The standard factoring approach involves application of day-of-week factors and month-of-year factors to obtain estimates of annual average daily traffic (AADT). First, day-of-week factors for the month of the sample are used to convert the 48-hour sample to a monthly average daily volume. Then, month-of-year factors are used to convert the monthly average daily traffic to the AADT. Appendix F presents an example of this method for extrapolating counts of traffic on a multiuse trail in Minnesota.

Although this standard approach can be used for non-motorized traffic, research has shown that an alternative approach called day-of-year factoring produces more accurate estimates of AADB from short-duration samples because it captures the effects of weather on non-motorized traffic volumes. In the day-of-year factoring approach, the ratio of the volume of a sample to AADB at a site is assumed to be the same as the ratio for a sample for the same period at a reference site to the AADB for the reference site. Appendix F also illustrates application of the day of year factoring method.

The day-of-year factoring approach is flexible and can be used in a variety of circumstances. In Minnesota, Hennepin County has used this approach to estimate AADB at short-duration count sites, and the Arrowhead Regional Development Commission has adapted this approach to estimate summertime average daily bicyclists on the Gitchi Gami Trail. Hennepin County launched a bicycle monitoring program in 2015 and completed 48-hour bicycle counts using pneumatic tubes at 31 on-road locations (Hennepin County 2016). The County then used day-of-year factors to estimate annual average daily bicyclists (AADB) from its short-duration counts. The County developed its factors from MnDOT's permanent monitoring station on Central Avenue in Minneapolis. To illustrate seasonal variation in traffic volumes, the County also used factors to estimate January and July ADB. Appendix G is an excerpt from Hennepin County's count report that summarizes its application of the day-of-year factoring method.

ARDC is using day-of-year factors from two automated control sites to estimate summertime average daily mixed-mode trail traffic from short-duration counts at 21 locations on the Gitchi-Gami Trail (ARDC 2015). In the summer of 2015, the ARDC used active infrared monitors to count trail users at 23 locations along the Gitchi-Gami Trail adjacent to Lake Superior in Lake and Cook Counties (ARDC 2016). Two of the sites were used as control sites for continuous automated monitoring. The ARDC completed counts of at least 10 days at the additional 21 locations. The ARDC then used day-of-year factors developed from their two control sites to extrapolate their short duration counts into estimates of summertime average daily traffic (SADT). The reason for focusing on SADT rather than AADT is that the Gitchi-Gami is not maintained (i.e., plowed) during winter months and trail managers are most interested in summertime use. Appendix G also includes an excerpt from ARDC's count report that summarizes its application of the day-of-year factoring method (ARDC 2016).

6.3.4 Data Archiving and Sharing

Procedures for archiving and sharing data are needed to ensure counts are available for planning and engineering applications and for future uses such as trend analyses. MnDOT and local jurisdictions are developing procedures for these purposes. As noted previously, the long-term objective is for MnDOT to integrate non-motorized traffic counts with motorized counts and used established protocols and systems for archiving and sharing. In the interim, MnDOT is using the Eco-Visio software provided by Eco-Counter and the spreadsheet templates developed data from other sensors to archive counts. In addition, MnDOT is sharing counts through an interactive, web-based map that displays all count locations and allows users to download count summaries from both the MnDOT spreadsheets and the Eco-Visio reports (Figure 30). The link for the interactive map is: http://arcg.is/2da0kqs.

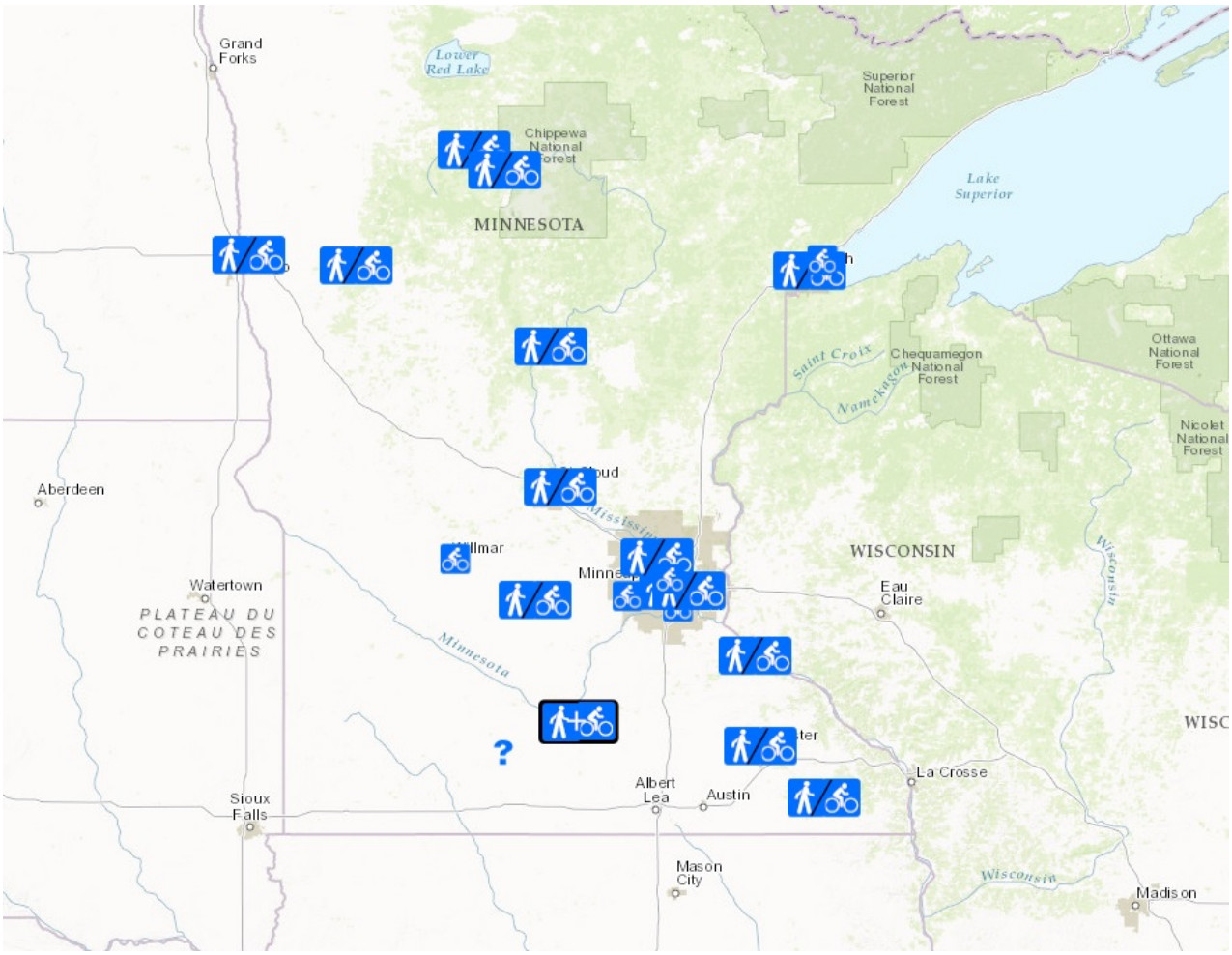


Figure 30: Screenshot of MnDOT Online, Interactive Map for Accessing Bicycle and Pedestrian Counts

Local agencies are developing similar procedures for archiving counts, including manual counts. The City of Minneapolis, which operates the largest and longest running manual count program in the state, maintains an integrated set of spreadsheets for archiving and sharing of data. Table 5 is an example of how an end user may organize data based on the approach used by the City of Minneapolis. Table 6 is an example of a table that summarizes trends in counts of bicyclists. Figures 31 and 32 illustrates different types of reports prepared from count data. The purpose of these examples is to show that many different types of reports can be prepared and to underscore the fact that the type of report needed depends on the specific planning or engineering problem that is being addressed.

Table 5: Example of Summarized Data for Multiple Count Locations

BICYCLIST TRAFFIC

		2 HOUR COUNT TOTAL									
ID	LOCATION	2007	2008	2009	2010	2011	2012	2013	2014	Change Since Previous	Change Since 2007
1	Ash St. Bridge over River	9	11	11	10	11	12	14	8	-43%	-11%
2	1st Av north of Main St.	32	29	31	29	39	40	43	36	-16%	13%
3	1st St S west of 3rd Av S	2	2	2	2	3	3	4	2	-50%	0%
4	Cty Rd J over Hwy 169	9	11	11	9	11	9	7	7	0%	-22%
5	River Parkway north of Main St.	24	33	28	18	27	25	32	33	3%	38%
6	Lake Ave west of 2nd Ave.	5	11	7	7	28	21	29	27	-7%	440%
7	Lake Trail west of River Trail	10	12	14	7	10	14	19	27	42%	170%
	Total	91	109	104	82	129	124	148	140	-5%	54%
	Change Since 2007	0%	20%	14%	-10%	42%	36%	63%	54%		
	Change Since Previous Year	0%	20%	-5%	-21%	57%	-4%	19%	-5%		

Table 6: Examples of Report on Trends in Counts of Bicyclists

BICYCLIST TRAFFIC

ID	LOCATION	FACILITY 2011	FACILITY 2012	FACILITY 2013	DATE 2011	DATE 2012	DATE 2013	METHOD 2011	METHOD 2012	METHOD 2013	% WOMEN 2011	% WOMEN 2012
1	Ash St. Bridge over River	shoulder	shoulder	bike lane	9/13/2011	9/10/2012	9/14/2013	manual	manual	manual	20%	25%
2	1st Av north of Main St.	none	none	none	9/13/2011	9/10/2012	9/14/2013	manual	trailer master	trailer master	10%	15%
3	1st St S west of 3rd Av S	shoulder	shoulder	shoulder	9/13/2011	9/10/2012	9/14/2013	manual	manual	eco counter	20%	23%
4	Cty Rd J over Hwy 169	side walk	side walk	side walk	9/13/2011	9/10/2012	9/14/2013	manual	manual	manual	40%	40%
5	River Parkway north of Main S	shoulder	shoulder	protected bike lane	9/13/2011	9/10/2012	9/14/2013	manual	trailer master	trailer master	20%	20%
6	Lake Ave west of 2nd Ave.	bike lane	bike lane	bike lane	9/13/2011	9/10/2012	9/14/2013	manual	manual	manual	30%	30%
7	Lake Trail west of River Trail	trail	trail	trail	9/13/2011	9/10/2012	9/14/2013	manual	manual	eco counter	45%	45%

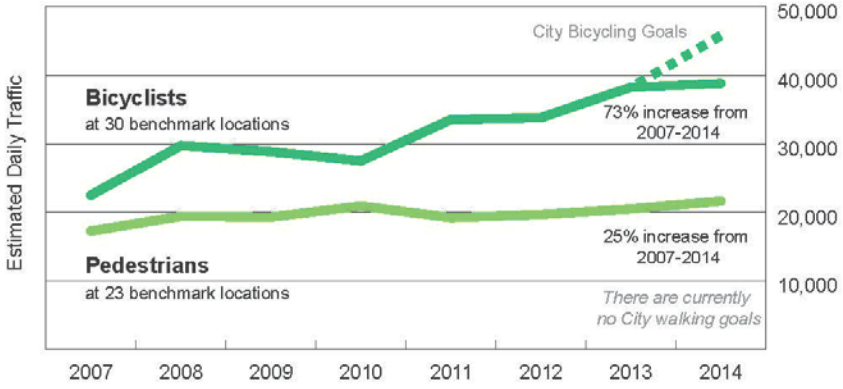


Figure 31: City of Minneapolis: Examples of Reports of Bicycle and Pedestrian Monitoring Results

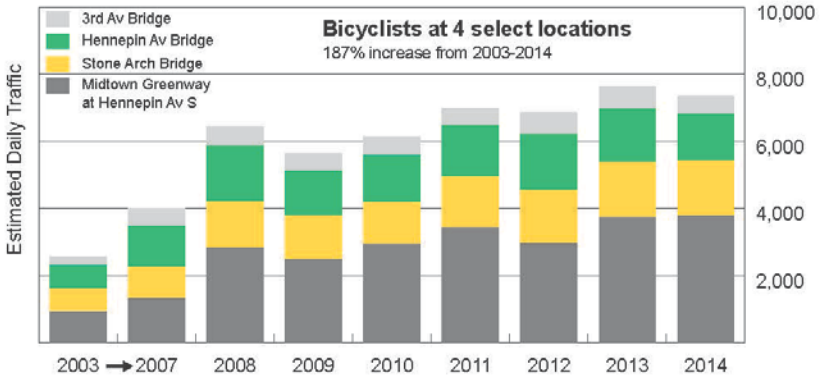


Figure 32: City of Minneapolis: Examples of Reports of Bicycle Counts Results

6.4 CASE STUDIES

The main goal of collecting bicycle and pedestrian traffic data is to increase the efficiency and safety of local transportation systems and facilities for all users. The data help transportation planners and traffic engineers make better decisions about investments and management of facilities. The impact of better data on the desired outcomes – more efficient transportation, fewer crashes, and fewer injuries and deaths – is difficult to document because outcomes like deaths are relatively rare and because multiple factors affect these outcomes, making it difficult to demonstrate cause and effect. However, it is possible to show that planners and engineers use bicycle and pedestrian traffic data to inform decision-making if data are available.

The cases presented here are brief examples of situations in Minnesota in which planners and engineers have used bicycle and pedestrian data to make better decisions. These cases illustrate different ways in which data can be used and why better data matters to the end-users – the people who use transportation facilities in Minnesota.

6.4.1 Need for Mid-block Crossings in Mankato, Minnesota

Problem. Pedestrian crossings on Monks Avenue near Minnesota State University in Mankato, Minnesota.

Agencies. City of Mankato, Blue Earth County State Health Improvement Program (SHIP).

Approach. Volunteers counted pedestrians for 25 hours in January 2015 to assess need for mid-block crossings as part of street reconstruction project slated for summer 2015. Reconstruction project already included other complete streets elements, including traffic slowing measures, bicycle lanes, and sidewalks.

Figure 33: Monks Avenue, Mankato – Need for Mid-block Crossing

Results. Counted 1,915 pedestrians crossing Monks Avenue in mornings without crossing treatments. Mankato City Engineering Department incorporated plans for three mid-block crossings in plans sent for bid for reconstruction project.

Source. Personal communication, Amber Dallman, Minnesota Department of Health; Kristin Friedrichs, Blue Earth County SHIP.

6.4.2 Validation of Pneumatic Tubes for Counting Bicycles in Mixed Traffic Flows

Problem. Assess potential for traffic monitoring agencies to use pneumatic tubes to count bicycle traffic in mixed traffic flows.

Agencies. Hennepin County, MnDOT, University of Minnesota.

Approach. Deployed TimeMark and Metrocount pneumatic tube counting devices in different configurations. Video-taped traffic flows, counted bicycle traffic on video manually, and compared counts from video and tubes counters using different classification algorithms. Estimated correction equations, and assessed potential for use of tubes to characterize bicycle traffic.

Results. The tube counters generally undercounted bicycles: relative error rates (i.e., differences in totals from tube counters and manual counts) for the observation periods ranged from 6% to 57% depending on the location, configuration of deployment, type of device, and classification algorithm (Table 7). Absolute error rates were substantially higher than relative error rates because false positive and negative errors sometimes offset each other. Inspection of video indicated most false negatives (i.e., undercounts) were due to occlusion, or bikes and vehicles crossing the tubes simultaneously. Calibration equations were estimated to adjust results. The practicability of using tube counters to count bicycles in mixed traffic flows depends on the applications and the relative need for accuracy in measurement. Deployment should be limited to bike lanes and no more than one traffic lane. Hennepin County used the results of the validation experiment to invest in new pneumatic tube counters to launch its new bicycle traffic monitoring program.

Table 7: Validation of Pneumatic Tube Counters for Bicycle Traffic in Mixed Traffic Flows

	Counter	Classification Algorithm*	Absolute Error	Relative Error
Portland Avenue	**MetroCount**	**ARX-Cycle**	**-16.70%**	**-6.30%**
		ARXm	**-12.10%**	**-9.80%**
		BOCO	**-25.30%**	**5.90%**
University Avenue Bike lane + 1 lane	MetroCount	ARX-Cycle	-65.20%	-26.50%
		ARXm	-71.00%	-24.60%
		BOCO	-65.80%	-19.30%
	TimeMark	15 Minute Bins	N/A	-48.30%
University Avenue Bike lane + 3 lanes	MetroCount	ARX-Cycle	-64.80%	-40.10%
		ARXm	-64.40%	-38.90%
		BOCO	-68.00%	-34.00%
	TimeMark	15 Minute Bins	N/A	-57.30%

*Results from tube counters include estimates of wheel base and speed that can be classified using different algorithms into bicycles and vehicles. ARX-Cycle is a classification algorithm for bicycles. ARX-m is an algorithm developed to separate bicyclists from the motorcycle classification using wheel based and speed. BOCO is a classification algorithm developed by a county engineer and a county planner in Boulder County, Colorado to extract bicycles from multiple vehicular classifications. TimeMark custom binned counts of bicycles were used with no additional reclassification.

Source.

Brosnan, M., Petesch, M., Pieper, J., Schumacher, S., and Lindsey, G. (2015, forthcoming). "Validation of Bicycle Counts from Pneumatic Tube Counters in Mixed Traffic Flows," *Transportation Research Record. Journal of the Transportation Research Board*.

Figure 34: Tubes in Hennepin County

6.4.3 Stop Signs on the Midtown Greenway

Problem. Determine traffic controls needed to minimize exposure to risk at five mid-block, at-grade crossings between a multiuse trail and residential cross streets.

