The Minnesota Bicycle and Pedestrian Counting Initiative: Methodologies for Non-motorized Traffic Monitoring

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Greg Lindsey, Principal Investigator
Hubert H. Humphrey School of Public Affairs
University of Minnesota

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16. Abstract (Limit: 250 words)

The purpose of this project was to develop methodologies for monitoring non-motorized traffic in Minnesota. The project included an inventory of bicycle and pedestrian monitoring programs; development of guidance for manual, field counts; pilot field counts in 43 Minnesota communities; and analyses of automated, continuous-motorized counts from locations in Minneapolis. The analyses showed hourly, daily, and monthly patterns are comparable despite variation in volumes and that adjustment factors can be used to extrapolate short-term counts and estimate annual traffic. The project technical advisory panel made five recommendations: (1) MnDOT should continue and institutionalize coordination of annual statewide manual bicycle and pedestrian counts; (2) MnDOT should improve methods for reporting results of field counts and explore web-based programs for data reporting and analysis; (3) MnDOT should lead efforts to deploy and demonstrate the feasibility of new automated technologies for bicycle and pedestrian counting, focusing on new technologies not presently used in Minnesota; (4) MnDOT should begin integration of non-motorized traffic counts from existing automated, continuous counters in Minneapolis into its new databases for vehicular traffic monitoring data; and (5) MnDOT should work with local governments and explore institutional arrangements for (a) establishing a network of permanent, automated continuous monitoring sites across the state and (b) sharing and deploying new technologies for short-duration monitoring to generate traffic counts that provide a more comprehensive understanding of spatial variation in non-motorized traffic volumes.

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Final Report

Prepared by:

Greg Lindsey
Junzhou Chen
Hubert H. Humphrey School of Public Affairs
University of Minnesota

Steve Hankey
Department of Civil Engineering
University of Minnesota

Xize Wang
Sol Price School of Public Policy
University of Southern California

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St. Paul, Minnesota 55155-1899

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- Lisa Bigham, MnDOT District 7;
- Simon Blenski, City of Minneapolis;
- Amber Dallman, Minnesota Department of Health;
- Rob Ege, MnDOT District 1 - State Aid;
- Brad Estochen, MnDOT Office of Traffic Safety;
- Tom Faella, RDC - LaCrosse Area Planning;
- James Gittemeier, Metropolitan Interstate Council, Duluth;
- Gene Hicks, MnDOT -Traffic Data and Analysis;
- Tony Hull, Toole Design;
- Cassandra Isackson, MnDOT TDA;
- Matt Johnson, RDC Mid-Minnesota Development Center;
- Tim Kelly, DNR Research;
- Muhammad Khan, Olmsted County;
- Thomas Mercier, Three Rivers Park District;
- Gina Mitteco, MnDOT Metro District Bike/Ped Coordinator;
- Gordy Pherson, Department of Public Safety;
- Bobbi Retzlaff, MnDOT Multimodal planning ;
- Dan Warzala, MnDOT Research Services; and
- Jan Youngquist, Metropolitan Council.

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The goal of this study was to develop general guidance and consistent methods for counting bicyclists and pedestrian in Minnesota. The research involved a literature review, identification of local bicycle and pedestrian counting programs and collection of bicycle and pedestrian counts, development of guidance for conducting manual field counts, implementation of pilot field counts and analyses of results, analyses of automated, continuous counts, and development of recommendations for automated non-motorized traffic monitoring. The research was guided by a technical advisory committee that included representatives from across Minnesota.

Trends in Bicycle and Pedestrian Counting

Federal, state, and local governments and nonprofit professional and advocacy organizations have launched initiatives to support non-motorized traffic monitoring. Two national initiatives have particular relevance for the state of Minnesota. The National Bicycle and Pedestrian Documentation Project (NBPDP), a partnership between the Institute of Transportation Engineers, and Alta+ Design, a consulting firm, encourages short-duration (e.g., two-hour) field counts of bicycles and pedestrians semi-annually following a standard set of protocols. In 2012, the Federal Highway Administration (FHWA) circulated a draft chapter on non-motorized traffic monitoring in its authoritative Traffic Monitoring Guide (TMG), the standard for vehicular traffic monitoring in all 50 states. The TMG addresses limitations of counts obtained with NPBDP protocols, assesses technologies available for automated, continuous monitoring of non-motorized traffic, and outlines steps in integrating continuous and short-duration non-motorized traffic monitoring programs.

Bicycle and Pedestrian Counting in Minnesota

Several municipalities, recreational agencies, and nonprofits in Minnesota currently are engaged in non-motorized traffic monitoring. The Minneapolis Department of Public Works (MDPW), conducts both manual field counts and operates three inductive loop detectors, is a leader in the state. Transit for Livable Communities (TLC) also has conducted manual field counts and undertaken both continuous and periodic automated counting of bicycle and pedestrian traffic. Both MDPW and TLC have adapted the NBPDP protocols. Recreational agencies, including the Minnesota Department of Natural Resources (DNR), the Metropolitan Council, the Three Rivers Park District, and the Minneapolis Park and Recreation Board, are participating in counting on multiuse trails. No jurisdictions in Minnesota apparently have experimented with automated, continuous counting of bicycles on streets, none deploy new pneumatic tubes on streets for short-duration continuous monitoring, and none has deployed integrated loop detectors and infrared sensors to differentiate bicyclists and pedestrian on multiuse trails or other facilities.

Guidance for Short-duration Manual Field Counts

The project team developed training materials and standard forms for manual counts of bicycle and pedestrian traffic. The guidance and protocols were based on protocols followed by MDPW and TLC that originally were based on NBPDP protocols. The materials, which MnDOT began distributing on its website in the summer of 2012, include:

1. Standard forms for field counts that can be modified to collect different attributes of bicyclists and pedestrians;
2. A Powerpoint slide show for training local count managers;
3. A Powerpoint slide show for training people (either employees or volunteers) for conducting manual counts; and
4. Sample public information sheets for distribution to passers-by to explain the purpose of counting;
5. Check lists for count managers and volunteers to ensure completion of valid counts;
6. Links to websites available for downloading smartphone applications that provide latitude and longitude of counting locations, and
7. Spreadsheets for results of field counts.

To train people in counting and to recruit participants for pilot field counts in September 2012, a webinar and training workshops were held in Alexandria, Bemidji, Duluth, Marshall, and Rochester in the summer of 2012. Seventy-five people attended the training sessions.

Short-duration Manual Field Counts: Pilot Project Results

In September 2012, MnDOT coordinated pilot statewide bicycle and pedestrian counts using the new forms. The Minnesota Department of Health collaborated in the counts and required recipients of State Health Improvement Program (SHIP) grants involved in active travel interventions to participate in the counts. Counts were undertaken at 133 locations in 43 communities. In addition, MDPW and TLC conducted counts at several hundred locations as part of their ongoing monitoring programs. Most counts were taken during evening peak hours on mid-week days. Across all cities at all times, mean hourly bicycle and pedestrian traffic volumes were 7.5 and 19.3, respectively. Mean hourly bicycle and pedestrian traffic was substantially higher in Class I cities with populations greater than 100,000 than in cities with smaller populations. Across smaller cities, mean hourly traffic volumes generally were comparable. A post-count survey of count managers found that many communities participated because of MDH requirements, that traffic volumes recorded were comparable to volumes expected, that the MnDOT guidance was helpful but that methods for reporting counts need to be improved, that data collected during the counts was already being used, and that some jurisdictions, but not all, would participate again if MnDOT held additional counts.

Analyses of Continuous Counts

Analyses of automated continuous counts from six locations on multi-use trails in Minneapolis with inductive loop detectors and active infrared monitors demonstrated the limitations of these technologies. The analyses also illustrated hourly, daily, and monthly patterns in bicycle, pedestrian, and mixed-mode traffic; and the feasibility of estimating average annual daily traffic and miles traveled on segments of multiuse trails using procedures outlined in FHWA’s Traffic Monitoring Guide. The automated continuous monitoring showed that annual trail traffic in Minneapolis is substantial but varies significantly across locations; that hourly, daily, and monthly patterns are comparable despite variation in volumes, and that adjustment factors developed from continuous counts can be used to extrapolate short-term counts to obtain estimates of annual traffic.

Conclusions and Recommendations

This research has documented:

- growing support for counting non-motorized traffic across the United States,
- the existence of successful local counting initiatives in Minnesota;
- the feasibility of standardizing approaches to manual field counts of bicyclists and pedestrians;
- the willingness of Minnesota communities to participate in field counts; and
- the feasibility of using analytic procedures historically used in vehicular traffic monitoring to analyze automated continuous counts of non-motorized traffic, develop adjustment factors for extrapolation of short-duration counts, and estimate average annual daily traffic and annual miles traveled.

Given these findings, the research team recommends:

1. MnDOT should continue and institutionalize coordination of annual statewide bicycle and pedestrian field counts using the new MnDOT guidance and forms.

2. MnDOT should improve methods for reporting results of field counts and explore web-based programs for data reporting and analysis, including opportunities to integrate short-duration field counts into databases used to archive vehicular monitoring data.

3. MnDOT should lead efforts to deploy and demonstrate the feasibility of new automated technologies for bicycle and pedestrian counting, focusing on new technologies not presently used in Minnesota. New technologies that have not yet been deployed in Minnesota include inductive loop detectors for counting bicycles in streets, pneumatic tubes for short-duration continuous counting of bicycles on streets, infrared counters for counting pedestrians on sidewalks, and integrated loop detectors and infrared monitors for differentiating and counting both bicycles and pedestrians on multiuse trails.

4. MnDOT should begin integration of non-motorized traffic counts from existing automated, continuous counters in Minneapolis into its new databases for vehicular traffic monitoring data.

5. MnDOT should work with local governments and explore institutional arrangements for: (a) establishing a network of permanent, automated continuous monitoring sites across the state to develop the data necessary for factoring and extrapolating short-duration counts, and (b) sharing and deploying new technologies for short-duration monitoring to generate traffic counts that provide a more comprehensive understanding of spatial variation in non-motorized traffic volumes. Special effort should be made to work with the State’s smallest jurisdictions to develop cost-effective strategies for acquiring information about bicycle and pedestrian traffic.

Chapter 1
Introduction

Traffic volumes are a basic input to transportation planning and engineering, and the U.S. Department of Transportation (USDOT), state departments of transportation, and local governments have established sophisticated, comprehensive monitoring systems to produce estimates of vehicular traffic on federal, state, and local roads. However, comparable systems for monitoring non-motorized traffic – bicyclists and pedestrians – have not been established, and transportation planners and engineers generally lack basic information about bicycle and pedestrian traffic volumes needed to plan for these modes. In Minnesota, for example, the Minnesota Department of Transportation (MnDOT) and collaborating local governments maintain more than 1,000 continuous monitoring sites for vehicular traffic and conduct short-duration (e.g., 48 hour) vehicular traffic counts at more than 30,000 sites on a five-year, rotating basis. In comparison, MnDOT historically has maintained no continuous monitoring sites for non-motorized traffic and has conducted bicycle and pedestrian counts only on a project-by-project basis when deemed necessary. Only a few local governments in Minnesota have monitored non-motorized traffic, and neither the state of Minnesota nor local governments have established consistent protocols for monitoring or conducting bicycle and pedestrian counts.

The goal of this study was to develop general guidance and consistent methods for counting bicyclists and pedestrian in Minnesota. The research involved a literature review, identification of local bicycle and pedestrian counting programs and collection of bicycle and pedestrian counts, development of guidance for conducting manual field counts, implementation of a pilot field count to test the protocols, analyses of field counts, analyses of automated, continuous counts including development of scaling factors for extrapolation of short-term counts, and development of recommendations for automated non-motorized traffic monitoring. The research was guided by a technical advisory committee that included representatives from state and local government and nonprofit organizations across Minnesota. This report summarizes basic findings, including recommendations for integrating non-motorized traffic monitoring with vehicular traffic monitoring systems in Minnesota.

Chapter 2
Counting Bicyclists and Pedestrians: An Overview

Transportation researchers have worked on the problem of monitoring bicycle and pedestrian traffic volumes for more than forty years, but increasing demand for traffic data, combined with the development of new technologies for monitoring, has sparked recent growth in the number of initiatives to count non-motorized traffic. This Chapter presents a general overview of recent progress and current initiatives in non-motorized traffic monitoring. This overview is purposeful, not exhaustive, and focuses on resources particularly useful for people planning to implement counting programs. It draws on the peer-reviewed academic literature; technical reports, memoranda; and powerpoint presentations; and web-sites maintained by state departments of transportation, local governmental agencies, and nonprofit organizations. The overview is presented in the format of "frequently asked questions" (FAQs) in anticipation of posting to the MnDOT website in addition to publication as a technical report. The reason for this format is to help make the findings more accessible to people in Minnesota and elsewhere who are interested in establishing or improving programs for counting bicyclists and pedestrians.

2.1 Why Count Bicyclists and Pedestrians?

Traffic counts are one of the basic building blocks of transportation planning and engineering (FHWA 2001, 2012). Transportation planners and engineers need information about volumes of bicyclists and pedestrians on streets, sidewalks, multiuse paths, and other facilities to design safe and efficient transportation systems. At the federal level, the Bureau of Transportation Statistics has determined there is a high priority for data on non-motorized transportation volumes (BTS 2000) and identified methods for estimating non-motorized traffic (USDOT 1999). Similarly, researchers and experts (e.g., Hunter and Huang 1995; Porter and Suhrbier 1999; Schneider et al. 2005) and nonprofit and professional organizations in the transportation field (National Bicycle and Pedestrian Documentation Project (NBPDP 2013) describe the practice and importance of counting bicyclists and pedestrians. Specific reasons to count bicyclists and pedestrians include to:

- Document use of facilities and establish benchmarks;
- Allocate resources;
- Assess efficiency of investments;
- Optimize facility operations & maintenance;
- Assess exposure rates and need for safety interventions;
- Improve systems planning; and
- Inform and conduct research.

For example, if transportation managers do not know traffic volumes, they cannot determine exposure and accident rates, and they cannot assess the effectiveness of programs to reduce bicyclist and pedestrian fatalities. Similarly, if transportation managers do not know volumes of bicyclists and pedestrians on particular facilities, they cannot determine efficient maintenance programs that maximize benefits of resources devoted to system operations.

2.2 What Approaches and Technologies Are Used to Count Bicyclists and Pedestrians?

State and local officials, advocates for non-motorized transportation, and researchers use a variety of approaches and methods to count bicyclists and pedestrians (e.g., FHWA 2012, NBPDP 2013). These approaches include both manual, field observations and automated, continuous counting using a variety of technologies. Although experts use somewhat different categories for purposes of classification, the following list captures the most commonly used approaches and technologies for counting:

- Manual field observations;
- Active infrared monitors;
- Passive infrared monitors;
- Inductive or magnetic loop detectors (in pavement);
- Pressure sensors (piezometric);
- Pneumatic tubes; and
- Video imaging.

Several authors have described the pros and cons of these different methods, their relative costs, tradeoffs inherent in the choice of technologies, and factors to consider in deployment (FHWA 2012; Dharmaraju et al. 2001; Greene-Roesel et al. 2008; Hudson et al. 2010; Papanikolopoulos 2010; Yang et al. 2010; Nordback and Janson 2011; AMEC 2011). Factors or considerations in the design and implementation of a counting program, including choice of automated technologies, include:

- How the counting technologies work;
- Type of data generated;
- Quality of data generated and the need for calibration;
- Ease of deployment (e.g., location, type of facility, relocation); and
- Cost of deployment.

Experts agree the choice among methods is mainly about trade-offs. The tradeoffs are fairly straightforward: approaches and technologies that provide more accurate, continuous counts over longer periods of time are more expensive than less accurate approaches for the same time period. Manual counting, which is generally the standard by which other methodologies are validated, is labor intensive, very expensive, and therefore not feasible for sustained continuous counts required to identify hourly, daily, monthly or annual traffic patterns. Manual field counts are useful if planned well for identifying characteristics or attributes of bicyclists or pedestrians that cannot be determined with most automated technologies. Table 2.1, which summarizes tradeoffs among technologies currently used by local agencies in Minnesota for counting, illustrates the types of tradeoffs that any state or local official must consider when deciding whether and how to implement a counting program.

Table 2.1 Examples of Tradeoffs in Methods of Counting Used in Minneapolis in 2011

Method of observation	Manual	Magnetic Loop Detector	Active Infrared Counters (beam/sensors)
Traffic observed	Cyclists (bi-directional) Peds (bi-directional)	Cyclists only (bi-directional, potentially)	Cyclists & Peds combined (no directional)
Output	Choice of time units	15 minute blocks	Time of event
Locations for deployment	On and off-street facilities & no facilities	Off-street facilities	Depends on counter type and facility characteristics
Length of observations	Based on staff availability (often two-hour blocks)	Continuous: 24 hours	Continuous: 24 hours
Limitations	Human error	Must calibrate	Must calibrate; systematic undercount (beam counters)
Sources of error	Distractions Large groups	Misses riders on edge of trail.	Misses users passing simultaneously
		Direction of riders in wrong lanes recorded incorrectly	
Data recorded	5 – 60 minute time intervals	15 minute counts	Time of “event”; can be aggregated to any time period
Other considerations	Can record groups, some user characteristics such as helmet use, gender, and age group	Cannot measure user characteristics	Cannot measure user characteristics

The technologies available for monitoring non-motorized traffic are developing rapidly, and communities are beginning to deploy technologies that only a few years ago were not available. For example, local governments across the country are now deploying inductive loop detectors in streets and bike lanes that can distinguish between bicycles and motor vehicles. Similarly, pneumatic tubes that distinguish between bicycles and cars now are being deployed. The National Cooperative Highway Research Program of the Transportation Research Board has initiated a study, *Methodologies and Technologies for Collecting Pedestrian and Bicycle Volume Data*, due to be released in 2014 that will include testing of these and other new technologies.

2.3 How Accurate Are Different Approaches and Technologies for Counting?

The accuracy of particular estimates varies, depending on the type of traffic being measured, the technology of the counter, the quality of installation and maintenance, and other human factors. All bicycle and pedestrian traffic volume counts are estimates, including counts from manual field observations. The accuracy of methods is improving as demand for technologies increases.

In a detailed assessment of automated loop detectors installed to count bicycles in Boulder, Colorado, Nordback and Janson (2011) documented error rates of less than 20%. Error rates as high as 50% have been reported for some technologies (AMEC 2011). Error rates associated with manual counts, especially at high volume intersections, may be as high as 25%, although rates for screenline counts at lower volume locations are lower. Recent studies of different technologies by students and researchers at the University of Minnesota documented different magnitudes of error with different technologies (Anderson and Senn 2010, Lindsey et al. 2012):

- Magnetic loop detectors installed by the Minneapolis Department of Public Works on different sections of the same trail both over-counted and undercounted. Hourly bicycle traffic volumes ranged from an average overestimate of 25%-30% to an average undercount of 5% - 15% when compared with manual counts;
- Active infrared counts systematically undercounted mixed-mode traffic volumes (i.e., undifferentiated bicycle and pedestrian flow) on a multiuse trail by 15% to 20% percent, depending on traffic flow and other characteristics.
- Manual screenline counts of hourly bicycle and pedestrian traffic resulted in average inter-observer errors of between one and two percent and varied with traffic flow.

In comparison, estimates of error rates for pneumatic tubes, the most commonly used technology for counting motor vehicles, are approximately 10%. Possible explanations for the apparent difference in accuracy among automated technologies for counting motorized and non-motorized transportation include differences in specific technologies, differences in patterns of traffic flow, differences in market demand for counters (which spurs innovation), and differences in experience with technology (e.g., agencies have been measuring motor vehicle volumes for more than 50 years).

2.4 Who Is Counting Bicyclists and Pedestrians?

Across the United States, most counting of bicyclists and pedestrians is done by local governments, nonprofit organizations, including advocacy organizations, and researchers. The National Bicycle and Pedestrian Documentation Project, described in section 2.5.1, is the largest initiative to date and has supported counts by municipal governments, recreational agencies and organizations, and other nonprofit organizations. Schneider et al. (2008) have described other counting programs.