Agency. Minneapolis Department of Public Works (DPW), Minneapolis, MN.

Approach. The Minneapolis DPW used inductive loop bicycle counters installed in the trail to count bicycle traffic and then compared bicycle traffic volumes to vehicular traffic volumes to determine whether trail traffic or the crossing road traffic should have the right of way.

Results. Counts revealed that average daily traffic on the Greenway trail was higher than the vehicular traffic at four of the five crossings (Table 8). The Minneapolis DPW changed traffic controls at each of the five crossings. At the four crossings where bicycle traffic exceeded vehicular traffic, stop signs facing the trail were removed, and different controls facing the street were installed. At three of the sites, stop signs facing the street were installed, and additional lighting was recommended. At the fourth site, a

yield sign with, an overhead flasher was installed. It also was recommended that four travel lanes be reduced to two travel lanes.

Table 8: Midtown Greenway Traffic Control Options (adapted from Anderson 2010)

Crossing	Type of X-ing	Street Class	Traffic Control Options[1.]	Street ADT[2.]	Grnwy EDT[3.]	Rec. Control	Other Recs.
James Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path –or– Stop/Yield Sign Facing Street	420	3,280	Stop Signs Facing the Street	Remove Stop Signs facing Trail Move Ex NB Stop Sign further North
Irving Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path –or– Stop/Yield Sign Facing Street	2,026	3,280	Stop Signs Facing the Street	Remove Stop Signs facing Trail Install Overhead Lighting Move NB Stop Sign Further North
Humboldt Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path –or– Stop/Yield Sign Facing Street	2,400	3,280	Stop Signs Facing the Street	Remove Stop Signs facing Trail Install Overhead Lighting
5th Avenue S	Mid-block Crossing	Local Street	Stop/Yield Sign Facing Path –or– Stop/Yield Sign Facing Street	1,680	2,900	Yield Signs Facing the Street	Remove Stop Signs Facing Trail
E 28th Street	Mid-block Crossing	B Minor Arterial	Stop Sign Facing Path –or– Traffic Signal	7,267	2,740	Overhead Flasher	Reduce Road from 4-Lanes to 2-Lanes at Crossing

Source.

Anderson, M. 2010 (February 15). "Memo: Midtown Greenway At-Grade Crossings." Minneapolis Department of Public Works, Traffic and Parking Services, Minneapolis, Minnesota.

Figure 35: Stop Signs on Midtown Greenway

6.4.4 Performance Measures for Multi-use Trails in Minneapolis

Problem. Determine annual average daily trail traffic (AADT) and trail miles traveled (TMT) on 80-mile multiuse trail network in Minneapolis.

Agencies. Minneapolis Park and Recreation Board (MPRB); Minneapolis Department of Public Works; University of Minnesota.

Approach. Implemented traffic monitoring protocols outlined in the FHWA *Traffic Monitoring Guide* using active infrared monitors. Monitoring was completed in 2013. Obtained mixed-mode traffic counts (i.e., undifferentiated or combined bicycle and pedestrian) for all segments in trail network. Used adjustment factors derived from six permanent, continuous monitoring sites to extrapolate short duration continuous counts on each segment. Estimated AADTT for each segment, and calculated TMT by multiplying segment AADTs times segment lengths.

Results. AADT on segments ranged from about 40 to more than 3,700, with summertime average daily traffic more than double AADT (Figure 36). Total distance traveled on the Minneapolis trail network in 2013 exceeded 28,000,000 miles.

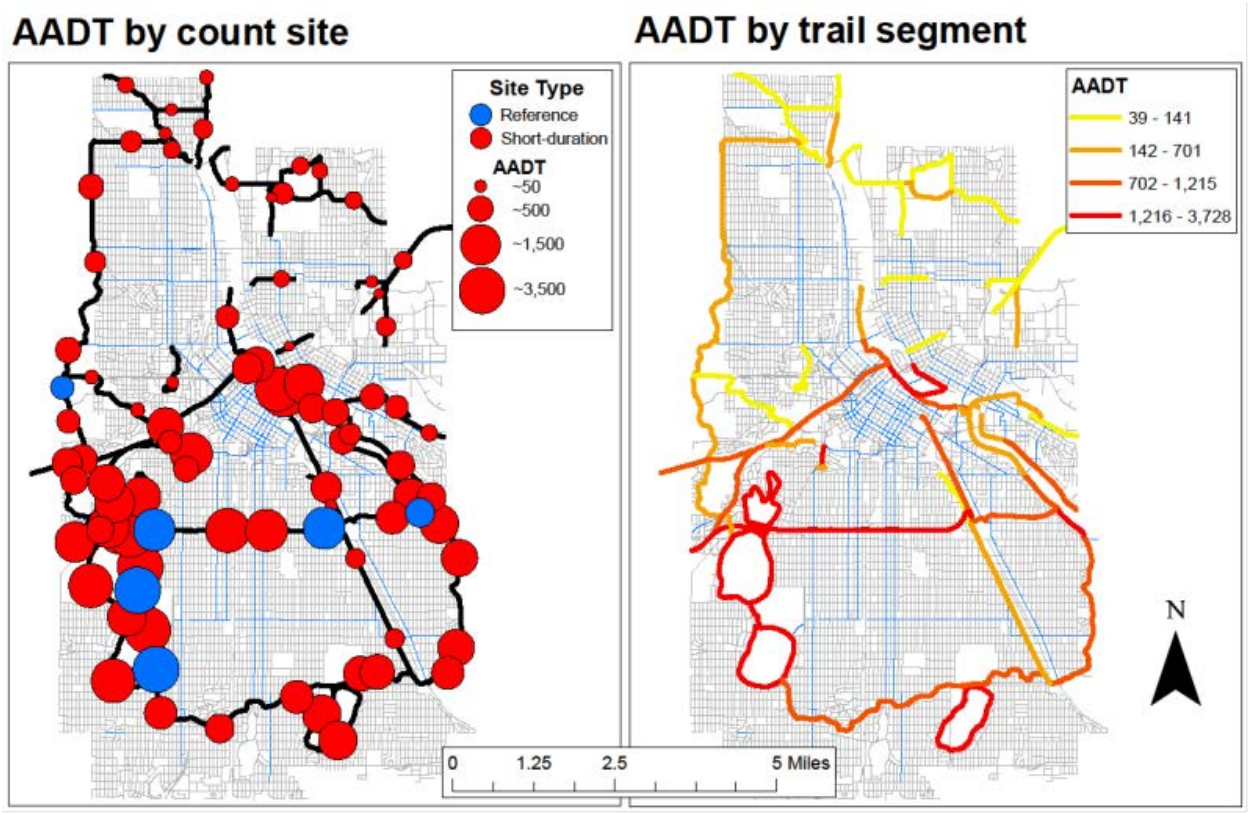


Figure 36: Minneapolis Trail AADTs by Count Site and Trail Segment (Lindsey et al. 2014)

Source.
Wang, J., Hankey, S., Wu, X., and Lindsey, G. (2016, forthcoming). "Monitoring and Modeling Urban Trail Traffic: Validation of Direct Demand Models in Minneapolis, MN and Columbus, OH. *Transportation Research Record. Journal of the Transportation Research Board*. 6.5.5 Signal Warrants at Urban Trail Crossings in Minneapolis (ongoing)

Problem. Assess need for traffic controls at all at-grade trail-road crossings in Minneapolis.

Agencies. Minneapolis Park and Recreation Board (MPRB); Minneapolis Department of Public Works; University of Minnesota.

Approach. Used 2013 trail traffic monitoring results of mixed-mode traffic (i.e., combined pedestrians and bicyclists) to apply warrants for traffic signals and high intensity activated crosswalks (HAWK beacons) in the Manual of Uniform Traffic Control Devices. Calculated annual and summertime peak hour trail traffic volumes by segment from short duration monitoring results. Determined peak hour vehicular traffic volumes from published data. Determined street-crossing widths by measuring from curb cut to curb cut in Google Earth. Compared estimates of peak hour trail traffic with peak hour vehicular traffic at 184 at-grade trail-road crossings. Applied MUTCD warrants, and compared assessment of need to existing controls. A limitation of the assessment is that MUTCD warrants are for pedestrians and only mixed-mode trail counts were available.

Results (Figure 36). Traffic volumes at most (> 93%) roadway-path crossings do not warrant traffic signals, irrespective of whether summertime weekday or weekend peak-hour traffic is considered. Nine crossings (5%) meet warrants for traffic signals based on weekday peak-hour volumes; 12 (6.5%) do so based on weekend traffic flows. Most of the crossings that meet the warrants already have signals. Of the 12 crossings that meet warrants based on weekend peak-hour flows, eight already have signals. Traffic signals may be needed at as many as four crossings.

Many more crossings meet the warrant requirements for pedestrian hybrid beacons (PHBs): 25% based on weekend peak-hour traffic volumes and 22% based on weekday peak-hour volumes (Table 2, Figures 1, 3). Among these crossings, the wider the road, the more likely the warrant is met. For example, of the 36 crossings wider than 72 feet, 61% met the requirements of the warrant with summertime, weekend peak-hour traffic volumes; approximately 38% of the crossings between 51 and 72 feet met warrant requirements, while just 24% of crossings between 35 and 50 feet met them. None of the local roads less than 35 feet wide met requirements for PHB warrants. Of the 46 crossings that met requirements of PHB warrants, 63% already have some type of traffic control. As many as 17 crossings, however, may warrant additional investigations to determine if PHB beacons are needed.

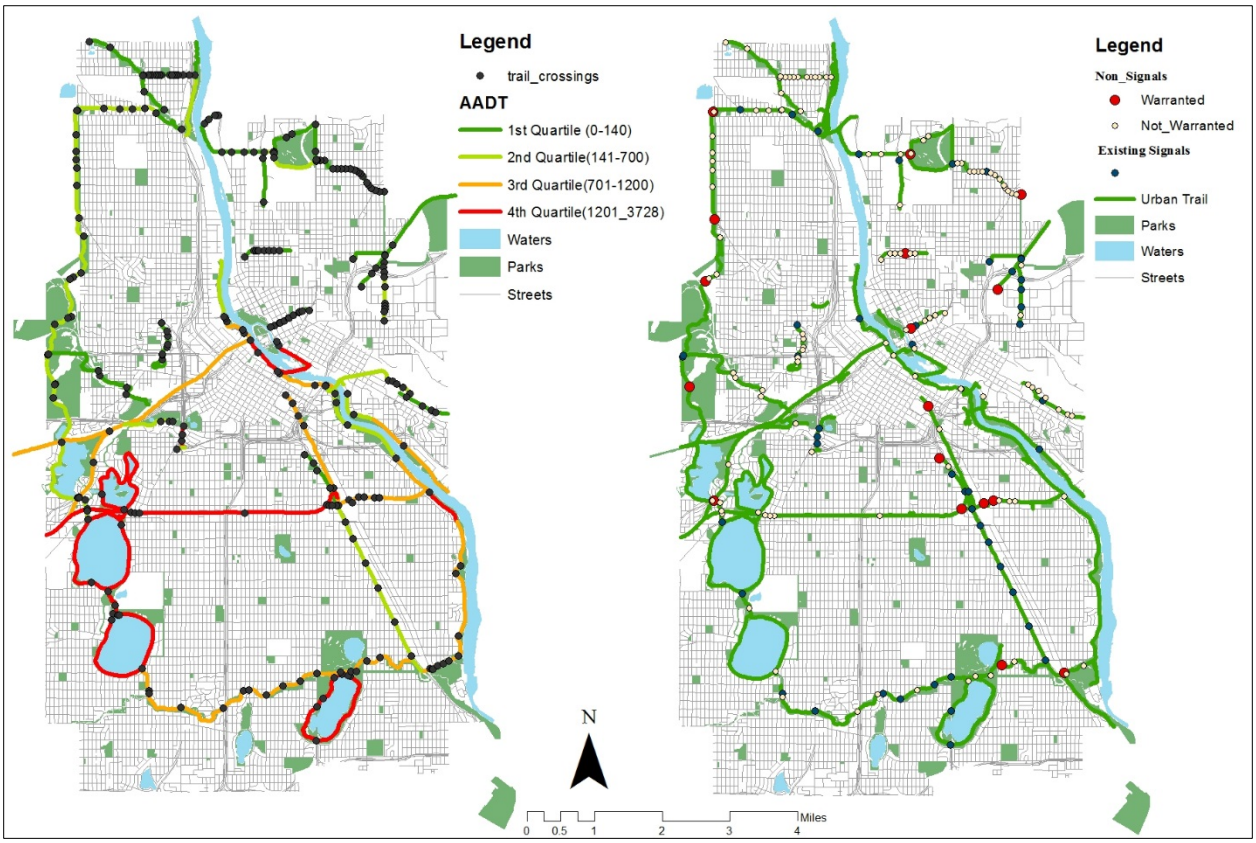


Figure 37: Minneapolis Trail Crossings, AADT by Quartiles, and Crossings that meet Warrants

Table 9: Results of Application Warrants for Traffic Signals and PHBs

				PHBs Signal Warrant			
		Traffic Signal Warrant	**Total**	Less than 35 Feet	35 - 50 Feet	51 - 72 Feet	Greater than 72 Feet
	N	184	184	67	49	32	36
Summer ADT Weekday	Exceed Warrant	9	41	0	11	11	19
	Existing Signal	7	25	0	5	4	16
	Warranted Signals	2	16	0	6	7	3
Summer ADT Weekend	Exceed Warrant	12	46	0	12	12	22
	Existing Signal	8	29	0	5	5	19
	Warranted Signals	4	17	0	7	7	3

Source.
Lindsey, G., Peterka, M., and Hankey, S. (2015). "Assessing the Need for Traffic Controls Using Trail Monitoring Data: Preliminary Results." Unpublished analyses: Contact G. Lindsey, University of Minnesota, Humphrey School of Public Affairs, Minneapolis, MN).

CHAPTER 7: CONCLUSIONS AND NEXT STEPS

MnDOT and many local jurisdictions throughout Minnesota have initiated bicycle and pedestrian monitoring programs and now are using monitoring results to inform planning, engineering, and policy-making. MnDOT has established a network of 29 automated, continuous counters, including at least two counters in each of its eight administrative districts, to provide information about traffic volumes and patterns on roads, sidewalks, and trails. MnDOT also has completed short-duration counts at dozens of locations in the state and established an equipment loan program that makes counters available to local units of government and nonprofit organizations in each region of Minnesota. Monitoring results from all permanent counters are available online with only one day lag time, and results from both permanent counters and short duration sites are being archived in an interactive, online website that planners and engineers can access. MnDOT hosts annual training sessions for local jurisdictions, and MnDOT has long-term plans to integrate counts taken by both MnDOT and local jurisdictions into databases now used exclusively for motorized traffic data.

Local jurisdictions, including regional planning commissions, counties, cities, and park districts are implementing monitoring programs. The ARDC is using active infrared sensors to monitor traffic on the Gitchi Gami Trail in Lake and Cook Counties (ARDC 2016). Hennepin County is using pneumatic tubes to monitor bicycle traffic at 60 on-road locations and applying extrapolation factors from a MnDOT permanent counter to estimate AADB (ARDC 2016). Minneapolis operates one of the most comprehensive manual count programs in the U.S. and is installing automated monitors to augment this program. St. Paul also has implemented an ambitious manual count program and has collaborated with MnDOT in the installation of automated counters. Automated monitors in cities such as Duluth, Mankato, and Rochester are generating data, which is being used to inform planning and engineering.

This manual reflects the knowledge acquired by MnDOT and its partners from monitoring efforts. While this manual provides information on all aspects of operating a monitoring program, from site selection to data analysis and archiving, it remains a dynamic guiding document. As MnDOT gains additional experience and data from multiple years of continuous monitoring are analyzed, effective practices will be indentified, and the manual will be updated. MnDOT staff are available to provide guidance and support for efforts to implement new bicycle and pedestrian monitoring programs.