A few states have initiated bicycle or pedestrian counting programs or are collaborating with local jurisdictions or nonprofit organizations, but in comparison to = programs for counting motor vehicles, these programs are in their infancy. In the spring of 2012, a team of graduate students in a workshop at University of Minnesota scanned all 50 state departments of transportation (DOT) websites for information about bicycle and pedestrian counting initiatives (Baker et al. 2012). Members of the team then followed up with telephone conversations with staff at DOTs to obtain more information about bicycle and pedestrian counting initiatives described on their websites. They concluded there was (Baker et al. 2012, p. 5):

- "extensive evidence" of DOT support for non-motorized traffic monitoring in three states: Colorado (bicycleinfo@dot.state.co.us), Vermont (http://www.aot.state.vt.us/planning/Documents/Planning/Technical_Memo2B.pdf), and Washington (http://www.wsdot.wa.gov/bike/Count.Htm);
- "some" evidence of DOT support for monitoring in 30 states, and
- "little or no" evidence of DOT support in 17 states.

Compared to programs for counting motor vehicles, even these programs were relatively new, very small, and involved counting at relatively few sites. These three initiatives varied substantially in their approaches and support for different methods of counting.

At the time of the survey, the Colorado DOT had invested in six automatic counters and was beginning to integrate bicycle counts into its motorized vehicle monitoring databases. The state also was supporting research to develop monitoring protocols and adjustment factors for extrapolating short-duration traffic counts. Colorado DOT administrators had concluded that the agency would not support counting efforts following NBPDP protocols because of the variability inherent in two-hour short-duration counts and issues of quality assurance and control associated with field counts by volunteers.

The Washington DOT, in contrast, had not yet invested in automated counters but was collaborating with a nonprofit, statewide bicycle organization in the Washington State Bicycle and Pedestrian Documentation Project, an initiative to recruit local organizations and volunteers to conduct counts following NBPDP protocols. The Washington DOT thus had taken an approach explicitly rejected by the Colorado DOT, noting that quality control will be provided by state and local staff and that field counts are valid measures of traffic. Publications summarizing local counts are available from the Washington DOT.

The Vermont DOT had taken a third approach, investing in automated counters but not maintaining continuous monitoring sites, and, instead, loaning counters to local collaborating agencies for local investigations. The Vermont DOT also has summarized results of local counts. While these three approaches vary, each of the state DOTs recognized the importance of using bicycle and pedestrian counts in transportation systems planning and management and the need to develop systematic, consistent approaches to non-motorized traffic monitoring.

2.5 Are There Standard Programs and Methods for Counting Bicyclists and Pedestrians?

Several initiatives to standardize approaches to bicycle and pedestrian counting are underway. These include the National Bicycle and Pedestrian Documentation Project (NBPDP), the Federal

Highway Administration's updating of the Traffic Monitoring Guide, and, as noted, state-level initiatives in Colorado, Washington, and Vermont.

2.5.1. The National Bicycle and Pedestrian Documentation Project

The NBPDP is a joint, voluntary initiative sponsored by the Institute of Traffic Engineers, a national professional association (http://www.ite.org/), and Alta Planning and Design, a consulting firm specializing in non-motorized transportation (http://www.altaplanning.com/). The purpose of the NBPDP is to provide a "consistent model of data collection and ongoing data for use by planners, governments, and bicycle and pedestrian professionals" (http://bikepeddocumentation.org/). The general approach in the NBPDP is to follow standard procedures used in analyses and extrapolation of motor vehicle counts so that non-motorized counts will be regarded similarly by traffic engineers and planners. The NBPDP has made a number of training materials available, is a repository for data generated by agencies, and provides some analyses of counts. Among the training materials are:

- Extrapolation Workbook (xls), for expanding hour counts to annual counts;
- Extrapolation Detailed Explanation (pdf);
- Bike-Pedestrian Counting Equipment 101 (pdf);
- NBPD Counts Training (pdf);
- NBPD Survey Training (pdf);
- NBPD Facts and FAQs (pdf).

Some organizations in Minnesota, notably Transit for Livable Communities (TLC) and the Minneapolis Department of Public Works (MDPW), generally follow the NBPDP protocols for data collection. The NBPDP initially focused on manual field observations but, with the growth of counting programs around the nation, is increasingly focusing on automated counts.

The NBPDP is generally recognized among bicycle and pedestrian professionals as the most ambitious initiative in the nation to standardize methodologies for counting, but many professionals are concerned about its sustainability because it historically has relied on volunteers and the growth in number of collaborating organizations is accelerating. In addition, many professional have questioned the validity and reliability of two hour counts taken by volunteers, noting the counts provide little information about daily traffic patterns and cannot be extrapolated to annual counts with confidence. Most transportation experts believe that the counts obtained using NBPDP protocols cannot be used to obtain satisfactory estimates of average annual daily bicyclists or pedestrians (i.e., the equivalent of measures of average annual daily traffic (AADT) used in vehicular traffic monitoring).

2.5.2 The FHWA Traffic Monitoring Guide: Chapter 4 Traffic Monitoring for Non-motorized Traffic

Spurred by both increasing national interest in bicycle and pedestrian traffic and the successes and limitations of the NBPDP, the U.S. Federal Highway Administration (FHWA) has revised its Traffic Monitoring Guide (TMG), which is the standard reference for monitoring motor vehicle traffic volumes in the United States, to include guidance for monitoring non-motorized traffic.

The FHWA convened a committee of experts has been convened and released a new draft Chapter 4 in 2012. The FHWA also has announced it will begin archiving and sharing non-motorized traffic counts taken by state and local organizations. The new chapter in the TMG reviews seven categories of technologies and provides an overview of concepts used to describe variability in traffic. The categories of technologies reviewed in the TMG include: inductance loop detectors; infrared sensors; magnetometers; pneumatic tubes; pressure and seismic sensors; video image processing; and emerging technologies. The chapter also illustrates time-of-day, day-of-week, and monthly variation in non-motorized traffic. Following standard procedures for vehicular traffic monitoring, the chapter also describes essential steps in establishing a permanent and short-duration data programs.

The key steps in establishing a permanent data program include (FHWA 2012):

1. Review existing continuous count program;
2. Develop inventory of count locations and equipment;
3. Determine traffic patterns to monitor;
4. Establish pattern/factor groups;
5. Determine number of continuous monitoring locations;
6. Select specific count locations;
7. Compute monthly, day-of-week, and hourly adjustment factors.

2.6. What Statistics Are Commonly Used to Describe Bicycle and Pedestrian Traffic?

Transportation engineers and planners commonly use traffic counts to construct indices, ratios, and factors to describe temporal patterns in traffic and inform planning, engineering, and management decisions. These indices and factors include:

- Average annual daily traffic (or average daily bicyclists and average daily pedestrians;
- Mean hourly traffic;
- Mean peak hour traffic and/or average peak hour percentage;
- Mean daily traffic and or daily traffic percentages;
- Mean monthly daily traffic;
- Traffic ratios (e.g., monthly average daily traffic / annual average daily traffic, weekend-weekday traffic ratios).

Depending on the method or technology used in counting (e.g., if manual counts are taken), the daily counts may refer to 8, 12, or 24-hour periods, with the latter always preferred but not always available.

Estimation of these types of factors enables engineers and planners to extrapolate short-duration counts to annual time periods. For example, with hour traffic percentages (or ratios), short, two-hour counts can be extrapolated to daily counts. Similarly, with daily percentages, these counts can be extrapolated to weekly counts. Estimates of average annual daily traffic can be derived using monthly (or seasonal percentages). Because weather and climate conditions affect volumes of non-motorized traffic, it is important to develop factors specific to specific locations in different geographic places. For example, time of day bicycle traffic is likely to be very different in the summer in Portland, Maine than in Phoenix, Arizona because of variations in daily temperature and humidity.

State DOTs routinely compute these types of factors for vehicular traffic, and the same types of factors are becoming available for non-motorized traffic. Lindsey et al. (2007) published time of day, weekend-weekday, and monthly traffic ratios for mixed-mode traffic on multi-use paths in Indianapolis. The NBPDP (2012) has published factors for extrapolating bicycle and pedestrian counts that include time of day, day of week, monthly, and regional factors, with the goal of producing an annual total traffic volume (http://bikepeddocumentation.org/). Nordback (2013) has shown that the uncertainty associated with extrapolation of two hour counts may result in invalid estimates.

As more data become available, researchers will be able to develop more specific factors that take into account variations in mode and facility type. For example, analyses of TLC and DWP 12-hour counts in Minneapolis indicate that hourly, time of day percentages are different for bicycles and pedestrians, with a noon-hour peak for pedestrians that does not existing for cyclists (Hankey et al. 2012). Comparisons of hourly bicycle flow on streets with hourly bicycle flow on paved, multi-use path indicates that peak hour percentages for bicycles on trails are higher than for bicycles on streets, which probably reflects greater recreational traffic. Similarly, analyses of mixed-mode traffic measured with active infrared counters on paved multiuse paths in Minneapolis and Indianapolis indicate that seasonal variation is greater in Minneapolis, with the percentage of annual traffic in the months of June, July, and August much higher in Minneapolis.

2.7 What Factors Influence Bicycle and Pedestrian Traffic?

Researchers have analyzed non-motorized traffic counts to determine factors that influence traffic volumes for more than 40 years (Pushkarev and Zupan 1971; Behnam and Patel 1977; Dill 2009; Guo, et al 2007; Haines and Andrzejweski 2010, Pratt et al. 2011). While similar categories of variables have been found to illustrate these volumes, the correlations vary for bicycles and pedestrian traffic. For example, street functional class may be associated with both bicycle and pedestrian volumes, but pedestrians may be greater on streets with bus lines while the presence of a bus line may not affect bicycle traffic volumes. The general categories of factors shown to correlate with non-motorized traffic volumes include:

- Weather, including temperature, precipitation, humidity, sunshine, pollution (Aultman-Hall et al. 2009; Lindsey et al. 2006, 2007; Holmes et al. 2009);
- Neighborhood socio-demographic characteristics such as age, gender, and education (Moudon et al. 2005; Rodriguez and Joo 2004; Dill and Carr 2003); and
- Urban form and facility type such as land use street network, intersection density, slope, tree cover (Ewing and Cervero 2010; Moudon et al. 2005; Handy et al. 2002; Forsyth 2008; Lindsey et al. 2008; Cao et al. 2006).