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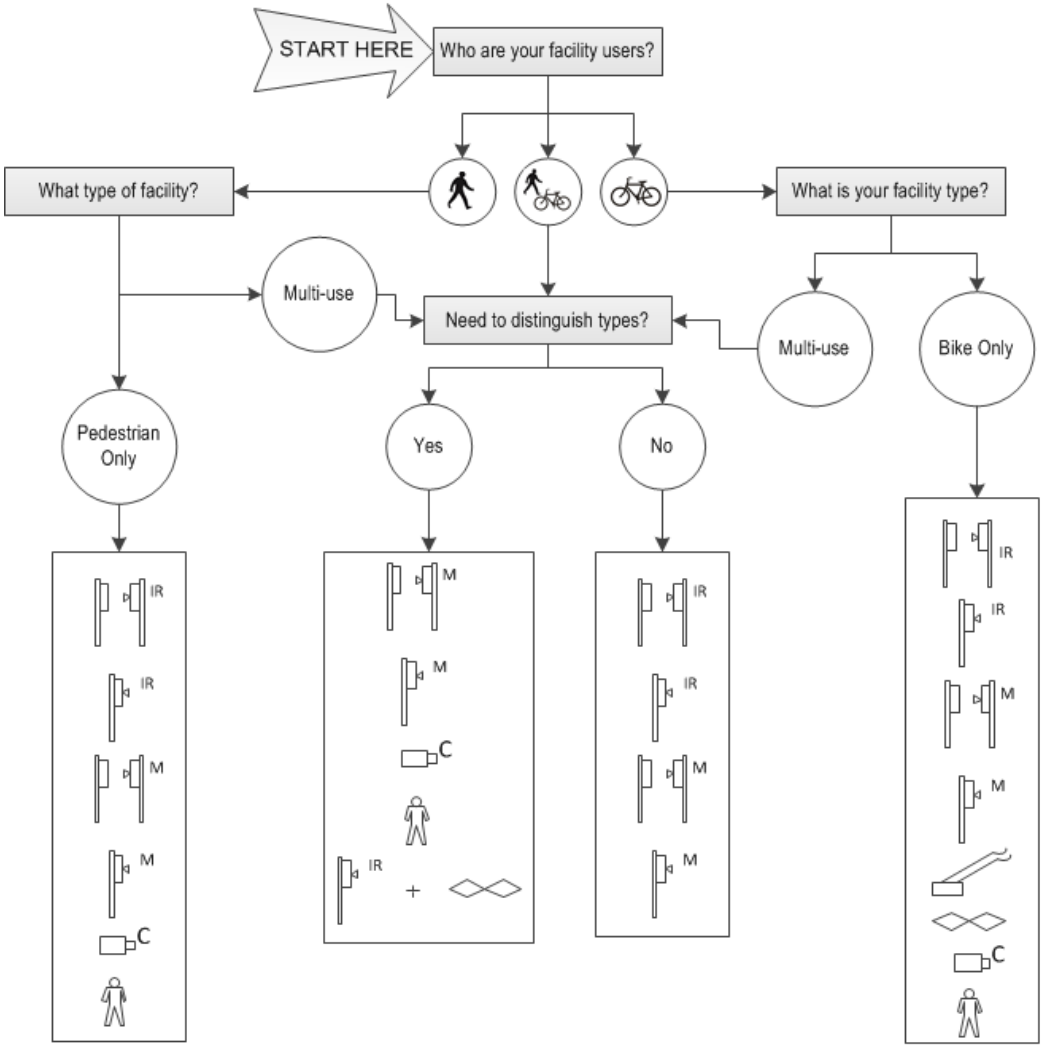
APPENDIX A – SENSOR SELECTION FLOW CHART



LEGEND

Active Infrared - Requires mounting equipment on each side of detection area. Review site to ensure it can accommodate sensor and receiver placement. Use for permanent or short duration counts.

Camera Images - Manual observation of video. Use for short duration counts; cost prohibitive for permanent counts.

Dual Microwave - Requires mounting equipment on each side of detection area. Review site to ensure it can accommodate sensor and receiver placement. Use for permanent or short duration counts.

Inductive Loop - Typically requires a unique loop configuration separate from motor vehicle loops, especially in a traffic lane shared by bicycles and motor vehicles. Use for permanent counts when sawcut in pavement; temporary counts for unpaved surfaces or if taped to pavement.

Manual - Use for short duration counts; cost prohibitive for permanent counts.

Microwave - Requires specific mounting configuration to avoid detection of background movement (nearby cars, bicycles or pedestrians). Ensure the product chosen is able to distinguish user type if installing on a mixed use trail or consider using dual technologies. Use for permanent or short duration counts.

Passive Infrared - Requires specific mounting configuration to avoid detection of background movement (nearby cars, bicycles or pedestrians). Ensure the product chosen is able to distinguish user type if installing on a mixed use trail or consider using dual technologies. Use for permanent or short duration counts.

Pneumatic Tubes - For bicycle detection only. Requires specific site configuration to avoid detection of motorized vehicles. Use for short duration counts; not robust for permanent installation.

APPENDIX B – MNDOT STANDARD MANUAL SCREENLINE COUNT FORM

MNDOT STANDARD MANUAL SCREENLINE COUNT FORM *DRAFT July 23, 2012*

Time		Bicyclists				Pedestrians							
						Unassisted				Assisted (skaters, wheelchairs, etc.)			
		Male		Female		Male		Female		Male		Female	
Hour	Minutes	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
	:00-:15												
	:15-:30												
	:30-:45												
	:45-:00												
Hour 1 Subtotal													
	:00-:15												
	:15-:30												
	:30-:45												
	:45-:00												
Hour 2 Subtotal													
Hour 1 + Hour 2 Total													
Two Hour Total – All Attributes													

2012 Fall Pilot Form

APPENDIX C – SENSOR ACCURACY ASSESSMENT

Whether manual counts are made in the field or in the office from video, the key steps in assessing sensor accuracy include:

1. Compare hourly totals from the manual and automated counts,
2. Calculate the percentage difference for each hour, and
3. Compute the average percentage error per hour.

The average percentage error provides a useful estimate of the relative accuracy of the sensor.

A useful step in the validation process is to create a scatterplot of the hourly automated and manual plots so their relationship can inspected visually. For example, Figure C1 is a scatterplot of counts from pneumatic tubes in two locations in Minneapolis and manual counts from video. As is evident from looking at the values of points in the graph, the hourly totals from the tube counters are lower than the hourly manual counts. In other words, the tube counters are undercounting. From inspection of the video, researchers determined occlusion – or multiple bicycles and/or vehicles passing simultaneously.

Figure C1 also includes lines that illustrate the relationship between the automated and manual counts. The equations for the lines can be interpreted as hourly "correction" equations. That is, the hourly totals from the automated counters can be adjusted using the equations to obtain a better estimate of the actual bicycle traffic volumes. Separate equations are included for each of the locations, and a more general equation based on combined data from both sites also is included. If an analyst wanted to adjust automated counts from a particular site, the equation for that site would be the best equation to use, but if, for example, an analyst wanted to adjust data from a third site for which no validation counts had been taken, the equation based on the combined data might be a better choice. The case studies in Section 6.5 of this guide includes more details on the use of correction equations.

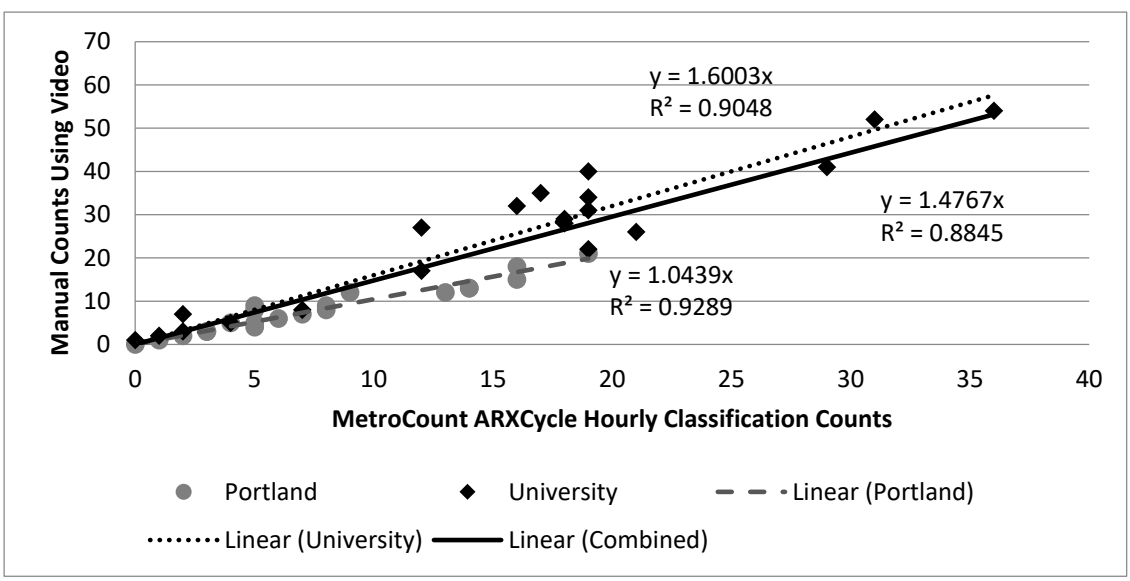


Figure C-1: Scatterplot of validation counts for tube counters at two locations

Additional Considerations in Assessing Sensor Accuracy

The three general steps in assessing accuracy listed above (comparing hourly totals from automated and manual counts, computing percentage differences, and calculating the average hourly error) hold for any device, but implementation of these steps may vary depending on the features of the sensor and the ways in which the sensor stores and reports data. For example, some sensors report the exact time a cyclist or pedestrian was counted, while other sensors only report data in 15-minute, hourly, or other time "bins" (e.g., 8:00 a.m. – 8:14:59 a.m.). Some devices (e.g., integrated bicycle and pedestrian sensors) provide separate counts for cyclists and pedestrians), while pneumatic tube counters used to classify vehicles in mixed traffic flows typically offer users their choice of classification algorithms to interpret air pulses and classify traffic, including bicycles. Understanding of these types of factors is important in validating counts and assessing accuracy.

Data validation generally is easiest and potentially more accurate if time stamped rather than "binned" data is used. This is because observers can determine and compare time stamps from the sensor and video and be more precise in determination of which traffic events were counted. For example, some pneumatic tube counters can be set to report traffic events with the individual time stamps (to the second) or in 15-, 30-, or 60-minute bins. For purposes of operations, many agencies set the devices to report hourly totals because this minimizes the post-processing step of aggregating time stamps into hourly totals for analysis. However, if only hourly totals are available, the quality of validation that can be accomplished is relatively low because observers cannot determine why counts were missed (or over-counts occurred). Some devices (e.g., Eco-counters) only report binned data. If working with binned data, it is best to select the shortest period available for purposes of validation (e.g., 15 minutes). These totals then can be aggregated after data validation is complete.

An additional time-related factor that complicates validation has to do with differences in time between the sensors internal clocks, the video tape recorders internal clock, and the watches or time-pieces used by observers. Prior to initiating observation or taping, it is important to compare times so that small differences, which can affect outcomes, can be reconciled. Knowing these time differences can speed up the identification of matches and overall validation process.

Different technologies present different options for classifying and reporting traffic events. In general, three general types of output will be generated, depending on the technology and the needs of the user:

- Mode-specific traffic counts. These types of counts provide estimates of traffic volumes for specific modes. Examples include bicycle counts from inductive loops in streets and separate bicycle and pedestrian counts from microwave systems or integrated infrared and inductive loop systems. These counts cannot be reclassified, although the estimates can be adjusted for systematic under- or over-counts.
- "Mixed-mode" traffic counts that cannot be differentiated. These types of counts yield information about traffic volumes but not mode (e.g., bicycle or pedestrian, or bicycle or

motorized vehicle). For example, mixed-mode counts are generated by infrared (active or passive) sensors that are used to count on facilities where there is both bicycle and pedestrian traffic. Similarly, when single tubes are deployed on roads with mixed traffic flows, they may count bicycles as part of overall traffic, but the number bicycles cannot be determined (dual tubes are required for classification counts). From the perspective of monitoring non-motorized transportation, mixed-mode counts on shared use paths or sidewalks will be encountered and used most often.

- "Mixed-mode" traffic counts that can be classified into separate modes using classification algorithms. For example, manufacturers of pneumatic tubes typically include multiple algorithms for classification of output (i.e., axle base, vehicle speed) from tubes. Some of these classification algorithms include criteria for separating bicycles from motorized vehicles. For example, while some algorithms classify all vehicles with axle bases less than six feet as motorcycles, some classify all vehicles with axle bases less than four feet as bicycles and use other criteria to classify motorcycles. The instruction manuals for tube counters like MetroCount and TimeMark devices contain information regarding specific vehicle classification methods.

Analysts also can develop their own classification algorithms for interpreting counter output. County staff in Boulder County, Colorado, for example, developed algorithms for identifying bicycles from a variety of different vehicle classifications. When validating counts from devices that require classification of output to obtain mode-specific information, results will vary depending on the specific classification algorithm that is used. The case study of the use of counts in 6.5.1 illustrates the results of validation using different classification algorithm.

APPENDIX D – QUALITY ASSURANCE / QUALITY CONTROL

All major guidance documents on bicycle and pedestrian data collection stress the importance of quality assurance/quality control (QA/QC; FHWA 2013, Ryus et al. 2014, Turner et al. 2013). Adapting procedures used in QA/QC for motorized vehicle traffic data, Turner (2013) advises the following steps:

- visual inspection of data,
- assessment of potential for outliers using a pre-specified cutoff criterion,
- assessment of zero counts, and
- use of professional engineering judgment to make final decisions about counts to include or censor from a dataset.

The following example illustrates Turner's basic approach using data from six of MnDOT's permanent monitoring stations (Table D-1; Vorvick and Lindsey 2016). The locations include three installations of inductive loops on roadways measuring bikes and three installations of integrated inductive loop and passive infrared devices at three locations on multiuse trails. Two sensors were installed at each roadway location to count bicycles traveling in opposite directions.

Approximately one year of data was analyzed for each site. Across locations, average daily traffic (ADT) ranged from 19 to 972 for bikes, and 75 to 787 for pedestrians. The traffic flows are characterized by high seasonality; to account for this, the data were separated into winter (October - March) and summer (April – September) datasets for some analyses. Summer average daily bicyclists (ADB) were an average of 154% of ADB for the entire dataset. Winter ADB were an average of 23% of ADB for the entire dataset. Seasonality was less pronounced in the pedestrian traffic on trails. Summer and winter average daily pedestrians (ADP) averaged, respectively 136% and 47% of ADP for the dataset.

Table D-1 Monitoring Sites and Sensors Included in QA/QC Example (Vorvick and Lindsey 2016)

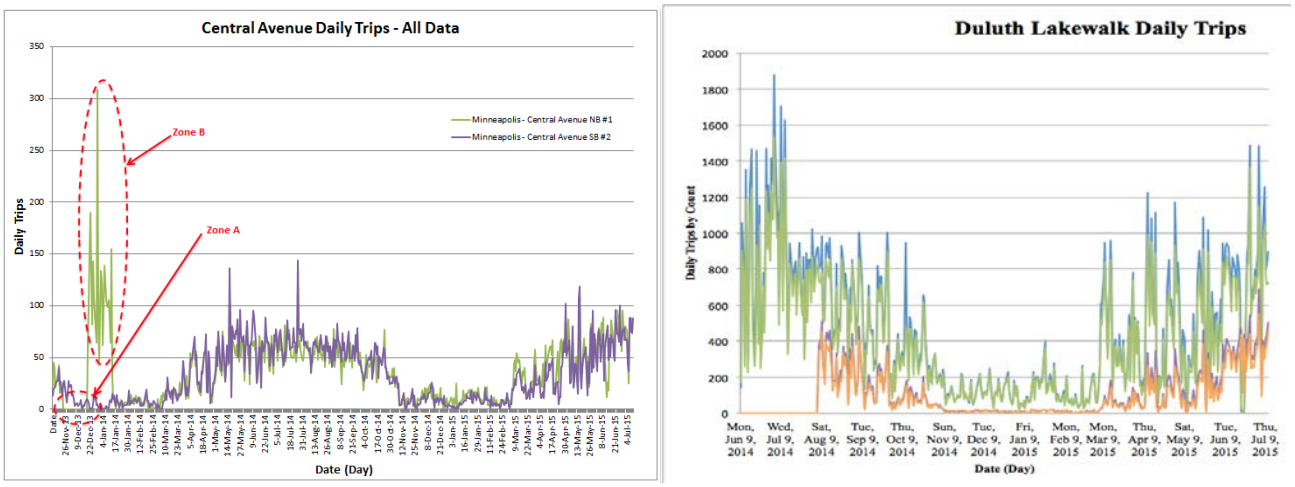
Site	Location	Name	Description	Sensor	Type	Mode	Data Days	Raw ADT
1	NE Mpls	Central Ave NB	Shoulder - Bike Lane	1	ZELT inductive loops with manhole	Bike	366	43
		Central Ave SB	Shoulder - Bike Lane	2	ZELT inductive loops with manhole	Bike	367	37
2	Duluth Kitchi Gami Park	Scenic 61 EB	Hwy Shoulder	3	ZELT inductive loops with manhole	Bike	366	22
		Scenic 61 WB	Hwy Shoulder	4	ZELT inductive loops with manhole	Bike	366	19
3	Eagan	TH 13 NB	Hwy Shoulder	5	ZELT inductive loops with manhole	Bike	366	21
		TH 13 SB	Hwy Shoulder	6	ZELT inductive loops with manhole	Bike	366	20
4	Mpls W. River Parkway	W River Greenway	Park Trail	7	3-Loop Wooden Post MULTI	Bike	396	972
				8	PYRO Zoom	Ped	396	413
5	Rochester Cascade Lake Park	Macnamara Bridge	Park Trail	9	2-loop ZELT	Bike	367	129
				10	mid-range PYRO	Ped	367	75
6	Duluth Canal Park	Lakewalk Multi	Park Trail	11	2-loop ZELT	Bike	368	257
				12	mid-range PYRO	Ped	368	787

Visual inspection is the first step in QA/QC, though if there are many locations, it is time consuming and may not always be possible. Visual inspection can help confirm the date a counter was installed. For example, some devices (e.g., Eco-Counter) may be inadvertently active prior to installation, resulting in a long string of zero counts prior to the first days actual counts are recorded. Visual inspection can identify and censor these types of counts.

Figure D-1 illustrates visual editing on daily data for two locations, Central Avenue in Minneapolis and the Lake Walk in Duluth, a shared-use path for both bicyclists and pedestrians. Visual inspection identified suspiciously high data and runs or “zero days” in mid-season. Data from three (25%) of the 12 sensors at the six locations required suppression or editing. The days that required editing included both winter and summer days: 2 winter days for one sensor; 11 summer and 2 winter days for a second

sensor, and 52 days for a third sensor. The maximum of 52 days is equivalent to 14% of the days in a year.

Figure D-1 also summarizes the effects of data suppression on estimates of ADB and ADP. For the Central Avenue location, visual editing reduced the estimate of ADB about 10.5% from 43 to 38.5. Suppressing invalid counts W. River Parkway multiuse trail slightly increased estimates of average daily traffic.



Summary Table

Location	Sensor	Mode	ADT	Direction	VE Day	VE Suppressed Days	VE ADT	VE % of Raw ADT
Central Avenue	1	Bike	AADT	NB	315	52	38.5	89%
West River Greenway	7	Bike	AADT	Two-Way	394	2	977.1	101%
	8	Ped	AADT	Two-Way	383	13	426.8	103%

Figure D-1 Examples of Invalid Daily Counts Identified with Visual Inspection

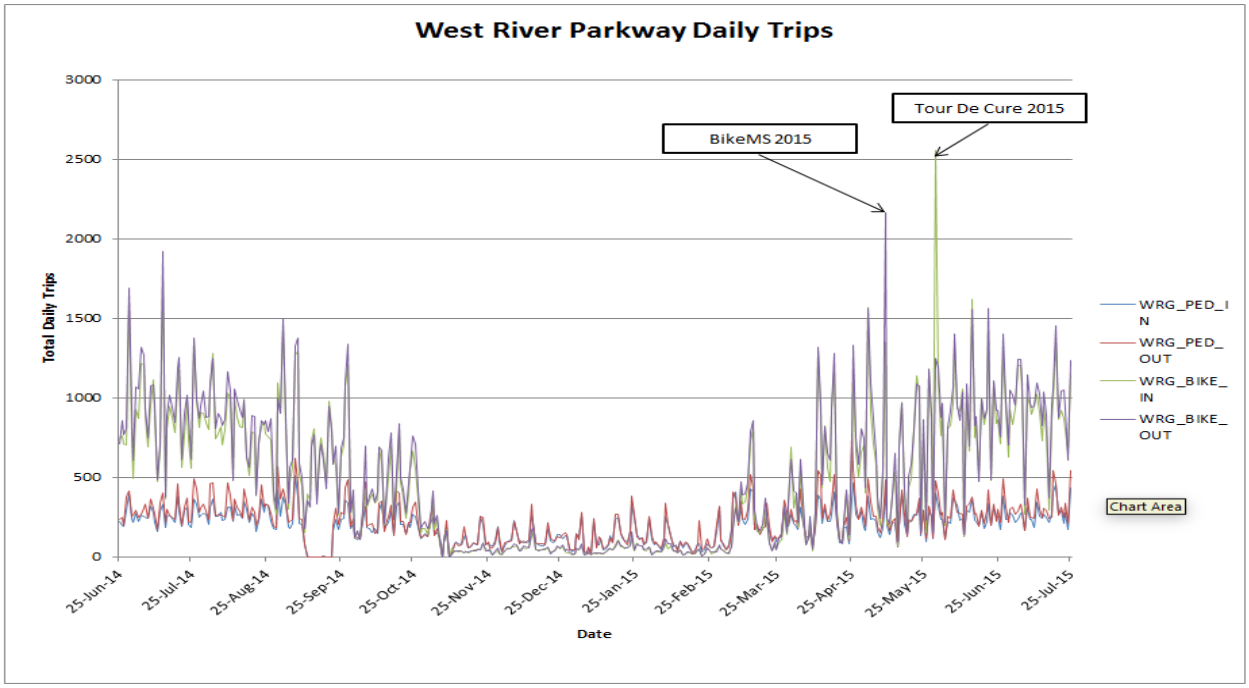
Following visual editing, the second general step in QA/QC involves censoring of counts with values above some pre-specified criterion that are believed to have a high probability of being invalid. For example, analysts may censor counts with values that more than two or three standard deviations above the mean.

Figure D-2 illustrates the effects of suppressing all values greater than two standard deviations above the mean on estimates of average daily traffic, both before and after visual editing. It is useful to explore both cases because visual editing first changes the dataset and therefore affects which values are suppressed as outliers. Because this step involves censoring high values, it reduces estimates of the average daily traffic. For these twelve sensors, this approach to controlling for outliers resulted in suppression of 146 days of counts, roughly 3% of days in the raw dataset. Across all sensors, ADB and

ADP were reduced an average 6% and 9% from raw values, respectively. The effects of this approach have greater effects on estimates of winter ADB and ADP than on summer ADB and ADP. Specifically, if "outliers" are censored, summer and winter ADB drop 5% and 21% respectively; summer and winter ADP dropped 7% and 20%, respectively.

One limitation of this approach is that these "outliers" may actually be valid counts that, depending on the purpose of the analysis, should be retained. Web searches can identify events that match many of the identified spikes. For example, in Figure D-2, two daily counts that appear to be outliers and would be censored if thresholds for censoring were followed blindly. These high counts occurred on days of events, specifically, charity rides for multiple sclerosis and diabetes. Another limitation is that this approach may miss invalid counts below the threshold. For example, some of the high values recorded on Central Avenue through visual inspection were below the threshold of two standard deviations but actually invalid. These types of problems (i.e., censoring valid counts and retaining invalid counts) cannot be avoided completely if threshold criteria for censoring values are followed blindly.

A third step in QA/QC is to assess the validity of counts of zero, or no bicycle or pedestrian traffic. For motorized vehicles on roadways, daily counts of zero and long consecutive hours of zero counts are relatively rare, so it is a common practice to flag these types of zero counts for inspection and/or suppression. Daily counts and long strings of hourly counts of zero are more common for bicycle and pedestrian traffic, especially on facilities in rural areas in winter when volumes may be quite low. Particularly because of the high seasonality of bicycle and pedestrian traffic, the type of decisions rules for counts of zero for motorized traffic cannot be applied to non-motorized traffic.



					2Sigma Spike Edit				Post VE 2Sigma Spike Edit				
Facility	Location	Sensor	Mode	Direction	2S Days	2S Suppressed Days	2S ADT	2S % of Raw ADT	VE2S Days	VE2S Suppressed Days	VE 2S ADT	VE2S % of VE ADT	
Roadside	Central Avenue	1	Bike	NB	346	20	41.2	96%	338	28	37.8	98%	98%
		2		SB	355	12	35.7	97%					97%
	Duluth Scenic 61	3	Bike	EB	353	13	20.0	90%					90%
		4		WB	355	11	17.4	90%					90%
	Eagan TH 13	5	Bike	NB	361	5	20.6	97%					97%
		6	Bike	SB	354	12	18.9	95%					95%
Multiuse Trail	West River Greenway	7	Bike	2-Way	385	16	909.4	94%	378	18	925.6	95%	95%
		8	Ped	2-Way	384	15	395.2	96%	366	30	405.6	95%	95%
	Rochester Macnamara Bridge	9	Bike	2-Way	359	8	122.4	95%					95%
		10	Ped	2-Way	356	11	63.2	84%					84%
	Duluth Lakewalk	11	Bike	2-Way	358	10	244.1	95%					95%
		12	Ped	2-Way	355	13	729.9	93%					93%

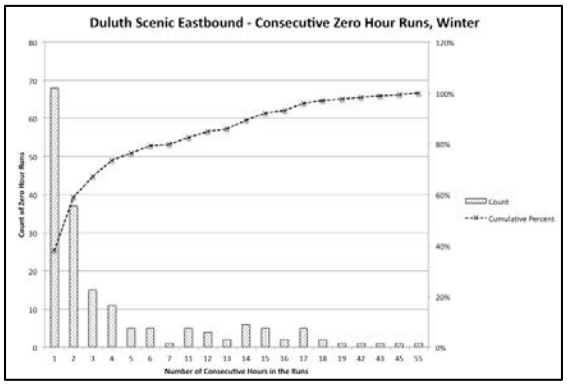
146

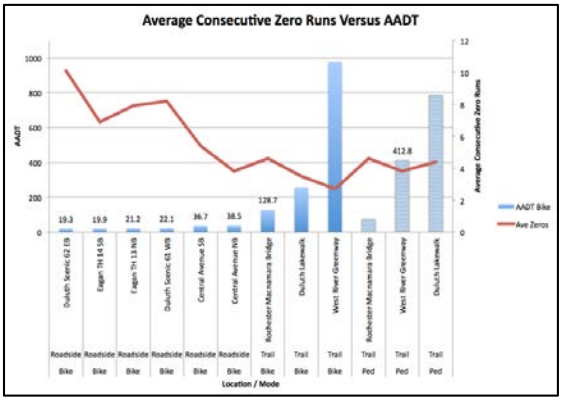
Ave Total Bike vs Raw	94%	Ave Total Bike vs Raw	95%
Ave Total Ped vs Raw	91%	Ave Total Ped vs Raw	91%
Ave Summer Bike vs Raw	95%	Ave Summer Bike vs Raw	95%
Ave Winter Bike vs Raw	79%	Ave Winter Bike vs Raw	79%
Ave Summer Ped vs Raw	93%	Ave Summer Ped vs Raw	92%
Ave Winter Ped Vs Raw	80%	Ave Winter Ped Vs Raw	80%

Figure D-2 Effects of Censoring Data Spikes Greater Than 2 Standard Deviations above the Mean (Vorvick and Lindsey 2016)

The challenges of assessing the validity of hourly counts of zero are illustrated in Figure D-3 for sensors on Scenic Highway 61 outside Duluth MN. For this example, a run of zero hours is defined by the maximum number of consecutive hours with counts of zero (e.g., eight consecutive hours of zero is a run of eight hours). One-hour runs of zero counts occurred most frequently (n=68), but most zero hours occurred in longer runs. Four zero runs of greater than 40 hours occurred, including one run of 55 zero

hours. Most of these long runs occurred in the winter when temperatures in northern Minnesota are very cold and snow many accumulate on road shoulders. Eco-Counter reports that inductive loops can record bicycles through at least four inches of snow. However, it is very difficult to know with certainty whether these runs of zeroes are valid or invalid. Retaining hourly or daily zeroes will lower estimates of average daily traffic, perhaps erroneously, while censoring them may artificially raise them. Hence, professional judgment is necessary when determining whether to suppress or censor hourly counts of zero.





					Consec Zero Hour Runs					
Facility	Location	Sensor	Mode	Direction	CZR Raw			CZR Post Visual Edit		
					Max	Ave		Max	Ave	
Roadside	**Central Avenue**	**1**	**Bike**	**NB**	**224**	**3.8**		**37**	**3.8**	
		2		**SB**	**54**	**5.4**				
	Duluth Scenic 61	**3**	**Bike**	**EB**	**193**	**8.2**				
		4		**WB**	**303**	**10.1**				
	Eagan TH 13	**5**	**Bike**	**NB**	**199**	**7.9**				
		6	**Bike**	**SB**	**199**	**6.9**				
Multiuse Trail	**West River Greenway**	**7**	**Bike**	**2-Way**	**14**	**2.7**		**14**	**2.7**	
		8	**Ped**	**2-Way**	**153**	**4.2**		**12**	**3.8**	
	Rochester Macnamara Bridge	**9**	**Bike**	**2-Way**	**63**	**4.6**				
		10	**Ped**	**2-Way**	**36**	**4.6**				
	Duluth Lakewalk	**11**	**Bike**	**2-Way**	**36**	**3.5**				
		12	**Ped**	**2-Way**	**24**	**4.4**				

Ave Annual Bike CZR	5.9		5.9	
Ave Annual Ped CZR	4.4		4.3	
Ave Summer Bike		60%		60%
Ave Winter Bike		131%		128%
Ave Summer Ped		82%		76%
Ave Winter Ped		95%		99%

Figure D-3 Consecutive Zero Count Hourly Runs

Several observations can be drawn from this example. Visual editing is an appropriate and necessary step in assessing data quality. The blind or automated use of pre-specified thresholds for identifying and suppressing unusually high counts may result in censoring of both valid and invalid counts. Conversely, retention of these values may result in inclusion of invalid counts. Internet research into events that correspond to spikes in daily counts can be conducted, but takes time. Reviewing hourly runs of zero is useful but automated decision rules should not be applied blindly. For the six locations and 12 sensors analyzed in the preceding example, multiple long hourly runs of zero, including runs of zero lasting as long as a day or two, were common. However, daily zero values in the summer should be investigated as anomalous.

Consistent application of professional judgment will be necessary when conducting QA/QC. One pragmatic consideration is whether retention or exclusion of suspect counts materially affects estimates of ADB. The preceding analyses showed that in most cases, censoring high values greater than two standard deviations above the mean reduced estimates of ADB by only a few percent. A relevant question is whether censoring makes any difference for practice and would materially affect any decision an engineer or planner might make. Seven of the 12 sensors recorded volumes less than 100 bicyclists or pedestrians per day. For a site with an ADB of 100, even if censoring high values reduced estimates by 10%, it would change the estimate only to 90. Few decisions would hinge of a difference in ADB of 10. For higher volume sites, the question is not so simple and it is possible to imagine that automatic application of rules for censoring suspect outliers could potentially affect engineering or policy decisions. One strategy for addressing these issues is to standardize procedures to explore the effects of following different decision rules and make decisions based on the particulars of the situation. This type of contingent process, however, is more difficult to administer and sustain. MnDOT has staff with expertise in traffic monitoring, and as the staff gains additional experience in non-motorized traffic monitoring, these general procedures will be refined.

APPENDIX E – INSTRUCTIONS FOR USE OF MNDOT SPREADSHEET TEMPLATE

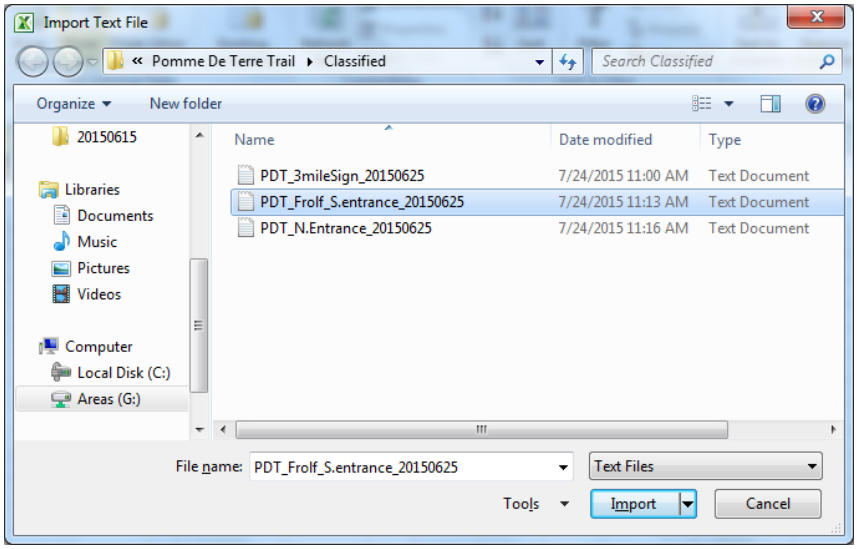
Operating Instructions for the MetroCount Summary Template

(Contact MnDOT Office of Transit for Templates for Manual Counts or

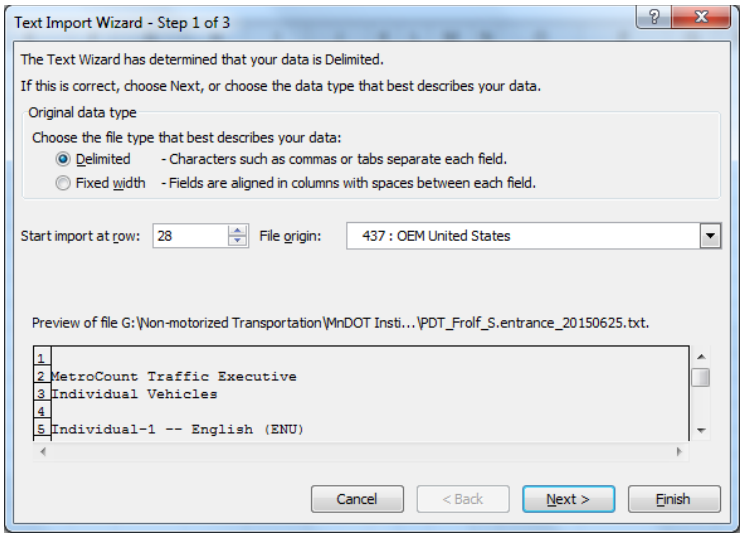
Counts taken with Chambers or TrailMaster Counters**)**

Michael Petesch (Michael.Petesch@state.mn.us; 11/10/15)

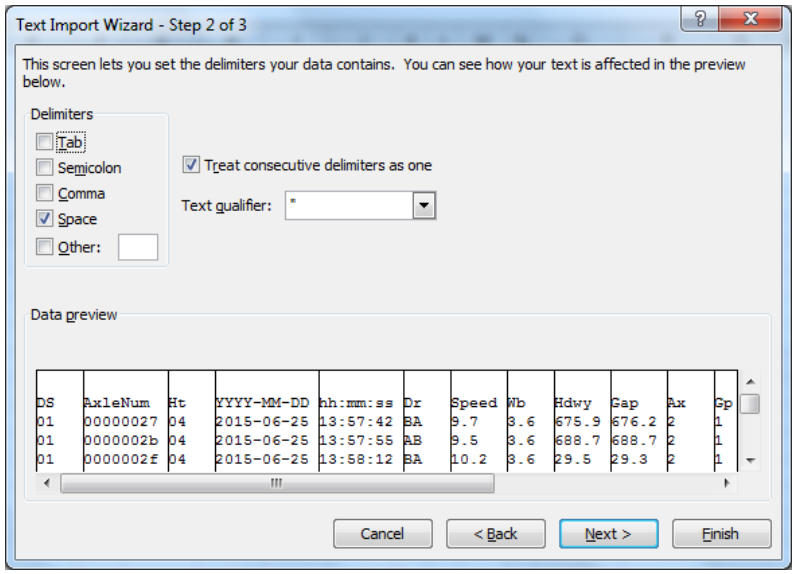
1. Open the Count Template Excel file
2. Navigate to “Raw Data” worksheet by clicking on the “Raw Data” tab at the bottom the Excel window
3. Click in Cell A2 **JUST BELOW** the **red cell** in the upper left corner
4. Click on "Data" tab in the top menu
5. Click on "From Text"
6. Select the .txt file with raw MetroCount date



7. Choose “Delimited” and start import at row “28”



8. Choose delimit by space (make sure that the cell in the second column of row 28 is labeled "AxleNum" with no space. If there is a space, open up the .txt file, delete the space, re-save the .txt file and redo steps 1-5 as stated above). Click “Next.”