These studies of factors that affect non-motorized traffic volumes can be useful in designing count programs.

Chapter 3
Bicycle and Pedestrian Counting in Minnesota

One of the objectives of this research was to identify places in Minnesota where systematic monitoring of non-motorized traffic has been undertaken. This chapter describes approach used to identify agencies and organizations that have conducted bicycle and pedestrian counts and summarizes the scope of existing monitoring programs.

3.1 Identification of Non-motorized Traffic Monitoring Programs in Minnesota

The research team used a “snowball” approach to identify non-motorized traffic monitoring programs in Minnesota. In collaboration with members of the technical advisory committee, researchers compiled a list of local governments and non-governmental organizations known to have conducted bicycle or pedestrian counts. Researchers then contacted these organizations to obtain information about their counting programs and copies of databases. Researchers also asked these organizations about other organizations involved in non-motorized traffic monitoring. These organizations then were contacted. The research team and the advisory committee believe that all major monitoring initiatives in the state were identified through this approach.

Organizations involved in the larger monitoring programs then were invited to a meeting of the technical advisory committee to make brief presentations and describe their counting programs. Presenters at the meeting included the Metropolitan Council, the Three Rivers Park District, the Minnesota Department of Natural Resources, the Minneapolis Department of Public Works, Transit for Livable Communities, and the University of Minnesota, Humphrey School of Public Affairs. Their presentations described methods of monitoring, modes of traffic monitored, and scope of programs.

3.2 Non-motorized Traffic Monitoring in Minnesota in 2012

Table 3.1 summarizes major bicycle and pedestrian counting programs in Minnesota as of 2012. The inventory revealed that, excluding site-specific counting undertaken as a precursor to particular infrastructure improvements such as installation of traffic lights, few local governments or nonprofit organizations have begun systematic collection of bicycle and pedestrian traffic volume data. Most counts taken in the state to date have been manual, short-duration (e.g., two-hour) counts, and state and local agencies have limited experience using technologies for automated continuous counts. Most of the automated continuous counts taken have been mixed mode counts on multiuse trails using infrared counters, although one organization has monitored bicycle traffic at three locations on a multiuse trails, and another organization has begun monitoring pedestrian traffic at one location on a sidewalk. No automated monitoring of bicycles on streets has been attempted in Minnesota.

Table 3.1 Minnesota Agencies Conducting Bicycle and Pedestrian Counts

Agency/Organization	Bikes	Peds	Mixed-Mode	Manual (locations)	Automated Technology (locations)	Protocols and Other Notes
Metropolitan Council and regional park implementing agencies: Anoka, Carver, Dakota, Ramsey, Scott and Washington Counties; City of Bloomington, Minneapolis Park and Recreation Board, City of St. Paul, Three Rivers Park District	X	X		± 500 trail segments		Metropolitan Council protocols for 10 regional park implementing agencies: annual counts of users entering trails. The counts are intended to quantify the number of visits to regional trails, not the volume of traffic on the trails. The Metropolitan Council is required by State Statute 473.351 to use its annual visit estimates in the formulas for the distribution of operations and maintenance funding and by State Statute 85.53 for the distribution of Parks and Trails Legacy Fund dollars to the metropolitan regional parks system. Reports four year averages (e.g., 2008 – 2011). Counts not comparable to screen line counts.
Minneapolis Dept. of Public Works (MDPW)	X	X		± 400 streets, sidewalks	3 inductive loops on trails	Manual counts follow modified National Bike and Pedestrian Documentation Project protocols. September manual counts since 2007. Continuous bike counts since 2007. In collaboration with TLC.
Minnesota Dept. of Natural Resources	X	X		12 state-owned trails		DNR protocols: counts users on trails by riding along trail (i.e., trail user scan). Count entire trail once per 10 years since 1990. Counts not comparable to screen line traffic counts.

Table 3.1 Minnesota Agencies Conducting Bicycle and Pedestrian Counts, continued

Agency/Organization	**Bikes**	**Peds**	**Mixed-Mode**	**Manual (locations)**	**Automated Technology (locations)**	**Protocols and Other Notes**
Transit for Livable Communities (TLC)	X	X	X	± 45 streets, sidewalks	4 infrared monitors	Manual counts follow modified National Bike and Pedestrian Documentation Project protocols. September manual counts since 2007 at 43 reference locations, including five locations monitored monthly. Continuous automated ped and mixed mode counts at four location using infrared technologies; periodic continuous counts at other locations. Counts in collaboration with MDPW.
Three Rivers Park District (count locations included in Metropolitan Council totals)	X	X	X	± 250 District trail segments	7 "semi-permanent sites passive infrared; ± 12 short-duration sites	Follows Metropolitan Council protocols for manual counts as baseline. To meet data needs, District has expanded monitoring program to include mode split, and users entering and passing on trail. Augments manual counts with periodic continuous automated, mixed mode counts.
UMN Humphrey School, Minneapolis Park and Recreation Board (MPRB), and MDPW			X		6 active infrared on trails	Continuous mixed-mode counts at six locations, including two locations with separate bike and ped paths, since 2010 or 2011, depending on site.

Key findings from the inventory included:

- Transit for Livable Communities (TLC), a nonprofit organization that advocates for sustainable transportation options and was responsible for administration of the Non-motorized Transportation Pilot Program (NTPP) in the Twin Cities metropolitan area, initiated a major counting program in 2007 as part of its evaluation of the NTPP. TLC's program, which generally follows protocols established in the National Bicycle and Pedestrian Documentation Project (NBPDP), includes twice-annual, two-hour field counts at more than 40 reference locations, monthly two-hour counts at a number of locations, a continuous pedestrian count for more than one year on one sidewalk in Minneapolis, and periodic continuous, automated counts on multiuse trails and sidewalks at other locations. TLC collaborates closely with the Minneapolis Department of Public Works, and most of its counts are in Minneapolis. TLC has published a series of reports on its annual counts that are available on its website (http://www.bikewalktwincities.org/).

- The Minneapolis Department of Public Works (MDPW) has conducted annual (fall), two hour field counts of bicyclists and pedestrians since 2007, and the agency plans to continue them. Like TLC, the MDPW has adapted the NBPDP protocols for its manual counts, and MDPW and TLC share data as part of their efforts to implement and evaluate the NTPP. Together, MDPW and TLC have completed counts at more than 400 locations in Minneapolis. MDPW also has completed 12-hour manual counts at 40 to 50 locations and has maintained three automated inductive loop detectors on the Midtown Greenway since 2007. MDPW collaborates with the University of Minnesota in collection and analysis of data from the inductive loop counters. MDPW has published a series of reports on its annual counts that are available on its website (http://www.minneapolismn.gov/bicycles/data/WCMS1P-088370).

- State and local agencies responsible for recreation have counted bicyclists and pedestrians on multi-use trails for at least two decades, but they follow different protocols than those typically used in traffic monitoring, and the counts are not directly comparable to the screen-line or cordon counts used to describe vehicular traffic or bicycle and pedestrian counts on streets and sidewalks. The Three Rivers Park District, which has one of the region's largest counting programs, has initiated automated counting of trail traffic to augment its manual counts done in collaboration with the Metropolitan Council. The District counts users entering trails at 252 locations following Metropolitan Council protocols; these counts occur annually, every few years, or several times annually depending on needs and site characteristics. The District has deployed automated infrared counters "semi-permanently" at seven locations on trails, conducted shorter-duration counts of two weeks to two months using automated counters at another dozen locations, and begun use of trail cameras to document mode split at low volume locations. The Metropolitan Council publishes an annual report that summarizes four-year average park and trail use (http://metrocouncil.org/getattachment/32a56a2c-f3f3-4396-a278-551a9fe4647a/.aspx).

- Faculty and students with the Humphrey School of Public Affairs at the University of Minnesota have initiated continuous, automated monitoring of traffic at six locations on multiuse trails in Minneapolis. At two of the locations where bicycle and pedestrian traffic is directed to separate paths during the spring, summer, and fall, separate monitors have been installed on bicycle and pedestrian facilities. This monitoring, which is done in collaboration with both the Minneapolis Park and Recreation Board and MDPW, was initiated in 2010. The Humphrey School has published analyses of its automated counts (Wang et al. 2012).

Other communities and organizations have initiated counts or expressed interest in counting to support local initiatives to plan for bicycling walking. For example, the Mississippi River National Recreation Area has identified bicycle and pedestrian counts on trails, streets, and sidewalks in the area as an indicator for monitoring the effectiveness of implementation, and the Cities of Duluth and Rochester expressed interest in monitoring as a way to support planning for non-motorized modes of traffic.

Overall, the inventory revealed broad interest in coordinated efforts to monitor bicycling and walking. People expressed interest in information about both manual, field counts and automated continuous counting. The level of interest in counting was a factor in the decision to initiate pilot field counts in September 2012 (see Chapter 5).

Chapter 4
Guidance for Short-duration Manual Field Counts

One of MnDOT's priorities for this research project was to develop guidance for conducting manual field observations that would enable jurisdictions to collect bicycle and pedestrian counts that can be compared and aggregated to inform understanding of traffic volumes and patterns. MnDOT established this priority because field observations and manual counts were the most common approach to monitoring non-motorized traffic in Minnesota, jurisdictions undertaking counts were following different protocols or not reporting protocols, increasing numbers of local jurisdictions were inquiring how to do counts, and development of standardized procedures would facilitate comparison with data collected by the Minneapolis Department of Public Works (MDPW) and by Transit for Livable Communities (TLC) in Minneapolis and by other participants in the National Bicycle and Pedestrian Documentation Project (NBPDP). In addition, manual field observations enable collection of information about the characteristics and attributes of bicyclists and pedestrians such as helmet use or gender that typically cannot be obtained with technologies used to obtain continuous automated counts.

4.1 Approach to Developing Guidance for Manual Field Counts

The approach to developing guidance for manual counts involved collection and review of existing protocols and forms, drafting of standard procedures and forms, consultation with the project technical advisory committee, informal field testing, and revision. The protocols and forms then were used in the pilot field counts completed in September 2012 (see Chapter 5).

To ensure consistency and compatibility with existing counting programs, the research team reviewed counting protocols used by the NBPDP, TLC, MDPW, and the Washington Department of Transportation (WDOT). The guidelines or procedures and the forms used by TLC, MDPW, and WDOT are similar and originally were based on the NBPDP protocols.

Each organization uses standard paper forms with sections to report location and other administrative information and to record numbers of bicyclists and pedestrians by a time increment (e.g., 15 minutes, 30 minutes, or one-hour). While there is some variation in design in the procedures and forms, the principal difference involves the level of detail to be collected about the bicyclists or pedestrians. Each organization has written a set of standard procedures for counting, and each organization trains field observers prior to counting. NBPDP and TLC also have developed training programs for "count managers" who are responsible for training employees or volunteers in counting. The protocols and training programs address challenges commonly encountered in the field. For example, representatives of TLC and MDPW serving on the technical advisory committee noted that at busy locations, observers struggled to record attributes of bicyclists and pedestrians and that standard procedure were to limit data collected to maximize validity of traffic volume counts.

In June, 2012, the team presented a draft set of protocols and forms to the technical advisory committee for feedback. Based on committee member comments, the team then revised the draft guidance. The MnDOT guidance was designed to include the common features of the different protocols and forms and to ensure, at minimum, collection of volume counts for similar time periods in consistent ways. MnDOT made the guidance available publicly on its web page in summer 2012.

4.2 MnDOT Guidance for Manual Non-motorized Traffic Counts

MnDOT guidance for manual counts of bicyclists and pedestrians includes:

1. Standard forms for field counts that can be modified to collect different attributes of bicyclists and pedestrians;
2. A powerpoint slide show for training local count managers;
3. A powerpoint slide show for training people (either employees or volunteers) for conducting manual counts; and
4. Sample public information sheets for distribution to passers-by to explain the purpose of counting;
5. Check lists for count managers and volunteers to ensure completion of valid counts;
6. Links to websites available for downloading smartphone applications that provide latitude and longitude of counting locations, and
7. Spreadsheets for results of field counts.

Copies of the training powerpoints and other documents are available at (http://www.dot.state.mn.us/bike/).

The powerpoint for count managers includes, among other items, a general, step-by-step approach to conducting field counts:

1. Consider the 5 W's and an H (who, what, when, where, why, and how);
2. Consult stakeholders and determine purpose;
3. Confirm partnerships;
4. Select locations, and create maps;
5. Recruit and train counters;
6. Conduct counts;
7. Report results to MnDOT; and
8. Evaluate experience and plan next count.

This approach emphasizes the importance of determining the purpose for counting prior to counting. For example, if the purpose is to evaluate a project such as installation of a bike lane, then a series of before and after counts may be warranted. If the purpose is to assess use of helmets, then manual field observations at randomly selected locations and times may be needed. If, however, the purpose is to determine average daily bicyclists and estimate annual bicycle miles traveled on a facility, then manual counts may be inappropriate and automated counting may be necessary. This approach also recognizes the importance of engaging stakeholders and partners in the process of counting. Collaborations are important for maximizing the value of counts.

The MnDOT standard form for counting is simple and requires observers to make few technical judgments (Figure 4.1). Because MnDOT is concerned principally with traffic volumes and not necessarily attributes of cyclists or pedestrians, the actual traffic volumes are the most important data to be recorded.

The research team and the technical advisory committee discussed issues associated with the validity and reliability of counts made by observers. The consensus of the committee was that, with training, the number of misjudgments and error rates associated with counting could be minimized and that the quality of the data would be sufficient for use. Periodic testing to determine inter-observer reliability rates is recommended. In addition, the committee agreed that review of field count forms by count managers is important to prevent administrative errors in reporting.

The original scope of work for this project called for a working conference to obtain peer review of the draft guidance, but in consultation with the MnDOT project leaders and the technical advisory committee, the team instead conducted a webinar and held workshops with practitioners across the state, in part to encourage communities to initiate field counts. The rationales for this change was that more would be learned from engaging communities in counting than in only obtaining feedback on draft forms at a conference and that outreach across the state would be more effective in building the partnerships required to build and sustain successful non-motorized traffic monitoring programs. The pilot field counts are described in Chapter 5.

	Count Station ID:
Date: _____ / _____ / _____	**Day:** *(circle)* Sunday Monday Tuesday Wednesday Thursday Friday Saturday
Location: Street or intersection (nearest address if relevant)	**Count duration, in hours:**
City or Town	**Type of count:** *(circle)* Bicycle Pedestrian Both
County **Minnesota**	**Count start time:** *(circle)* am / pm
Count recorder name(s):	**Name of agency / organization managing count:**
Counter Telephone and Email	**Agency Telephone and Email**
Weather: *(circle and complete)* http://climate.umn.edu/doc/historical.htm Precipitation: yes / no High (F°): _____ Low (F°): _____ Are temperature estimates from UMN climate website? yes / no	**Latitude / Longitude (if available) or GPS coordinates / notes:**

<u>Guidelines for using this count form:</u>

- Please complete all of the fields on both sides of this form.
- Count all bicyclists and pedestrians crossing your screen line under the appropriate categories. ***Make only one tally mark for each person.***
- Count for two hours in 15 minute increments. Record the hour you begin counting in the hour column. Change rows every 15 minutes.
- Count bicyclists who ride on the sidewalk. Ignore the attribute column if no extra details about bicyclists or pedestrian are being collected.
- Count the number of people on the bicycle (i.e., bicyclists), not the number of bicycles.
- Pedestrians include all people not on bicycles. Record pedestrians in wheelchairs, on skates, on scooters, etc. in "Pedestrians Assisted" columns.
- Do your best when traffic volumes are high or people talk to you; it is easy to lost count. Do your best, but note if you lose track.
- If bicycle and pedestrian traffic is too heavy to track attributes, revert to counting just the total bicyclists and pedestrians.

<u>Notes:</u>

Figure 4.1 MnDOT Standard Form for Counting Bicycle and Pedestrian Traffic

Time		Bicyclists			
		Male		Female	
Hour	Minutes	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					

Pedestrians							
Unassisted				Assisted (skaters, wheelchairs, etc.)			
Male		Female		Male		Female	
Adult	Child	Adult	Child	Adult	Child	Adult	Child

Figure 4.1 MnDOT Standard Form for Counting Bicycle and Pedestrian Traffic (Continued)

Sources: Federal Highway Administration (FHWA), National Bicycle and Pedestrian Documentation Project (NBPD), Bike Walk Twin Cities – Transit for Livable Communities (BWTC / TLC), and the Minneapolis Department of Public Works (MDPW)

Chapter 5
Short-duration Manual Counts: Pilot Project Results

In summer 2012, the MnDot project leader, the research team, and members of the technical advisory committee organized five workshops and one webinar to introduce local officials to the Minnesota Bicycle and Pedestrian Counting Initiative, obtain feedback on the draft guidance for field counts, and recruit participants for September pilot field counts. MnDOT and the research team then coordinated pilot field counts in September 2012. The research team analyzed the results, and the MnDOT project leader surveyed local participants to obtain feedback on both the forms and the experience of participating in the field counts.

The Minnesota Department of Health (MDH), which was represented by a member on the technical advisory committee, played an especially important role in the planning and implementation of the pilot field counts. MDH supports a number of initiatives to address health problems related to obesity, including projects to encourage active travel – bicycling and walking – among different populations. As part of its efforts to evaluate its initiatives related to active travel, MDH decided to require all State Health Improvement Program (SHIP) grantees that received support for active travel interventions (e.g., Safe Routes to Schools) to participate in the September pilot field counts. This decision by MDH increased participation in the training workshops in the summer of 2012 and in the September field counts.

5.1 MnDOT Bicycle and Pedestrian Counting Workshops

MnDOT and the research team held a webinar and five workshops throughout Minnesota in July and August 2012 to introduce local officials to non-motorized traffic monitoring, explain the MnDOT protocols and forms for field counts, and present topics in automated continuous monitoring, and recruit participants for the September pilot counts (Table 5.1). The workshops were held in diverse regions of the state in MnDOT regional offices or other local agency offices. The number of participants in the workshops ranged from 5 to 25 and included MnDOT and county engineers, representatives of MDH SHIP grantees, planners from regional and municipal planning organizations, staff and volunteers from nonprofit and advocacy organizations, and other interested individuals.

Table 5.1 MnDOT Bicycle and Pedestrian Counting Workshops

Workshop	Date	Number of Participants
Alexandria	7/31/2012	13
Bemidji	8/1/2012	11
Duluth	8/6/2012	10
Marshall	7/23/2012	5
Rochester	8/2/2012	11
Webinar	8/9/2012	25
Totals	6 workshops	75

The workshops lasted for approximately one and one-half hours and included presentation of the MnDOT count manager powerpoint, distribution of forms and checklists, and time for questions and discussion. Most of the participants were positive about the sessions and appreciated MnDOT's efforts to reach out across the state and to build evidence to support its programs. A few participants expressed some skepticism about the potential value of the counts. In addition, some SHIP grantees expressed some dissatisfaction with the MDH requirement counting and were skeptical about the potential value of the counts. A representative at MDH was present at most workshops and explained the rationale for the MDH decision to require participation, noting that grantees were required to count at only one location. Many participants indicated they would consider participating in the September pilot field counts.

5.2 MnDOT Pilot Bicycle and Pedestrian Field Counts

MnDOT and the research team planned field counts for early to mid-September to coincide with days for field counts planned by the NBPDP, MDPW, and TLC. In addition to the MDH requirement that some of its SHIP grantees participate, participants were recruited through the training workshops, announcements made on various email distribution lists, and contact with regional and local transportation, planning and economic development organizations.