9. Click on "Finish." The data will import and fill the worksheet

10. Click on the other worksheet tabs at the bottom the Excel window and visually verify that data cells have been automatically populated

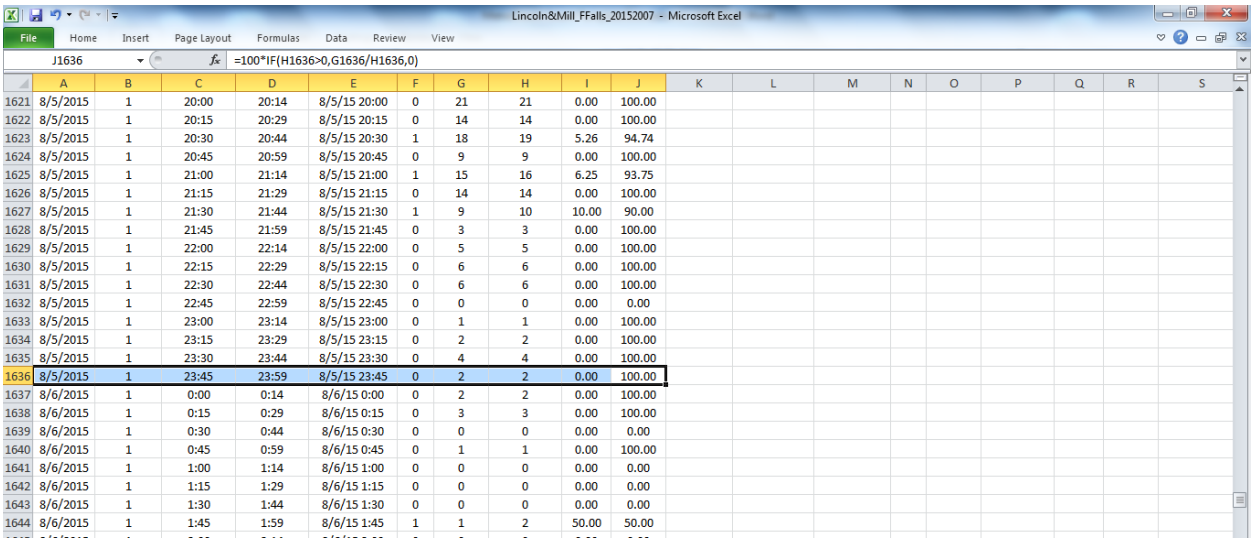
OPTIONAL: <u>“15 Minutes” worksheet (aggregates data into 15 minute bins):</u>

Manually enter the row number of the last valid cell (the last count on the last day of the collection) in column F into the formulas in N5, N104 and N203. Then drag each cell right to column P and fill down through each table which are stacked vertically on top of each other:

- Total Hourly Distribution (for full, valid days)
- Weekday Hourly Distribution (for full, valid days)
- Weekend Hourly Distribution (for full, valid days)

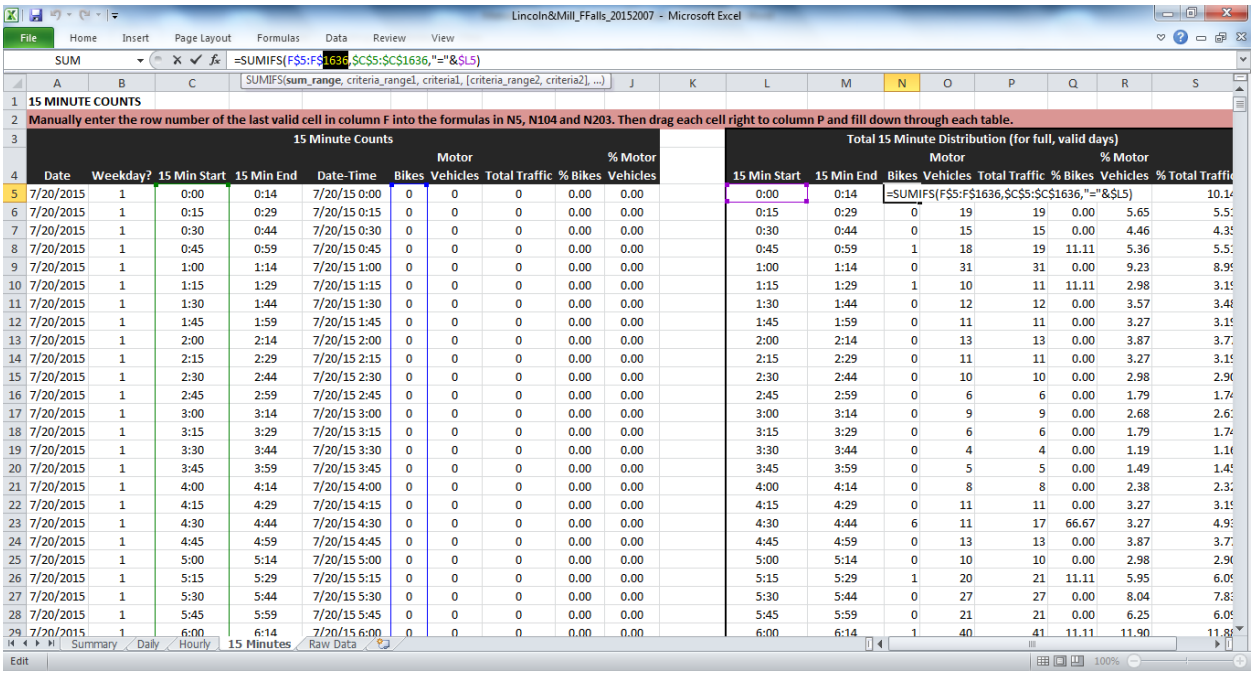
Here are some visuals for manually finishing the 15 Minutes worksheet:

1. Find the last row of the last complete day of data (the second to last day of data because the last day is a partial day). This is the “last valid row” number:



	A	B	C	D	E	F	G	H	I	J
1621	8/5/2015	1	20:00	20:14	8/5/15 20:00	0	21	21	0.00	100.00
1622	8/5/2015	1	20:15	20:29	8/5/15 20:15	0	14	14	0.00	100.00
1623	8/5/2015	1	20:30	20:44	8/5/15 20:30	1	18	19	5.26	94.74
1624	8/5/2015	1	20:45	20:59	8/5/15 20:45	0	9	9	0.00	100.00
1625	8/5/2015	1	21:00	21:14	8/5/15 21:00	1	15	16	6.25	93.75
1626	8/5/2015	1	21:15	21:29	8/5/15 21:15	0	14	14	0.00	100.00
1627	8/5/2015	1	21:30	21:44	8/5/15 21:30	1	9	10	10.00	90.00
1628	8/5/2015	1	21:45	21:59	8/5/15 21:45	0	3	3	0.00	100.00
1629	8/5/2015	1	22:00	22:14	8/5/15 22:00	0	5	5	0.00	100.00
1630	8/5/2015	1	22:15	22:29	8/5/15 22:15	0	6	6	0.00	100.00
1631	8/5/2015	1	22:30	22:44	8/5/15 22:30	0	6	6	0.00	100.00
1632	8/5/2015	1	22:45	22:59	8/5/15 22:45	0	0	0	0.00	0.00
1633	8/5/2015	1	23:00	23:14	8/5/15 23:00	0	1	1	0.00	100.00
1634	8/5/2015	1	23:15	23:29	8/5/15 23:15	0	2	2	0.00	100.00
1635	8/5/2015	1	23:30	23:44	8/5/15 23:30	0	4	4	0.00	100.00
1636	8/5/2015	1	23:45	23:59	8/5/15 23:45	0	2	2	0.00	100.00
1637	8/6/2015	1	0:00	0:14	8/6/15 0:00	0	2	2	0.00	100.00
1638	8/6/2015	1	0:15	0:29	8/6/15 0:15	0	3	3	0.00	100.00
1639	8/6/2015	1	0:30	0:44	8/6/15 0:30	0	0	0	0.00	0.00
1640	8/6/2015	1	0:45	0:59	8/6/15 0:45	0	1	1	0.00	100.00
1641	8/6/2015	1	1:00	1:14	8/6/15 1:00	0	0	0	0.00	0.00
1642	8/6/2015	1	1:15	1:29	8/6/15 1:15	0	0	0	0.00	0.00
1643	8/6/2015	1	1:30	1:44	8/6/15 1:30	0	0	0	0.00	0.00
1644	8/6/2015	1	1:45	1:59	8/6/15 1:45	1	1	2	50.00	50.00

2. Replace the height of the range with the “last valid row” number in cell N5:

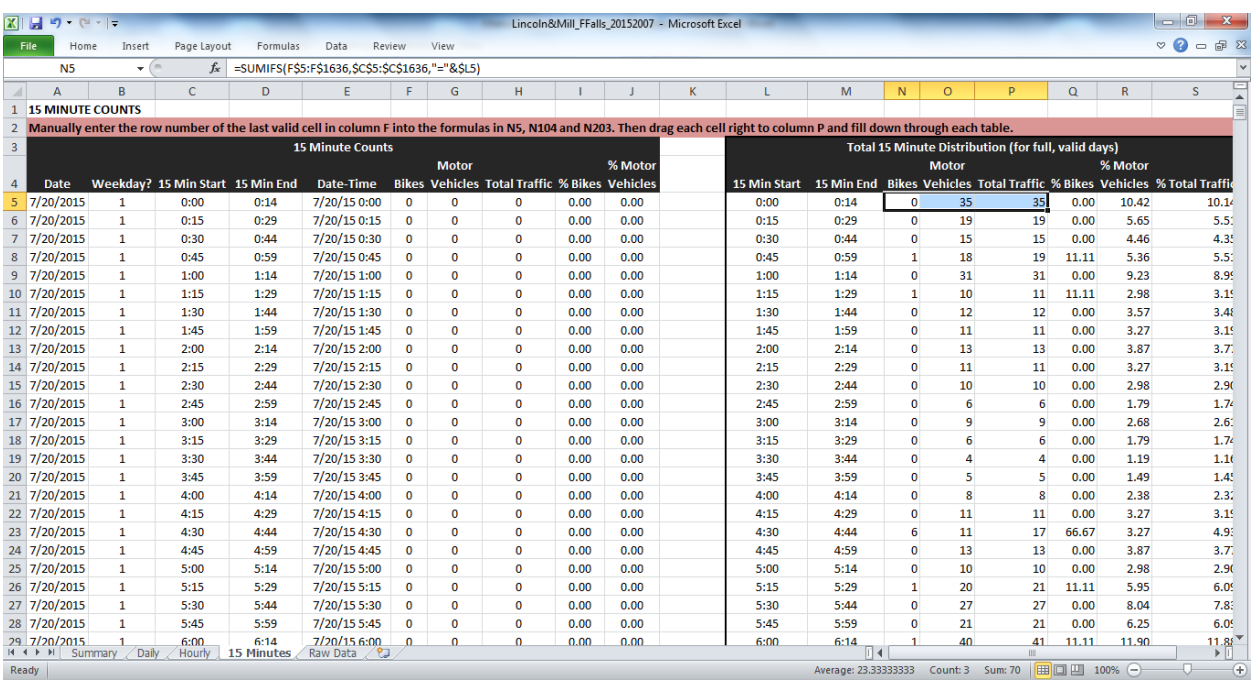


15 MINUTE COUNTS

Manually enter the row number of the last valid cell in column F into the formulas in N5, N104 and N203. Then drag each cell right to column P and fill down through each table.

	15 Minute Counts									Total 15 Minute Distribution (for full, valid days)							
Date	Weekday?	15 Min Start	15 Min End	Date-Time	Bikes	Motor Vehicles	Total Traffic	% Bikes	% Motor Vehicles	15 Min Start	15 Min End	Bikes	Motor Vehicles	Total Traffic	% Bikes	% Motor Vehicles	% Total Traffic
7/20/2015	1	0:00	0:14	7/20/15 0:00	0	0	0	0.00	0.00	0:00	0:14	=SUMIFS(F$5:F$1636,$C$5:$C$1636,"="&$L5)					10.14
7/20/2015	1	0:15	0:29	7/20/15 0:15	0	0	0	0.00	0.00	0:15	0:29	0	19	19	0.00	5.65	5.5
7/20/2015	1	0:30	0:44	7/20/15 0:30	0	0	0	0.00	0.00	0:30	0:44	0	15	15	0.00	4.46	4.3
7/20/2015	1	0:45	0:59	7/20/15 0:45	0	0	0	0.00	0.00	0:45	0:59	1	18	19	11.11	5.36	5.5
7/20/2015	1	1:00	1:14	7/20/15 1:00	0	0	0	0.00	0.00	1:00	1:14	0	31	31	0.00	9.23	8.9
7/20/2015	1	1:15	1:29	7/20/15 1:15	0	0	0	0.00	0.00	1:15	1:29	1	10	11	11.11	2.98	3.1
7/20/2015	1	1:30	1:44	7/20/15 1:30	0	0	0	0.00	0.00	1:30	1:44	0	12	12	0.00	3.57	3.4
7/20/2015	1	1:45	1:59	7/20/15 1:45	0	0	0	0.00	0.00	1:45	1:59	0	11	11	0.00	3.27	3.1
7/20/2015	1	2:00	2:14	7/20/15 2:00	0	0	0	0.00	0.00	2:00	2:14	0	13	13	0.00	3.87	3.7
7/20/2015	1	2:15	2:29	7/20/15 2:15	0	0	0	0.00	0.00	2:15	2:29	0	11	11	0.00	3.27	3.1
7/20/2015	1	2:30	2:44	7/20/15 2:30	0	0	0	0.00	0.00	2:30	2:44	0	10	10	0.00	2.98	2.9
7/20/2015	1	2:45	2:59	7/20/15 2:45	0	0	0	0.00	0.00	2:45	2:59	0	6	6	0.00	1.79	1.7
7/20/2015	1	3:00	3:14	7/20/15 3:00	0	0	0	0.00	0.00	3:00	3:14	0	9	9	0.00	2.68	2.6
7/20/2015	1	3:15	3:29	7/20/15 3:15	0	0	0	0.00	0.00	3:15	3:29	0	6	6	0.00	1.79	1.7
7/20/2015	1	3:30	3:44	7/20/15 3:30	0	0	0	0.00	0.00	3:30	3:44	0	4	4	0.00	1.19	1.1
7/20/2015	1	3:45	3:59	7/20/15 3:45	0	0	0	0.00	0.00	3:45	3:59	0	5	5	0.00	1.49	1.4
7/20/2015	1	4:00	4:14	7/20/15 4:00	0	0	0	0.00	0.00	4:00	4:14	0	8	8	0.00	2.38	2.3
7/20/2015	1	4:15	4:29	7/20/15 4:15	0	0	0	0.00	0.00	4:15	4:29	0	11	11	0.00	3.27	3.1
7/20/2015	1	4:30	4:44	7/20/15 4:30	0	0	0	0.00	0.00	4:30	4:44	6	11	17	66.67	3.27	4.9
7/20/2015	1	4:45	4:59	7/20/15 4:45	0	0	0	0.00	0.00	4:45	4:59	0	13	13	0.00	3.87	3.7
7/20/2015	1	5:00	5:14	7/20/15 5:00	0	0	0	0.00	0.00	5:00	5:14	0	10	10	0.00	2.98	2.9
7/20/2015	1	5:15	5:29	7/20/15 5:15	0	0	0	0.00	0.00	5:15	5:29	1	20	21	11.11	5.95	6.0
7/20/2015	1	5:30	5:44	7/20/15 5:30	0	0	0	0.00	0.00	5:30	5:44	0	27	27	0.00	8.04	7.8
7/20/2015	1	5:45	5:59	7/20/15 5:45	0	0	0	0.00	0.00	5:45	5:59	0	21	21	0.00	6.25	6.0
7/20/2015	1	6:00	6:14	7/20/15 6:00	0	0	0	0.00	0.00	6:00	6:14	1	40	41	11.11	11.90	11.8

3. Then drag the formula from T5 across to column V and fill down through the table.



15 MINUTE COUNTS

Manually enter the row number of the last valid cell in column F into the formulas in N5, N104 and N203. Then drag each cell right to column P and fill down through each table.

	15 Minute Counts									Total 15 Minute Distribution (for full, valid days)							
Date	Weekday?	15 Min Start	15 Min End	Date-Time	Bikes	Motor Vehicles	Total Traffic	% Bikes	% Motor Vehicles	15 Min Start	15 Min End	Bikes	Motor Vehicles	Total Traffic	% Bikes	% Motor Vehicles	% Total Traffic
7/20/2015	1	0:00	0:14	7/20/15 0:00	0	0	0	0.00	0.00	0:00	0:14	0	35	35	0.00	10.42	10.14
7/20/2015	1	0:15	0:29	7/20/15 0:15	0	0	0	0.00	0.00	0:15	0:29	0	19	19	0.00	5.65	5.5
7/20/2015	1	0:30	0:44	7/20/15 0:30	0	0	0	0.00	0.00	0:30	0:44	0	15	15	0.00	4.46	4.3
7/20/2015	1	0:45	0:59	7/20/15 0:45	0	0	0	0.00	0.00	0:45	0:59	1	18	19	11.11	5.36	5.5
7/20/2015	1	1:00	1:14	7/20/15 1:00	0	0	0	0.00	0.00	1:00	1:14	0	31	31	0.00	9.23	8.9
7/20/2015	1	1:15	1:29	7/20/15 1:15	0	0	0	0.00	0.00	1:15	1:29	1	10	11	11.11	2.98	3.1
7/20/2015	1	1:30	1:44	7/20/15 1:30	0	0	0	0.00	0.00	1:30	1:44	0	12	12	0.00	3.57	3.4
7/20/2015	1	1:45	1:59	7/20/15 1:45	0	0	0	0.00	0.00	1:45	1:59	0	11	11	0.00	3.27	3.1
7/20/2015	1	2:00	2:14	7/20/15 2:00	0	0	0	0.00	0.00	2:00	2:14	0	13	13	0.00	3.87	3.7
7/20/2015	1	2:15	2:29	7/20/15 2:15	0	0	0	0.00	0.00	2:15	2:29	0	11	11	0.00	3.27	3.1
7/20/2015	1	2:30	2:44	7/20/15 2:30	0	0	0	0.00	0.00	2:30	2:44	0	10	10	0.00	2.98	2.9
7/20/2015	1	2:45	2:59	7/20/15 2:45	0	0	0	0.00	0.00	2:45	2:59	0	6	6	0.00	1.79	1.7
7/20/2015	1	3:00	3:14	7/20/15 3:00	0	0	0	0.00	0.00	3:00	3:14	0	9	9	0.00	2.68	2.6
7/20/2015	1	3:15	3:29	7/20/15 3:15	0	0	0	0.00	0.00	3:15	3:29	0	6	6	0.00	1.79	1.7
7/20/2015	1	3:30	3:44	7/20/15 3:30	0	0	0	0.00	0.00	3:30	3:44	0	4	4	0.00	1.19	1.1
7/20/2015	1	3:45	3:59	7/20/15 3:45	0	0	0	0.00	0.00	3:45	3:59	0	5	5	0.00	1.49	1.4
7/20/2015	1	4:00	4:14	7/20/15 4:00	0	0	0	0.00	0.00	4:00	4:14	0	8	8	0.00	2.38	2.3
7/20/2015	1	4:15	4:29	7/20/15 4:15	0	0	0	0.00	0.00	4:15	4:29	0	11	11	0.00	3.27	3.1
7/20/2015	1	4:30	4:44	7/20/15 4:30	0	0	0	0.00	0.00	4:30	4:44	6	11	17	66.67	3.27	4.9
7/20/2015	1	4:45	4:59	7/20/15 4:45	0	0	0	0.00	0.00	4:45	4:59	0	13	13	0.00	3.87	3.7
7/20/2015	1	5:00	5:14	7/20/15 5:00	0	0	0	0.00	0.00	5:00	5:14	0	10	10	0.00	2.98	2.9
7/20/2015	1	5:15	5:29	7/20/15 5:15	0	0	0	0.00	0.00	5:15	5:29	1	20	21	11.11	5.95	6.0
7/20/2015	1	5:30	5:44	7/20/15 5:30	0	0	0	0.00	0.00	5:30	5:44	0	27	27	0.00	8.04	7.8
7/20/2015	1	5:45	5:59	7/20/15 5:45	0	0	0	0.00	0.00	5:45	5:59	0	21	21	0.00	6.25	6.0
7/20/2015	1	6:00	6:14	7/20/15 6:00	0	0	0	0.00	0.00	6:00	6:14	1	40	41	11.11	11.90	11.8

4. Repeat steps 2 and 3 for cells T32 and T59 starting with replacing the height of the ranges with the “last valid row” of data.

EXAMPLE: The highlighted “2000s” are stand ins ad should be replaced with the number of the last valid row: =SUMIFS(F$5:F$**2000**,$C$5:C**2000**,"="&$L5)

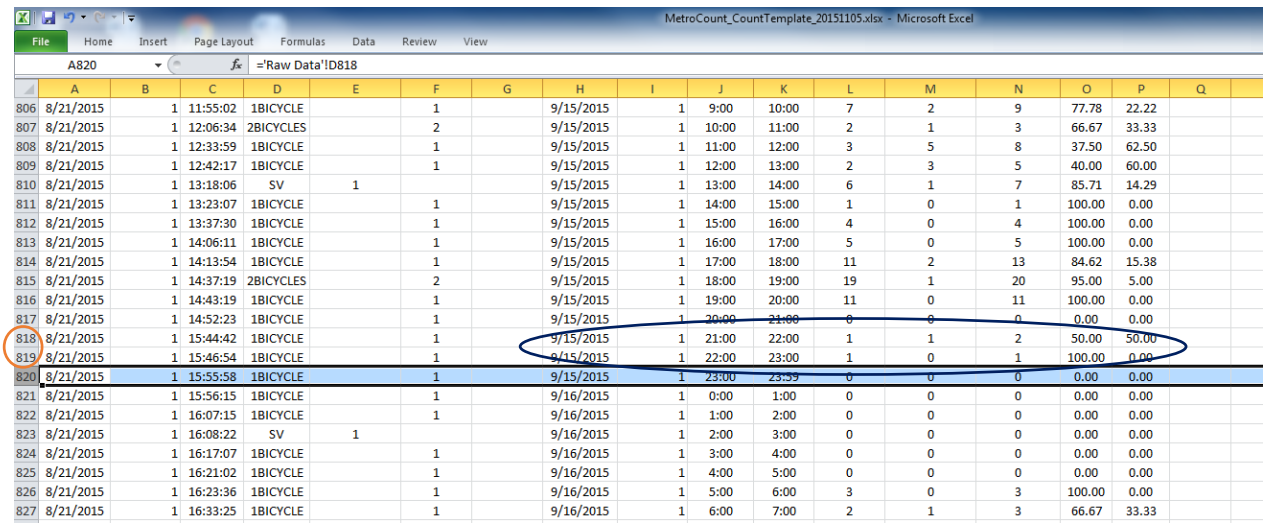
“Hourly” worksheet (aggregates data into hourly bins):

Manually enter the row number of the last valid cell (the last count on the last day of the collection) in column D into the formulas in T5, T32 and T59. Then drag each cell right to column V and fill down through each table which are stacked vertically on top of each other:

- Total Hourly Distribution (for full, valid days)
- Weekday Hourly Distribution (for full, valid days)
- Weekend Hourly Distribution (for full, valid days)

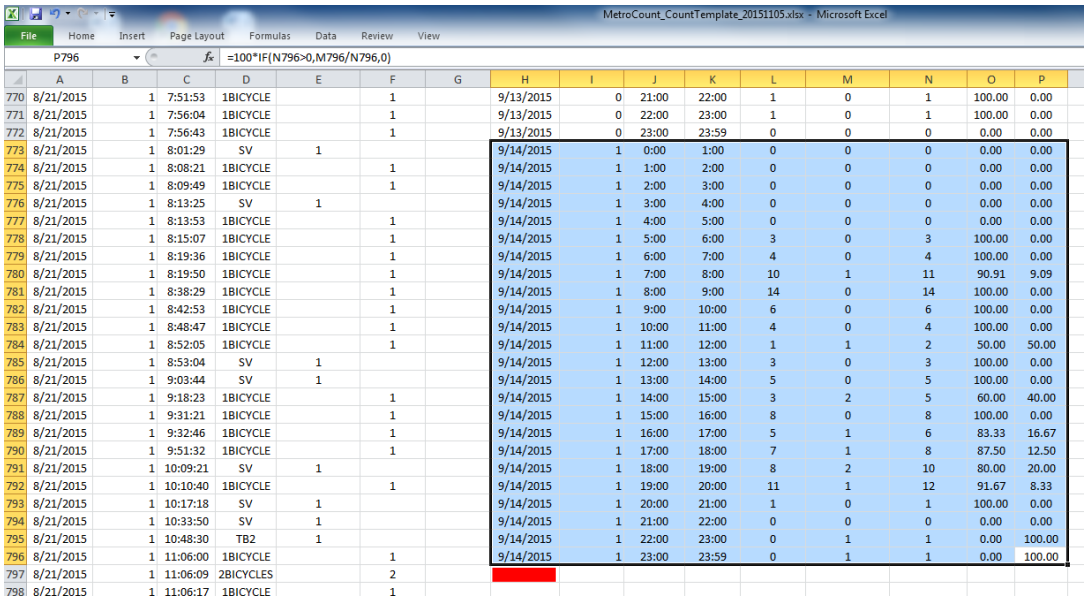
Here are some visuals for manually finishing the Hourly worksheet:

1. Find the midnight row of the last complete day of data (the big oval which shows the second to last day of data because the last day (pickup day) is a partial day). This is the “last valid row” number (little circle):



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
806	8/21/2015	1	11:55:02	1BICYCLE		1		9/15/2015	1	9:00	10:00	7	2	9	77.78	22.22	
807	8/21/2015	1	12:06:34	2BICYCLES		2		9/15/2015	1	10:00	11:00	2	1	3	66.67	33.33	
808	8/21/2015	1	12:33:59	1BICYCLE		1		9/15/2015	1	11:00	12:00	3	5	8	37.50	62.50	
809	8/21/2015	1	12:42:17	1BICYCLE		1		9/15/2015	1	12:00	13:00	2	3	5	40.00	60.00	
810	8/21/2015	1	13:18:06	SV	1			9/15/2015	1	13:00	14:00	6	1	7	85.71	14.29	
811	8/21/2015	1	13:23:07	1BICYCLE		1		9/15/2015	1	14:00	15:00	1	0	1	100.00	0.00	
812	8/21/2015	1	13:37:30	1BICYCLE		1		9/15/2015	1	15:00	16:00	4	0	4	100.00	0.00	
813	8/21/2015	1	14:06:11	1BICYCLE		1		9/15/2015	1	16:00	17:00	5	0	5	100.00	0.00	
814	8/21/2015	1	14:13:54	1BICYCLE		1		9/15/2015	1	17:00	18:00	11	2	13	84.62	15.38	
815	8/21/2015	1	14:37:19	2BICYCLES		2		9/15/2015	1	18:00	19:00	19	1	20	95.00	5.00	
816	8/21/2015	1	14:43:19	1BICYCLE		1		9/15/2015	1	19:00	20:00	11	0	11	100.00	0.00	
817	8/21/2015	1	14:52:23	1BICYCLE		1		9/15/2015	1	20:00	21:00	0	0	0	0.00	0.00	
818	8/21/2015	1	15:44:42	1BICYCLE		1		9/15/2015	1	21:00	22:00	1	1	2	50.00	50.00	
819	8/21/2015	1	15:46:54	1BICYCLE		1		9/15/2015	1	22:00	23:00	1	0	1	100.00	0.00	
820	8/21/2015	1	15:55:58	1BICYCLE		1		9/15/2015	1	23:00	23:59	0	0	0	0.00	0.00	
821	8/21/2015	1	15:56:15	1BICYCLE		1		9/16/2015	1	0:00	1:00	0	0	0	0.00	0.00	
822	8/21/2015	1	16:07:15	1BICYCLE		1		9/16/2015	1	1:00	2:00	0	0	0	0.00	0.00	
823	8/21/2015	1	16:08:22	SV	1			9/16/2015	1	2:00	3:00	0	0	0	0.00	0.00	
824	8/21/2015	1	16:17:07	1BICYCLE		1		9/16/2015	1	3:00	4:00	0	0	0	0.00	0.00	
825	8/21/2015	1	16:21:02	1BICYCLE		1		9/16/2015	1	4:00	5:00	0	0	0	0.00	0.00	
826	8/21/2015	1	16:23:36	1BICYCLE		1		9/16/2015	1	5:00	6:00	3	0	3	100.00	0.00	
827	8/21/2015	1	16:33:25	1BICYCLE		1		9/16/2015	1	6:00	7:00	2	1	3	66.67	33.33	

2. If the last visible row is NOT the midnight hour of the last complete day of your sample, copy the entire block of data from the last day (all 24 hours between Column H to Column P) and paste it in the first cell in Column H beneath the previous date (shaded cell in graphic below). Repeat pasting the 24 hour blocks of time until the last day of your count sample shows up in Column H.

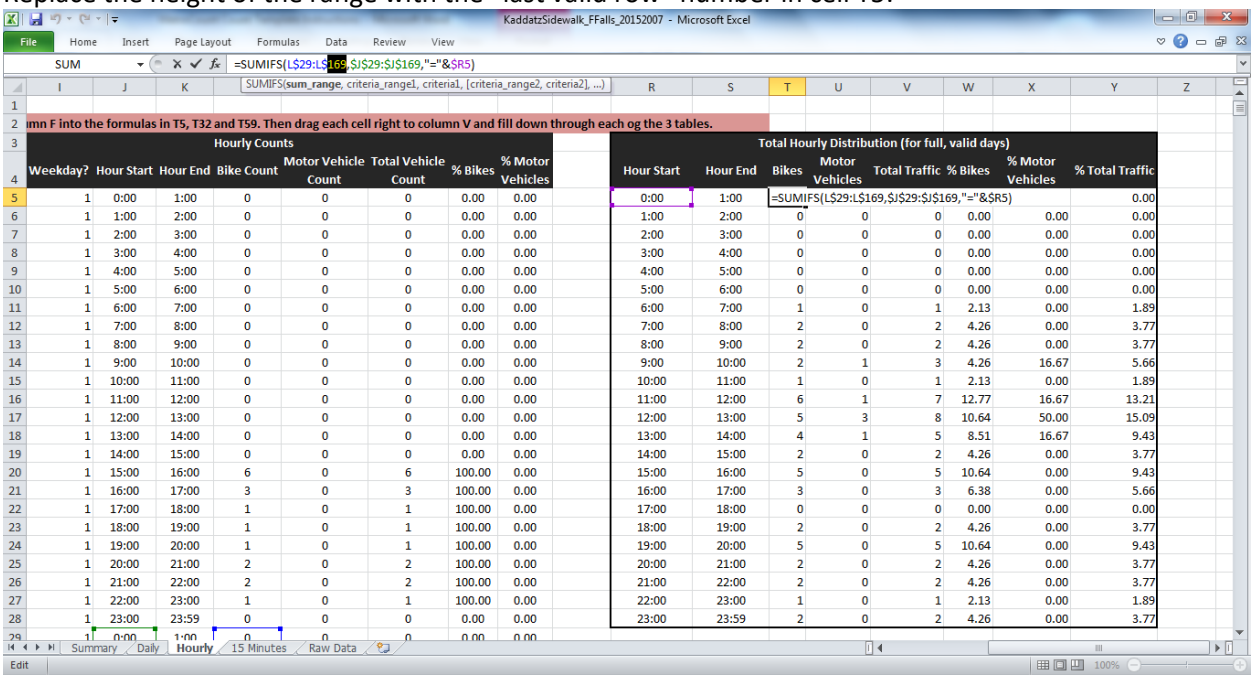


MetroCount_CountTemplate_20151105.xlsx - Microsoft Excel

P796 =100*IF(N796>0,M796/N796,0)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
770	8/21/2015	1	7:51:53	1BICYCLE		1		9/13/2015	0	21:00	22:00	1	0	1	100.00	0.00
771	8/21/2015	1	7:56:04	1BICYCLE		1		9/13/2015	0	22:00	23:00	1	0	1	100.00	0.00
772	8/21/2015	1	7:56:43	1BICYCLE		1		9/13/2015	0	23:00	23:59	0	0	0	0.00	0.00
773	8/21/2015	1	8:01:29	SV	1			9/14/2015	1	0:00	1:00	0	0	0	0.00	0.00
774	8/21/2015	1	8:08:21	1BICYCLE		1		9/14/2015	1	1:00	2:00	0	0	0	0.00	0.00
775	8/21/2015	1	8:09:49	1BICYCLE		1		9/14/2015	1	2:00	3:00	0	0	0	0.00	0.00
776	8/21/2015	1	8:13:25	SV	1			9/14/2015	1	3:00	4:00	0	0	0	0.00	0.00
777	8/21/2015	1	8:13:53	1BICYCLE		1		9/14/2015	1	4:00	5:00	0	0	0	0.00	0.00
778	8/21/2015	1	8:15:07	1BICYCLE		1		9/14/2015	1	5:00	6:00	3	0	3	100.00	0.00
779	8/21/2015	1	8:19:36	1BICYCLE		1		9/14/2015	1	6:00	7:00	4	0	4	100.00	0.00
780	8/21/2015	1	8:19:50	1BICYCLE		1		9/14/2015	1	7:00	8:00	10	1	11	90.91	9.09
781	8/21/2015	1	8:38:29	1BICYCLE		1		9/14/2015	1	8:00	9:00	14	0	14	100.00	0.00
782	8/21/2015	1	8:42:53	1BICYCLE		1		9/14/2015	1	9:00	10:00	6	0	6	100.00	0.00
783	8/21/2015	1	8:48:47	1BICYCLE		1		9/14/2015	1	10:00	11:00	4	0	4	100.00	0.00
784	8/21/2015	1	8:52:05	1BICYCLE		1		9/14/2015	1	11:00	12:00	1	1	2	50.00	50.00
785	8/21/2015	1	8:53:04	SV	1			9/14/2015	1	12:00	13:00	3	0	3	100.00	0.00
786	8/21/2015	1	9:03:44	SV	1			9/14/2015	1	13:00	14:00	5	0	5	100.00	0.00
787	8/21/2015	1	9:18:23	1BICYCLE		1		9/14/2015	1	14:00	15:00	3	2	5	60.00	40.00
788	8/21/2015	1	9:31:21	1BICYCLE		1		9/14/2015	1	15:00	16:00	8	0	8	100.00	0.00
789	8/21/2015	1	9:32:46	1BICYCLE		1		9/14/2015	1	16:00	17:00	5	1	6	83.33	16.67
790	8/21/2015	1	9:51:32	1BICYCLE		1		9/14/2015	1	17:00	18:00	7	1	8	87.50	12.50
791	8/21/2015	1	10:09:21	SV	1			9/14/2015	1	18:00	19:00	8	2	10	80.00	20.00
792	8/21/2015	1	10:10:40	1BICYCLE		1		9/14/2015	1	19:00	20:00	11	1	12	91.67	8.33
793	8/21/2015	1	10:17:18	SV	1			9/14/2015	1	20:00	21:00	1	0	1	100.00	0.00
794	8/21/2015	1	10:33:50	SV	1			9/14/2015	1	21:00	22:00	0	0	0	0.00	0.00
795	8/21/2015	1	10:48:30	TB2	1			9/14/2015	1	22:00	23:00	0	1	1	0.00	100.00
796	8/21/2015	1	11:06:00	1BICYCLE		1		9/14/2015	1	23:00	23:59	0	1	1	0.00	100.00
797	8/21/2015	1	11:06:09	2BICYCLES		2										
798	8/21/2015	1	11:06:17	1BICYCLE		1										

3. Replace the height of the range with the "last valid row" number in cell T5:



KaddatzSidewalk_FFalls_20152007 - Microsoft Excel

SUM =SUMIFS(L$29:L$169,$J$29:$J$169,"="&$R5)

SUMIFS(sum_range, criteria_range1, criteria1, [criteria_range2, criteria2], ...)