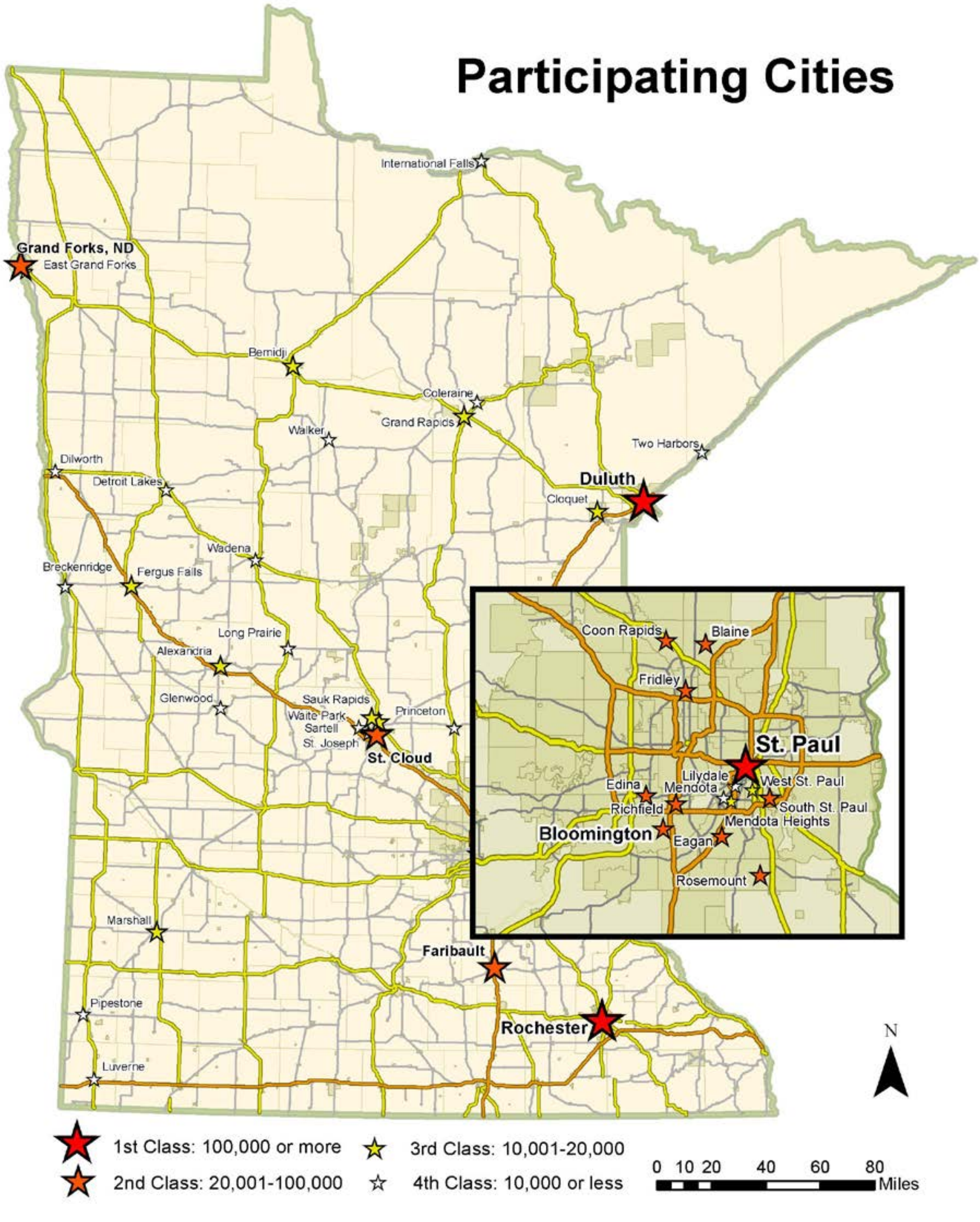
The MnDOT project leader coordinated contacts with participating organizations, including distribution of forms (via the MnDOT website) and collection of spreadsheets with the results of field counts. The research team consulted with participants about the selection of locations for counting, interpretation of forms, and questions about reporting. The MnDOT project leader provided copies of all spreadsheets including results to the research team whose members collated and analyzed the results.

5.2.1 Community Participation in Field Counts

Agencies, organizations, or individuals from forty-three municipalities in 28 counties participated in the September pilot field counts, not counting MDPW or TLC (Map 5.1). As noted, MDPW and TLC have conducted counts since 2007, developed the protocols on which the MnDOT protocols are based, and already make their counts publicly available. Both MDPW and TLC counted in 2012 have and distributed the results of their counts. The MDPW and TLC counts are not summarized in this report.

The state of Minnesota divides cities and towns into four population classes for administrative purposes. Participation in the pilot counts included communities in each population class (Table 5.2). Approximately five percent of all Minnesota cities and towns participated in the field counts, including more than 25% of cities with populations greater than 10,000.

The participants in the pilot count counted at 133 locations for a total of 848 hours (Table 5.2, Table 5.3). In general, larger communities counted at more locations and for more hours. The mean number of counting locations per community was slightly more than three, with the mean number of locations in Class I cities (population > 100,000) about 4.7 and a mean of 2.6



Map 5.1 Minnesota Cities Participating in MnDOT Pilot Field Counts

Table 5.2 Participants in Field Counts by City Population Class

Minnesota City Population Class	Minnesota Cities in Population Class	Participants in MnDOT Pilot Field Counts	Cities (%) in Population Class in Field Counts	Locations Counted	Hours Counted
I. > 100,000	4	3*	75%	14	98
II. 20,001 – 100,000	51	12	25%	36	204
III. 10,001 – 20,000	40	10	24%	37	272
IV. ≤ 10,000	758	18	2%	46	274
Total	853	43	5%	133	848
*Does not include Minneapolis, which has conducted field counts since 2007 and did not participate in pilot test of MnDOT forms. Minneapolis did count non-motorized traffic in September 2012.					

Table 5.3 Locations and Hours Counted in Minnesota Municipalities

City	City Class	Locations	Hours	City	City Class	Locations	Hours
Alexandria	3	3	18	Long Prairie	4	2	12
Bemidji	3	16	114	Luverne	4	1	2
Blaine	2	2	13	Marshall	3	4	15
Bloomington	2	7	36	Mendota	4	1	6
Breckenridge	4	3	27	Mendota Heights	3	1	2
Cloquet	3	3	48	Pipestone	4	1	2
Coleraine	4	1	10	Princeton	4	3	18
Coon Rapids	2	4	14	Richfield	2	4	22
Detroit Lakes	4	3	12	Rochester	1	8	56
Dilworth	4	3	18	Rosemount	2	4	42
Duluth	1	3	36	Sartell	3	1	2
Eagan	2	1	4	Sauk Rapids	3	1	2
East Grand Forks	4	3	28	South St. Paul	2	1	2
Edina	2	3	8	St. Cloud	2	2	4
Faribault	2	1	8	St. Joseph	4	1	2
Fergus Falls	3	3	27	St. Paul (Vento Park)	1	3	6
Fridley	2	5	35	Two Harbors	4	11	56
Glenwood	4	2	18	Wadena	4	3	30
Grand Forks	2	2	16	Waite Park	4	1	1
Grand Rapids	3	4	40	Walker	4	2	12
International Falls	4	3	16	West St. Paul	3	1	4
Lilydale	4	2	4				

locations in Class IV cities (population ≤ 10,000). Thirteen communities, or nearly 25% of the total, counted in only one location. Two communities (Bemidji (16) and Two Harbors (11)) accounted for 20% of the total number of counting locations. The mean number of hours counted per location was 6.4. Communities in which SHIP grantees were required to participate tended to count at fewer locations and for fewer hours.

5.2.2 Monitoring Days and Hours

Communities were encouraged to count on Tuesdays, Wednesdays, and Thursdays of the second week of September during the evening peak hours of 4:00 p.m. to 6:00 p.m. These are the days and times recommended by the National Bicycle and Pedestrian Documentation Project and when the MDPW and TLC annually conduct counts. If communities were unable to count on these dates, they were encouraged to count on Tuesdays, Wednesdays, or Thursdays in subsequent weeks. Communities also were encouraged to count on Saturdays and on other days and times important locally. For example, if a community was interested in Safe Routes to Schools, they were encouraged to count at times when children would be walking to and from school. All decisions about when to count were made locally.

Figures 5.1 and 5.2 summarize the dates and days of week when counting occurred during the MnDOT pilot project. Most counting (75% of all hours) occurred on September 11, 12, and 13 (Figure 5.1). Including the following two weeks that were specified as alternate dates, approximately 89% of all counts were taken on Tuesdays, Wednesdays, and Thursdays (Figure 5.2).

Figure 5.3 summarizes the times of day when counts occurred. Counts occurred during all hours of the day between 7:00 a.m. and 6:00 p.m. Most counts (68%) were completed during evening peak hours (i.e., 4:00 p.m. – 5:00 p.m.). An additional eight percent were completed at 3:00 p.m. Approximately 3.3% (i.e., 28 hours) were not initiated on the hour, which complicates analyses because totals must be assigned to the preceding or following hour. The time of monitoring was not reported for two hours.

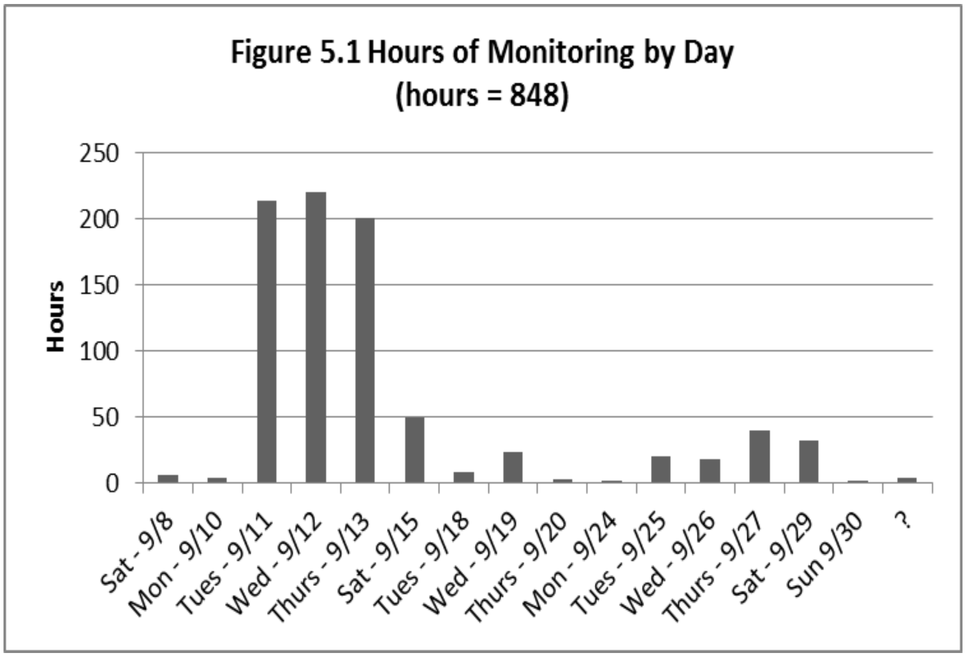


Figure 5.1 Hours of Monitoring by Day

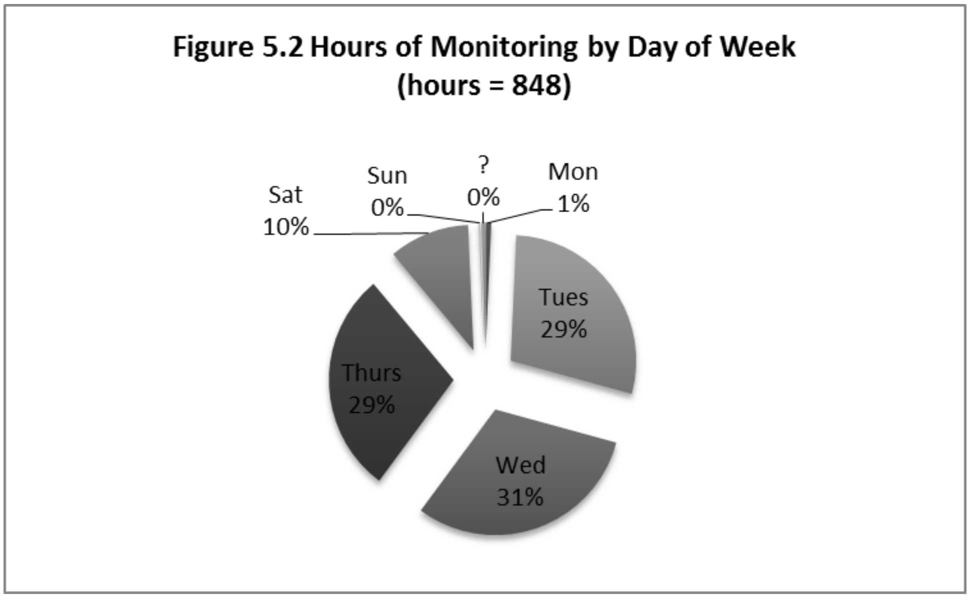


Figure 5.2 Hours of Monitoring by Day of Week

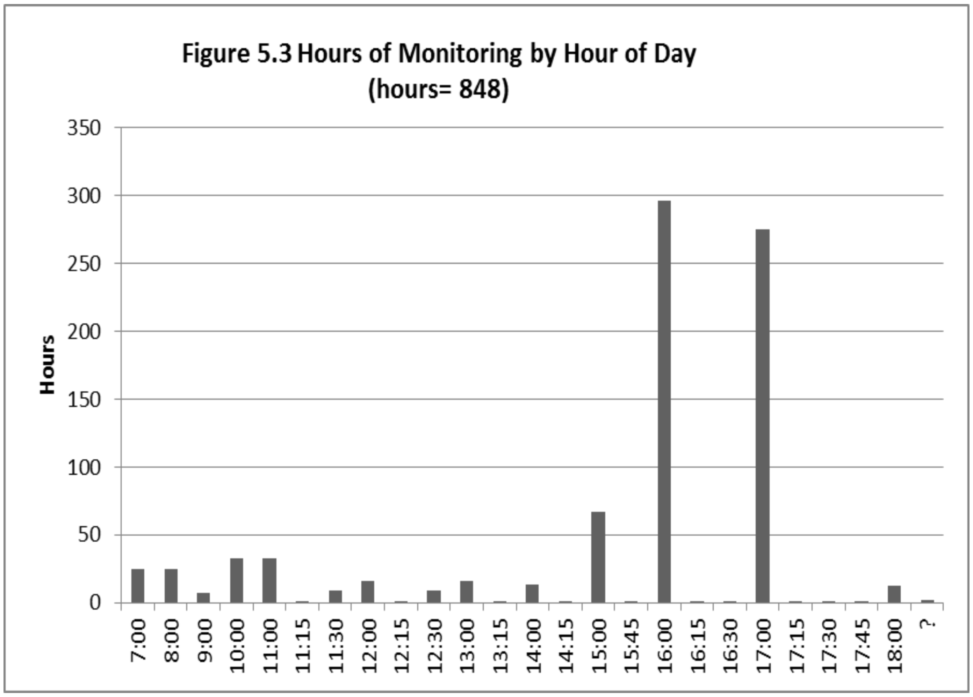


Figure 5.3 Hours of Monitoring by Hour of Day

5.2.3 Monitoring Results: Bicycle and Pedestrian Volumes

Across all cities and all times, the mean bicyclist and pedestrian traffic volumes per hour were 7.5 and 19.3, respectively (Table 5.4). The median hourly volumes were much lower (4 and 8, respectively), indicating that average hourly volumes are influenced by relatively small numbers of large hourly counts. The maximum number of pedestrians per hour observed at any location in the sample was 322, more than three times the highest bicycle volume (104). Observers recorded no bicycle and pedestrian traffic during 14% and 6.7%, respectively, of all hours counted. Hourly traffic volumes varied by day of week and time of day.

Table 5.5 presents bicycle and pedestrian volumes for days and times when, across all communities, at least 20 hours of counts were available. Relative to overall mean hourly volumes, there is not great variation – which is to be expected given that most counts were taken on mid-weekdays during evening peak hours. Saturday morning mean hourly bicycle traffic is somewhat higher than weekday evening peak hour traffic, although the sample sizes are smaller. Saturday morning mean hourly pedestrian traffic does not vary as much from mean hourly evening pedestrian traffic. During the mid-weekdays, mean hourly pedestrian traffic at 3:00 p.m. was lower than mean hourly traffic at 4:00 p.m. and 5:00 p.m., but this difference was not observed in bicycle traffic.

Table 5.4 Hourly Bicycle and Pedestrians: All Cities, All Times

Mode	Mean Hourly Count	Median Hourly Count	Maximum Hourly Count	Percent Hours = 0
Bicycles	7.5	4	104	14.0%
Pedestrians	19.3	8	322	6.7%

Table 5.5 Variation in Bicycle and Pedestrian Traffic by Day of Week and Hour of Day

Day of Week	Hour of Day	Hours Counted	Bicyclists / Hour			Pedestrians / Hour		
			Mean	Median	Max	Mean	Median	Max
Saturdays	10:00 a.m.	26	14.6	8	79	21.1	9.5	193
Saturday	11:00 a.m.	27	21.8	10	104	25.0	10	322
Tuesdays	3:00 p.m.	23	6.4	7	16	19.4	14	109
Tuesdays	4:00 p.m.	101	7	4	45	16.8	7	231
Tuesdays	5:00 p.m.	93	7.4	4	47	15.6	6	233
Wednesdays	3:00 p.m.	23	6.7	4	25	33.5	27	146
Wednesdays	4:00 p.m.	92	5.7	4	31	18.5	8	200
Wednesdays	5:00 p.m.	85	6.4	3	44	19.5	10	224
Thursdays	3:00 p.m.	21	4	4	18	23.3	15	82
Thursdays	4:00 p.m.	97	6.7	4	41	18.6	9	234
Thursdays	5:00 p.m.	90	7.2	5	59	18.5	9	241
All days	All hours	848	7.5	4	104	19.3	8	322
*Traffic volumes reported only for hours and days of week where sample size across communities was great than 20 hours.								

Traffic volumes vary in response to locational factors in addition to day of week and time of day. Mean hourly bicycle and pedestrian volumes in Class I cities with populations more than 100,000 were higher than volumes in smaller cities, with a much greater difference observed between pedestrian traffic volumes than bicycle volumes (Figure 5.4). Average hourly bicycle and pedestrian traffic volumes did not vary much across Class II, III, and IV Cities.

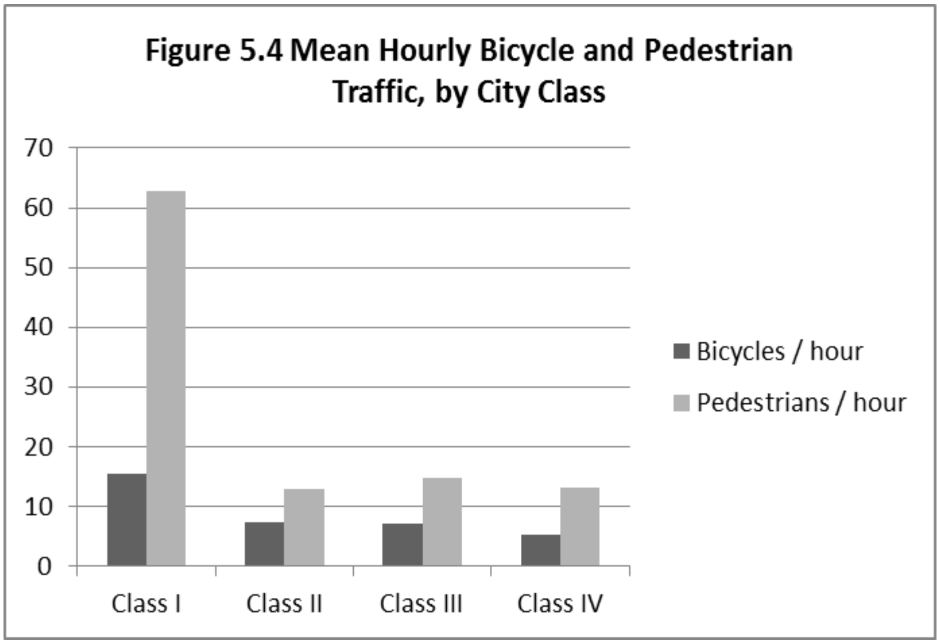


Figure 5.4 Mean Hourly Bicycle and Pedestrian Traffic, by City Class

Communities participating in the pilot field counts selected locations to count for different reasons. Some communities, for example, wanted to obtain pre-treatment volumes before installation of a bike lane or other facility, while others wanted to document volumes on multiuse trails. As a result, the types of transportation infrastructure on which volumes were measured varied across communities. To obtain insight into how bicycle and pedestrian traffic volumes vary by infrastructure across communities, the research team obtained information about the type of road (i.e., street functional class) for each counting location. This task involved looking up each of the counting locations on Google Maps and then matching locations with the MnDOT traffic monitoring website that lists average annual daily vehicular traffic and street functional class for all major roads in Minnesota.