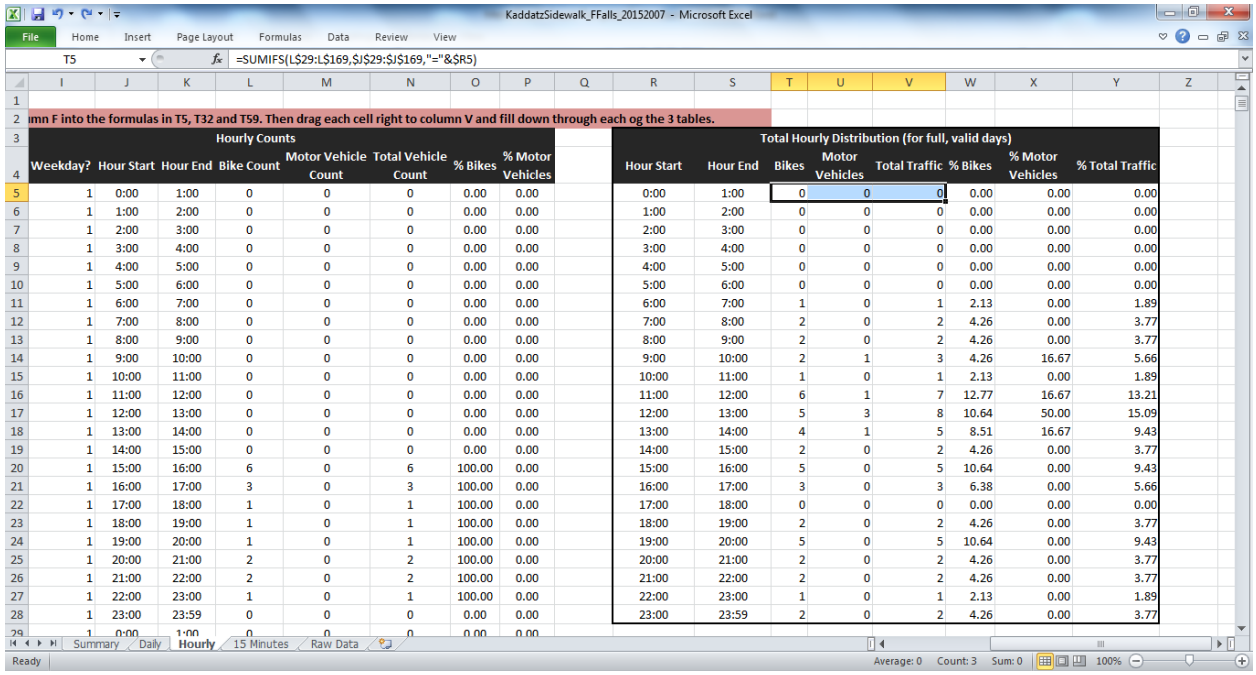
mn F into the formulas in T5, T32 and T59. Then drag each cell right to column V and fill down through each og the 3 tables.

Hourly Counts							
Weekday?	Hour Start	Hour End	Bike Count	Motor Vehicle Count	Total Vehicle Count	% Bikes	% Motor Vehicles
1	0:00	1:00	0	0	0	0.00	0.00
1	1:00	2:00	0	0	0	0.00	0.00
1	2:00	3:00	0	0	0	0.00	0.00
1	3:00	4:00	0	0	0	0.00	0.00
1	4:00	5:00	0	0	0	0.00	0.00
1	5:00	6:00	0	0	0	0.00	0.00
1	6:00	7:00	0	0	0	0.00	0.00
1	7:00	8:00	0	0	0	0.00	0.00
1	8:00	9:00	0	0	0	0.00	0.00
1	9:00	10:00	0	0	0	0.00	0.00
1	10:00	11:00	0	0	0	0.00	0.00
1	11:00	12:00	0	0	0	0.00	0.00
1	12:00	13:00	0	0	0	0.00	0.00
1	13:00	14:00	0	0	0	0.00	0.00
1	14:00	15:00	0	0	0	0.00	0.00
1	15:00	16:00	6	0	6	100.00	0.00
1	16:00	17:00	3	0	3	100.00	0.00
1	17:00	18:00	1	0	1	100.00	0.00
1	18:00	19:00	1	0	1	100.00	0.00
1	19:00	20:00	1	0	1	100.00	0.00
1	20:00	21:00	2	0	2	100.00	0.00
1	21:00	22:00	2	0	2	100.00	0.00
1	22:00	23:00	1	0	1	100.00	0.00
1	23:00	23:59	0	0	0	0.00	0.00
1	0:00	1:00	0	0	0	0.00	0.00

Total Hourly Distribution (for full, valid days)							
Hour Start	Hour End	Bikes	Motor Vehicles	Total Traffic	% Bikes	% Motor Vehicles	% Total Traffic
0:00	1:00	=SUMIFS(L$29:L$169,$J$29:$J$169,"="&$R5)					0.00
1:00	2:00	0	0	0	0.00	0.00	0.00
2:00	3:00	0	0	0	0.00	0.00	0.00
3:00	4:00	0	0	0	0.00	0.00	0.00
4:00	5:00	0	0	0	0.00	0.00	0.00
5:00	6:00	0	0	0	0.00	0.00	0.00
6:00	7:00	1	0	1	2.13	0.00	1.89
7:00	8:00	2	0	2	4.26	0.00	3.77
8:00	9:00	2	0	2	4.26	0.00	3.77
9:00	10:00	2	1	3	4.26	16.67	5.66
10:00	11:00	1	0	1	2.13	0.00	1.89
11:00	12:00	6	1	7	12.77	16.67	13.21
12:00	13:00	5	3	8	10.64	50.00	15.09
13:00	14:00	4	1	5	8.51	16.67	9.43
14:00	15:00	2	0	2	4.26	0.00	3.77
15:00	16:00	5	0	5	10.64	0.00	9.43
16:00	17:00	3	0	3	6.38	0.00	5.66
17:00	18:00	0	0	0	0.00	0.00	0.00
18:00	19:00	2	0	2	4.26	0.00	3.77
19:00	20:00	5	0	5	10.64	0.00	9.43
20:00	21:00	2	0	2	4.26	0.00	3.77
21:00	22:00	2	0	2	4.26	0.00	3.77
22:00	23:00	1	0	1	2.13	0.00	1.89
23:00	23:59	2	0	2	4.26	0.00	3.77

Summary | Daily | Hourly | 15 Minutes | Raw Data

4. Then drag the formula from T5 across to column V and fill down through the table.



KaddatzSidewalk_FFalls_20152007 - Microsoft Excel

T5 =SUMIFS(L$29:L$169,$J$29:$J$169,"="&$R5)

umn F into the formulas in T5, T32 and T59. Then drag each cell right to column V and fill down through each og the 3 tables.

Hourly Counts							
Weekday?	Hour Start	Hour End	Bike Count	Motor Vehicle Count	Total Vehicle Count	% Bikes	% Motor Vehicles
1	0:00	1:00	0	0	0	0.00	0.00
1	1:00	2:00	0	0	0	0.00	0.00
1	2:00	3:00	0	0	0	0.00	0.00
1	3:00	4:00	0	0	0	0.00	0.00
1	4:00	5:00	0	0	0	0.00	0.00
1	5:00	6:00	0	0	0	0.00	0.00
1	6:00	7:00	0	0	0	0.00	0.00
1	7:00	8:00	0	0	0	0.00	0.00
1	8:00	9:00	0	0	0	0.00	0.00
1	9:00	10:00	0	0	0	0.00	0.00
1	10:00	11:00	0	0	0	0.00	0.00
1	11:00	12:00	0	0	0	0.00	0.00
1	12:00	13:00	0	0	0	0.00	0.00
1	13:00	14:00	0	0	0	0.00	0.00
1	14:00	15:00	0	0	0	0.00	0.00
1	15:00	16:00	6	0	6	100.00	0.00
1	16:00	17:00	3	0	3	100.00	0.00
1	17:00	18:00	1	0	1	100.00	0.00
1	18:00	19:00	1	0	1	100.00	0.00
1	19:00	20:00	1	0	1	100.00	0.00
1	20:00	21:00	2	0	2	100.00	0.00
1	21:00	22:00	2	0	2	100.00	0.00
1	22:00	23:00	1	0	1	100.00	0.00
1	23:00	23:59	0	0	0	0.00	0.00

Total Hourly Distribution (for full, valid days)							
Hour Start	Hour End	Bikes	Motor Vehicles	Total Traffic	% Bikes	% Motor Vehicles	% Total Traffic
0:00	1:00	0	0	0	0.00	0.00	0.00
1:00	2:00	0	0	0	0.00	0.00	0.00
2:00	3:00	0	0	0	0.00	0.00	0.00
3:00	4:00	0	0	0	0.00	0.00	0.00
4:00	5:00	0	0	0	0.00	0.00	0.00
5:00	6:00	0	0	0	0.00	0.00	0.00
6:00	7:00	1	0	1	2.13	0.00	1.89
7:00	8:00	2	0	2	4.26	0.00	3.77
8:00	9:00	2	0	2	4.26	0.00	3.77
9:00	10:00	2	1	3	4.26	16.67	5.66
10:00	11:00	1	0	1	2.13	0.00	1.89
11:00	12:00	6	1	7	12.77	16.67	13.21
12:00	13:00	5	3	8	10.64	50.00	15.09
13:00	14:00	4	1	5	8.51	16.67	9.43
14:00	15:00	2	0	2	4.26	0.00	3.77
15:00	16:00	5	0	5	10.64	0.00	9.43
16:00	17:00	3	0	3	6.38	0.00	5.66
17:00	18:00	0	0	0	0.00	0.00	0.00
18:00	19:00	2	0	2	4.26	0.00	3.77
19:00	20:00	5	0	5	10.64	0.00	9.43
20:00	21:00	2	0	2	4.26	0.00	3.77
21:00	22:00	2	0	2	4.26	0.00	3.77
22:00	23:00	1	0	1	2.13	0.00	1.89
23:00	23:59	2	0	2	4.26	0.00	3.77

Summary | Daily | Hourly | 15 Minutes | Raw Data

Ready Average: 0 Count: 3 Sum: 0 100%

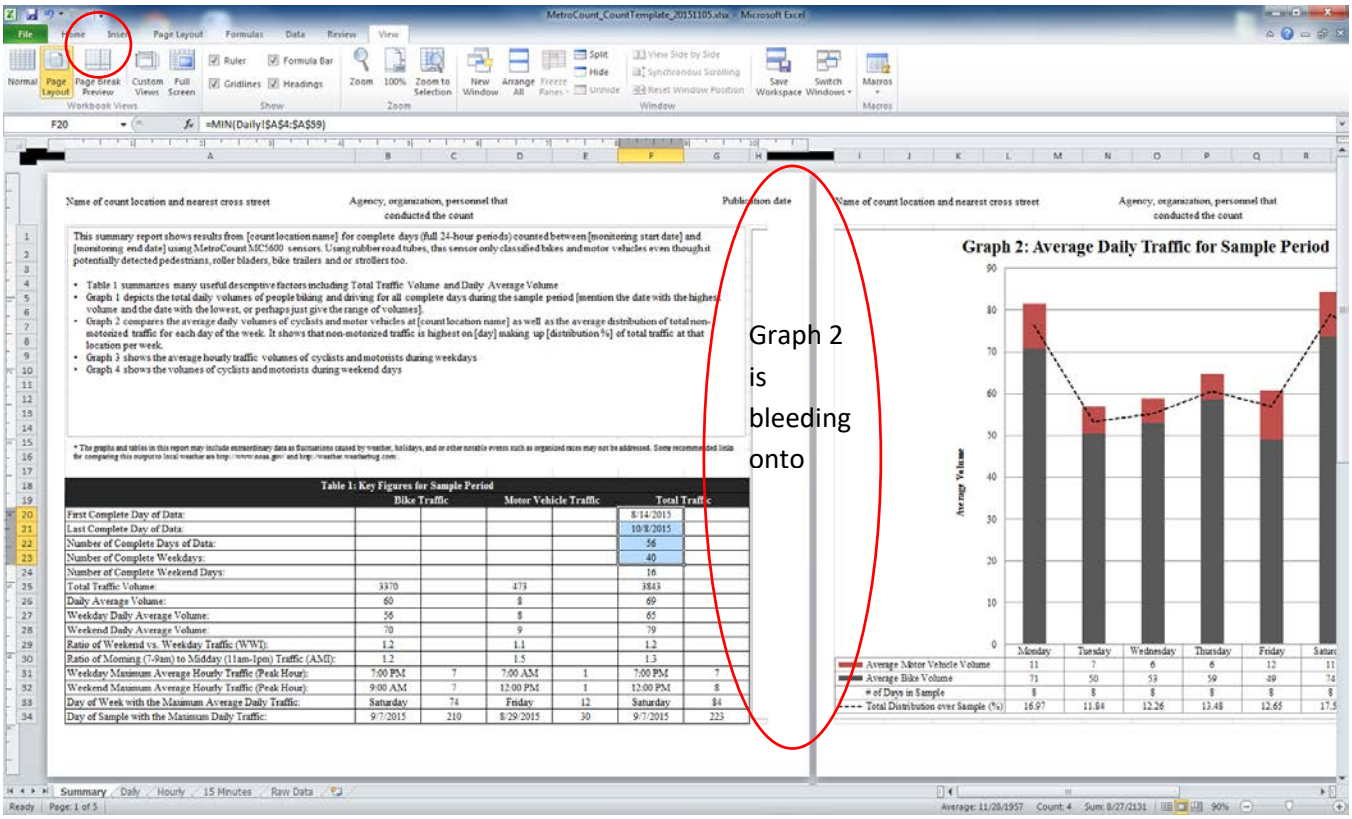
5. Repeat steps 2 and 3 for cells T32 and T59 starting with replacing the height of the ranges with the "last valid row" of data. **EXAMPLE:** The highlighted "2000s" are stand ins and should be replaced with the number of the last valid row: =SUMIFS(F$5:F$**2000**,$C$5:C**2000**,"="&$L5)

<u>"Daily" worksheet (aggregates data into days):</u>

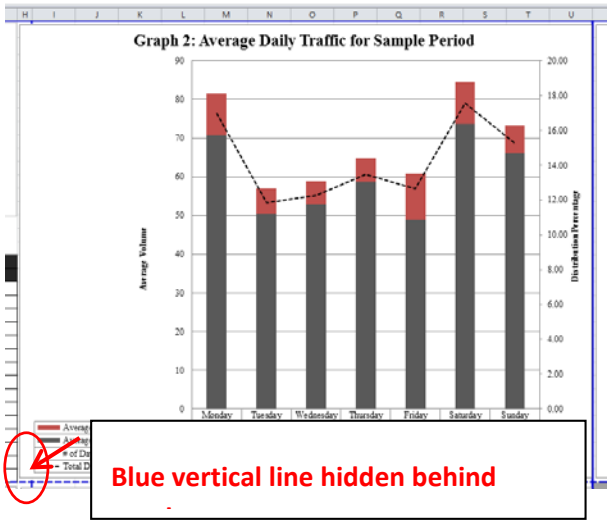
1. Data collected on the day of installation are automatically eliminated, but the days the equipment was installed, taken down and the days after take down must be manually removed from the main table
2. Eliminate incomplete days of data by selecting columns A through M of the rows of with dates when midnight to midnight was not continuously counted
3. Right click and choose "Delete" and then "Shift cells up"
4. The tables and graphs in the "Daily" and "Summary" worksheets will automatically correct themselves based on the changes to this table

<u>"Summary" worksheet (aggregates data into days):</u>

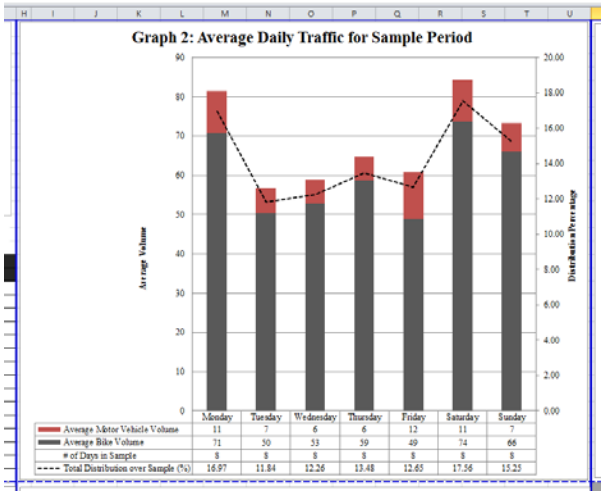
1. If the graphs and table are bleeding onto multiple pages as the picture below shows, click on the "View" tab in Excel, click "Page Break Preview," and then drag the blue dotted lines (both horizontal and vertical) until they box in each of your pages (shown on next page).



BEFORE



AFTER

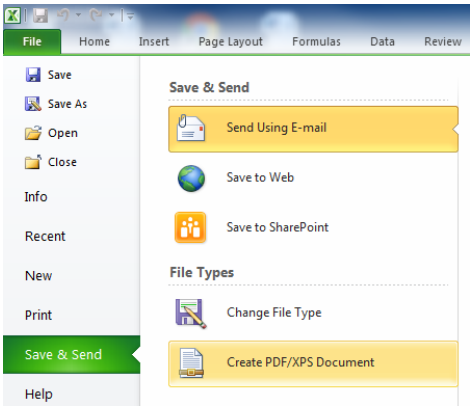


2. Read the prompts in the headers and then replace them with your count details

3. Edit the summary text box so that it addresses the specific collection site, characteristics, and data output.

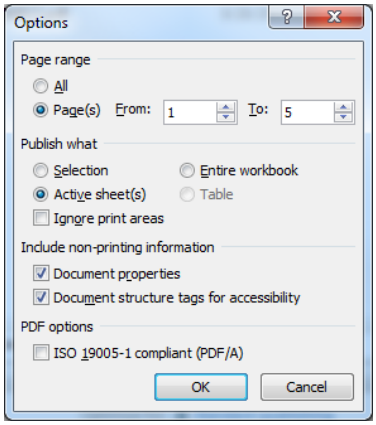
<u>Saving a PDF copy of your report:</u>

1. Click on the "File" tab in Excel, click on "Save & Send" and choose "Create PDF/XPS Document"



2. When the "Publish for PDF or XPS" window appears, click on "Options" and enter the page range (typically 5 pages but if change accordingly if you customize the template or add extra tables / graphs).

3. When the "Publish for PDF or XPS" window appears, click on "Options" and enter the page range (typically 5 pages but if change accordingly if you customize the template or add extra tables / graphs).



4. When the "Publish for PDF or XPS" window appears, click on "Options" and enter the page range (typically 5 pages but if change accordingly if you customize the template or add extra tables / graphs).

5. When the "Publish for PDF or XPS" window appears, click on "Options" and enter the page range (typically 5 pages but if change accordingly if you customize the template or add extra tables / graphs).

APPENDIX F – ADJUSTMENT FACTORS FOR EXTRAPOLATING SHORT-DURATION COUNTS

This appendix illustrates the development and estimation of factor groups for non-motorized transportation by drawing on an example from analyses of counts of mixed-mode traffic on shared-use paths in Minneapolis that also is featured in FHWA's TMG (FHWA 2013).

The Minneapolis Park and Recreation Board (MPRB), the Minneapolis Department of Public Works (DPW), and the University of Minnesota have collaborated to count bicyclists and pedestrians on shared-use paths (i.e., multiuse trails) in Minneapolis since about 2010. In addition to other outputs such as daily, monthly, and annual traffic volumes, the collaboration has included:

- Estimation of day-of-week and month-of-year factors for selected permanent monitoring sites in 2011;
- An experiment in 2012 to compute standard day-of-week and month-of-year adjustment factors and compare accuracy in estimation of AADB with estimates from a novel "day-of-year factoring approach that better takes into consideration the weather conditions that affected traffic flows on each day of the year; and
- An exercise in 2013 to estimate AADB and trail miles traveled on the entire 80-mile trail network (see case study 6.5.4).

One of the useful outputs from this monitoring is a table that summarizes day-of-week and month-of-year factors for trail traffic 2011 (Table F1). Table F1 originally was prepared for inclusion in FHWA's *Traffic Monitoring Guide* as part of an example to illustrate the ratios can be used as adjustment factors to extrapolate results from short duration samples. (http://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/traffic-monitoring-for-non-motorized.cfm).

The data in Table F1 summarize variation in monthly traffic relative to AADT. For example, the ratio of monthly average daily traffic in July (4,099) to AADB (1,975) is 2.08. This ratio means that, at this particular location, monthly traffic in July – the month with the highest traffic – is on average twice the AADB. In comparison, January average daily traffic is only about 12% of AADB. The example in the TMG illustrates how samples of different duration can be extrapolated to estimate AADB using these types of ratios. A long-term goal on the bicycle and pedestrian counting initiative in Minnesota is to develop similar tables of ratios and factors for different factor groups.

Another useful example from the same collaboration includes an experiment to assess the effect of the length of short duration samples on the accuracy of estimates of AADB (Hankey et al. 2014). This experiment also compared the accuracy of estimates of AADB using different extrapolation methods. Figure F-1 includes three graphs that show traffic ratios computed from year-long monitoring results at six permanent infrared monitors on Minneapolis trails. These graphs show the ratios of average day-of-week traffic to AADB, average monthly traffic to AADB, and day-of-year traffic to AADB. For example, the day-of-week ratios show that, on average, both Saturday and Sunday traffic, are higher than AADB while weekday traffic is lower than AADB. The graph of monthly ratios shows visually what Table F1

shows, namely, that summertime traffic is about double AADB. The effects of weather on traffic volumes can be seen clearly in the day-of-year ratios, with traffic on some days as high as five times AADB.

Table F-1. Mixed Mode 2011 Traffic Volume Measures for Midtown Greenway near Hennepin Avenue, Minneapolis, Minnesota												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Monthly Average Daily Traffic	239	354	586	1,807	2,753	3,699	4,099	3,896	2,805	1,960	886	495
Sunday Average Traffic / Monthly Average Daily Traffic	0.89	1.33	0.89	1.55	0.88	1.29	1.18	1.34	1.06	1.20	0.75	1.11
Monday Average Traffic / Monthly Average Daily Traffic	1.01	0.66	1.10	1.10	0.98	0.95	0.98	0.87	1.22	0.96	1.00	1.08
Tuesday Average Traffic / Monthly Average Daily Traffic	1.10	0.74	0.91	0.96	1.27	0.89	0.91	0.74	0.86	1.03	1.01	1.07
Wednesday Average Traffic / Monthly Average Daily Traffic	1.15	0.96	0.93	0.76	1.11	0.96	0.94	1.07	0.99	0.87	1.03	0.97
Thursday Average Traffic / Monthly Average Daily Traffic	1.06	1.00	1.03	0.88	0.93	0.96	0.90	1.03	0.85	0.87	0.97	0.92
Friday Average Traffic / Monthly Average Daily Traffic	0.97	1.04	0.84	0.78	0.79	0.96	0.95	0.88	0.87	0.82	1.31	0.91
Saturday Average Traffic / Monthly Average Daily Traffic	0.88	1.27	1.34	1.03	1.02	1.02	1.09	1.15	1.23	1.16	0.91	0.98
Annual Average Daily Traffic	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975	1,975
Monthly Average Daily Traffic / Annual Average Daily Traffic	0.12	0.18	0.30	0.92	1.39	1.87	2.08	1.97	1.42	0.99	0.45	0.25

Figure F-2 shows the effects of both duration of sampling and method of factoring on estimates of AADB (Hankey 2013). For samples of between five and seven days, error in estimates of AADB can be as low as 10% - 15%. The key insights from Figure D-2 are:

- The optimal length of short duration samples is between five and seven days because samples from longer time periods do not greatly increase the accuracy of estimates of AADB: and
- Use of "day-of-year" factors results in greater accuracy than the standard approach to factoring used to extrapolate short duration counts of motorized traffic. This result occurs because the day-of-year factors better reflect weather.

Other studies also have shown that sample periods of five to seven days and use of day-of-year factors result in greater accuracy in estimates of AADB (Nordback XX; Miranda). A limitation of the day-of-year factoring approach is that a year's worth of data that includes the sample periods is needed to development the factors. The standard approach, which involves estimation of factors based only on the day-of-week and month (and does not consider weather) is more general and can be applied using historical data across years. Figure F-2 also illustrates that, within a fixed time period, the number of monitors required to implement a short duration count program depends on the duration or length of sampling.

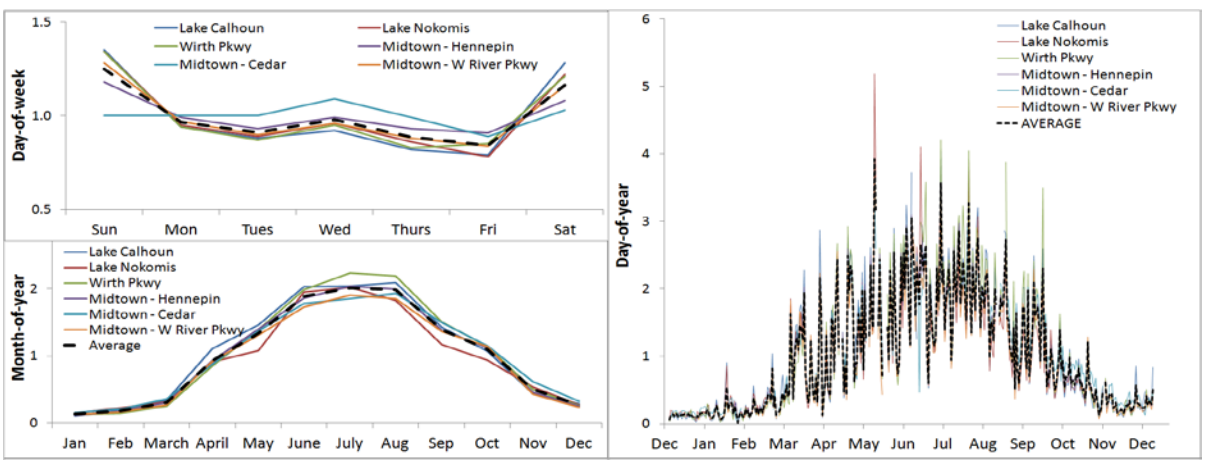


Figure F-1: Day-of-week, month-of-year, and day-of-year traffic ratios at permanent monitoring stations on trails in Minneapolis

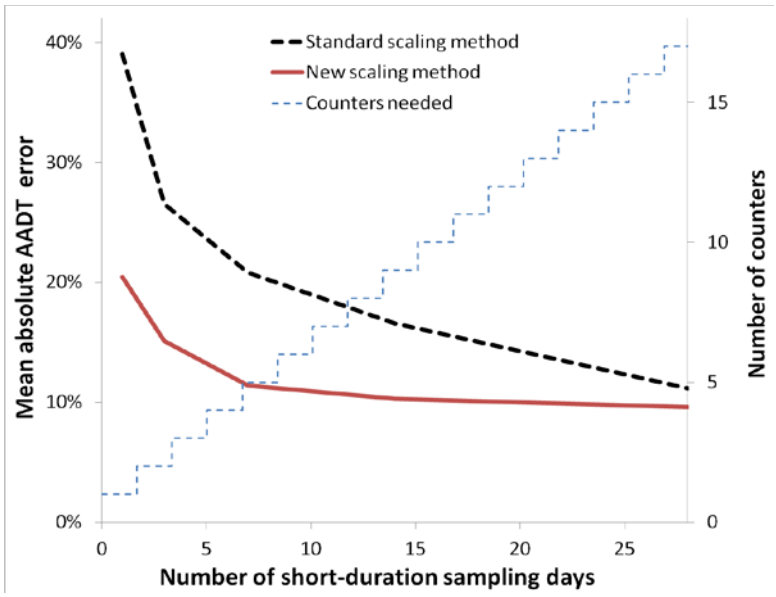


Figure F-2: Effects of length of sample and extrapolation method on error in estimate of AADT (Hankey et al. 2013).

A third example that builds on these results was an exercise in 2014 to estimate AADB and trail miles traveled on an 80-mile network in Minneapolis. This exercise, which involved application of principles for factoring outlined in the TMG and used by MnDOT for factoring of motorized counts, showed that AADB on trail segments ranged from approximately 40 to more than 3,700 and that cyclists and pedestrians traveled more than 28,000,000 miles on the network in 2013. A detailed example of the use of adjustment factors is presented in the case study in Section 6.5.4.

APPENDIX G – DAY-OF-YEAR FACTORING APPROACHES USED BY LOCAL AGENCIES

In order to calculate AADB, staff used a permanent counting station at Central Ave and Lowry Ave in Minneapolis that collected bicycle volumes 365 days per year to **estimate how bicycle traffic on any given day compared to the average bicycle traffic from that entire year**. This serves as a control for weather and other unknown daily factors.

Steps to calculate AADB are as follows:

1. Obtain a chart that lists the hourly traffic at the Central Ave & Lowry Ave site for every hour of 2015.
2. Calculate bicycle volumes at the Central Ave site (southbound only because northbound broke) for the exact time period of each 48 hour count. For example, for site 303 EB, 123 bicyclists were counted between 11am on 9/14/15 and 11am on 9/16/15.
3. Divide that number by the total volume for the year at the Central Ave site. This will give you the percentage of annual traffic at this location that took place during each 48 hour sample period. At site 303 EB, that calculation is 123 / 13146 = .00917. In other words, 0.917% of annual traffic at the Central Ave location took place between 11am on 9/14/15 and 11am on 9/16/15.
4. Divide the 48 hour raw counts at each location by the percentage calculated in step 3 above. This will give you the estimated annual traffic at each location. For site 303 EB, this calculation is 389 / .00917 = 42429. In other words, the estimated annual bicycle traffic at site 303 EB is 42,429.
5. Divide the estimated annual traffic at each location by 365 to get annual average daily bicycle traffic (AADB). At site 303 EB, this is 42429 / 365 = 389.
6. For one-way sites or sites where both directions were counted at the same place at the same time (i.e. both directions are represented in the 48 hour raw count), you are finished. For sites where the 48 hour raw counts are listed separately for each direction because they were calculated at different times or in different places, simply add the AADB for the two directions. Note that if counts were collected in different times or places, you do need to calculate AADB independently for each direction – do not combine raw counts unless taken at the exact same time and place.

Steps to calculate monthly or seasonal average are as follows:

1. Obtain a chart that lists the hourly traffic at the Central Ave & Lowry Ave site for every hour of 2015.
2. Calculate bicycle volumes at the Central Ave site (southbound only because northbound broke) for the exact time period of each 48 hour count.
3. Divide that number by the total volume for the month or season of interest. This will give you the percentage of monthly/seasonal traffic at this location that took place during each 48 hour sample period.
4. Divide the 48 hour raw counts at each location by the percentage calculated in step 3 above. This will give you the estimated monthly/seasonal bicycle traffic at each location.
5. Divide the estimated monthly/seasonal traffic at each location by the number of days in that time period of interest to get the average daily bicycle traffic for that time period.
6. For one-way sites or sites where both directions were counted at the same place at the same time, you are finished. For sites where the 48 hour raw counts are listed separately for each direction because they were calculated at different times or in different places, simply add the AADB for the two directions. Note that if counts were collected in different times or places, you do need to calculate AADB independently for each direction – do not combine raw counts unless taken at the exact same time and place.

Figure G-1 Hennepin County Day-of-Year Factoring Method for Estimating AADB (Hennepin County 2016)

… To derive SADT, ARDC calculated the percent of summer traffic that occurred at the control site, divided the count at each sample site by the percent of summer traffic at the control site to derive the estimated summer traffic at each site, and divided the estimated summer traffic at each site by the total number of collection days at each site to derive the average daily traffic count for the summer. This calculation can be represented with the following string of equations, where N_C is adjusted trail user counts at the control site throughout summer, N_s is adjusted trail user counts at a sample site throughout summer, n_c is adjusted trail user counts at the control site during sample dates, n_s is adjusted trail user counts at a sample site during sample dates, P_{nc} is the percentage of summer traffic at the control site during the sample dates, and $SADT_s$ is the SADT at a sample site:

$$\frac{n_c}{N_c} = P_{nc}$$

$$\frac{n_s}{P_{nc}} = N_s$$

Figure G-2 ARDC Day-of-Year Factoring Method for Estimating Summertime Average Daily Traffic (SADT; ARDC 2016)