Bicycle and pedestrian traffic volumes varied by street functional class within and across communities of different sizes, but not in consistent ways (Figures 5.5 – 5.8 and Figures 5.9 – 5.12). In Class I communities (Rochester, St. Paul, and Duluth), pedestrian traffic was greater than bicycle traffic regardless of street type (Figure 5.5). The largest difference between pedestrian and bicycle volumes was observed on local streets, which reflects volumes reported from downtown locations in Rochester. Average pedestrian volumes were larger than average bicycle volumes on trails in Class I cities, primarily because of results from Duluth, which measured traffic at locations along its Lakewalk, a trail that serves a large pedestrian population in a downtown commercial district by Lake Superior. These averages mask the modal spilt in St. Paul along the Vento Trail where mean hourly bicycle volumes were greater than pedestrian volumes (Figure 5.9). The modal split on the Vento Trail in St. Paul is more consistent with the modal split observed on trails in smaller cities.

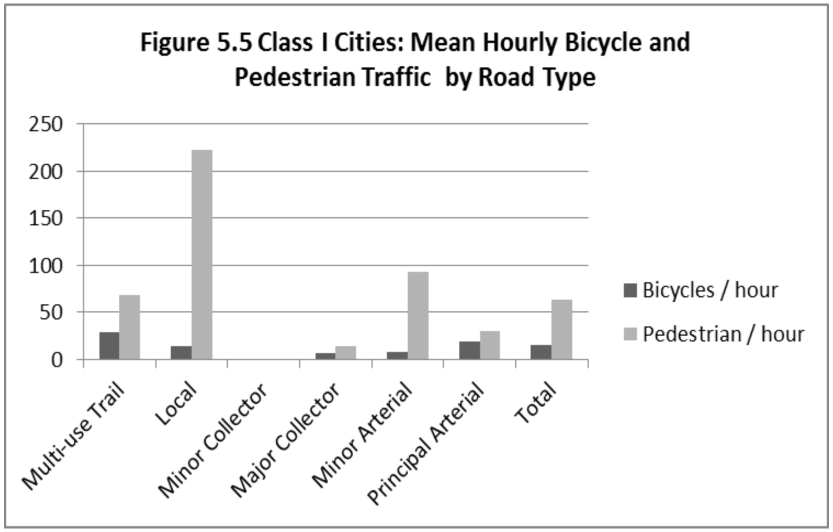


Figure 5.5 Class I Cities: Mean Hourly Bicycle and Pedestrian Traffice by Road Type

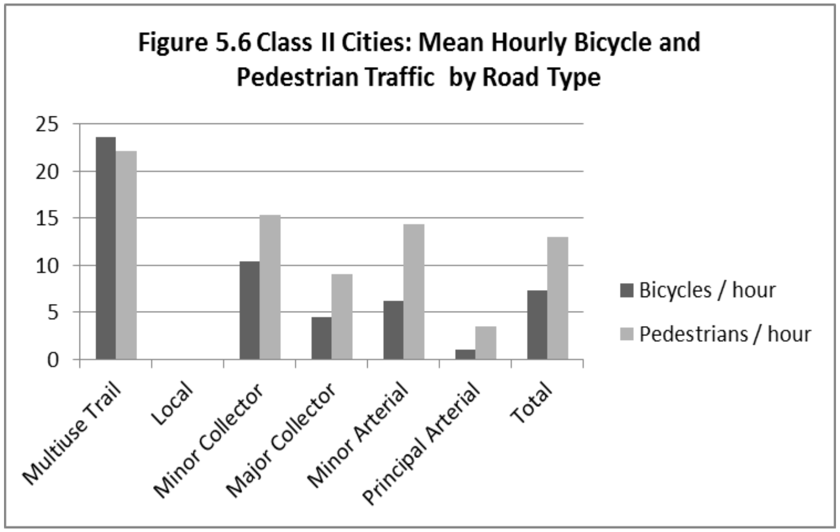


Figure 5.6 Class II Cities: Mean Hourly Bicycle and Pedestrian Trafficy by Road Type

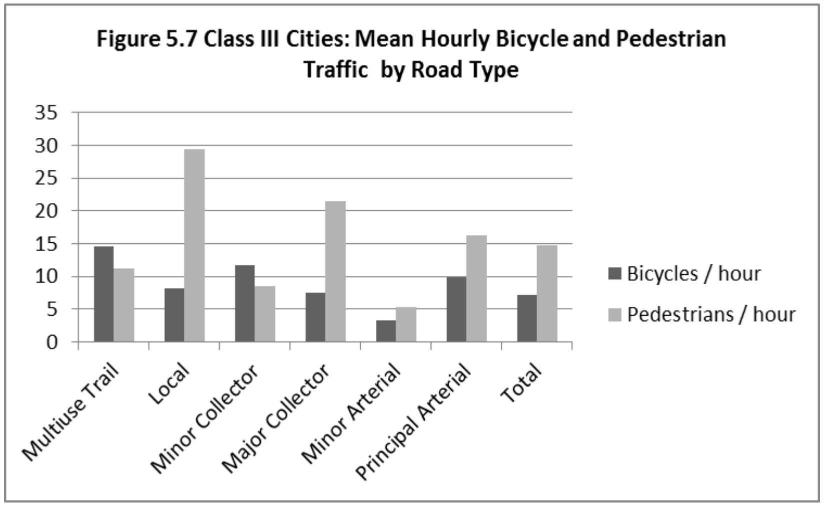


Figure 5.7 Class III Cities: Mean Hourly Bicycle and Pedestrian Traffic by Road Type

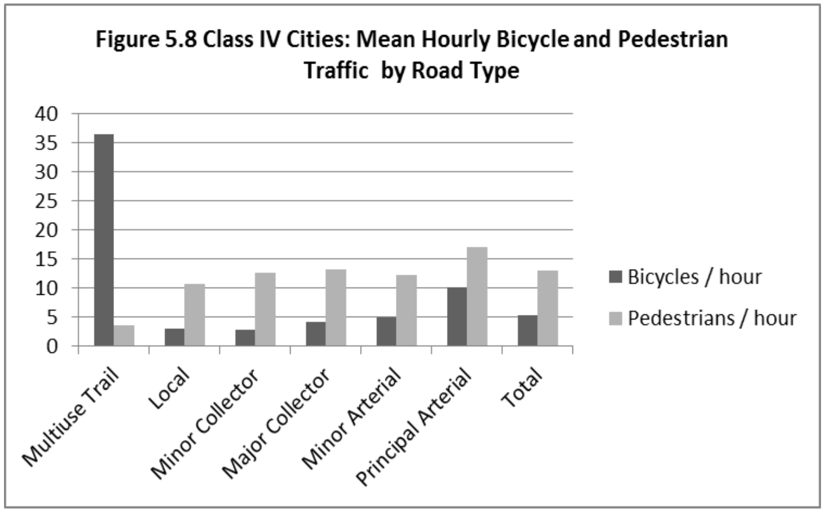


Figure 5.8 Class IV Cities: Mean Hourly Bicycle and Pedestrian Traffic by Road Type

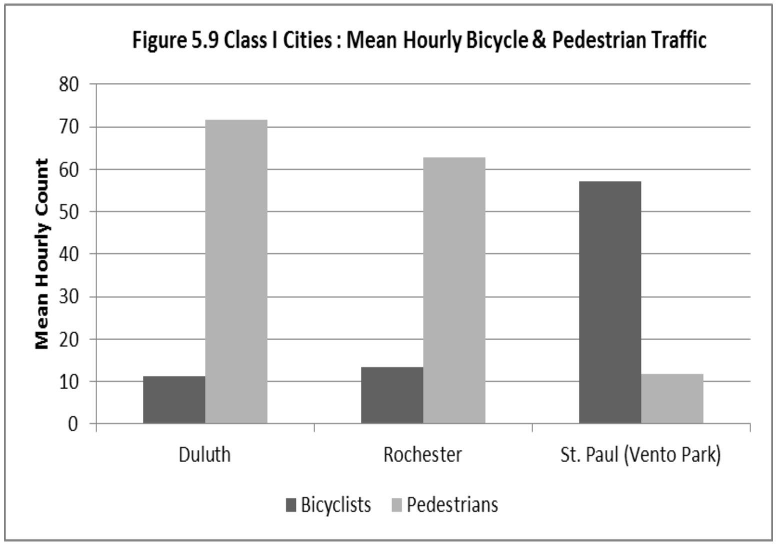


Figure 5.9 Class I Cities: Mean Hourly Bicycle and Pedestrian Traffic

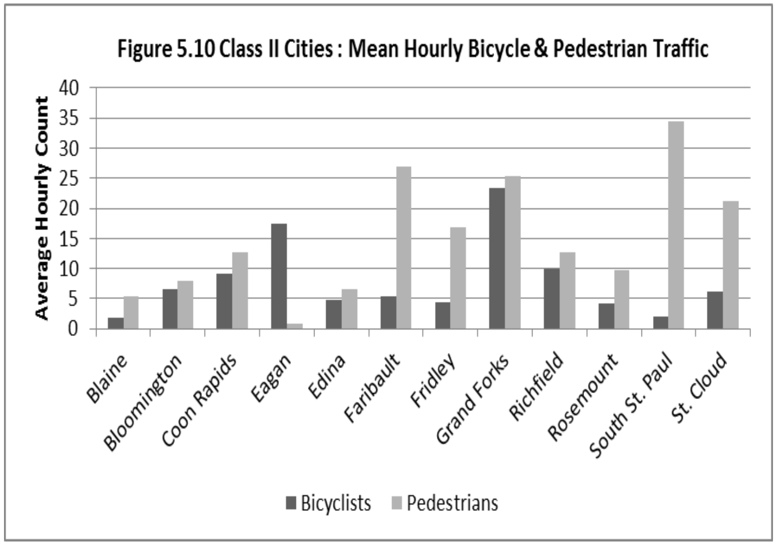


Figure 5.10 Class II Cities: Mean Hourly Bicycle and Pedestrian Traffic

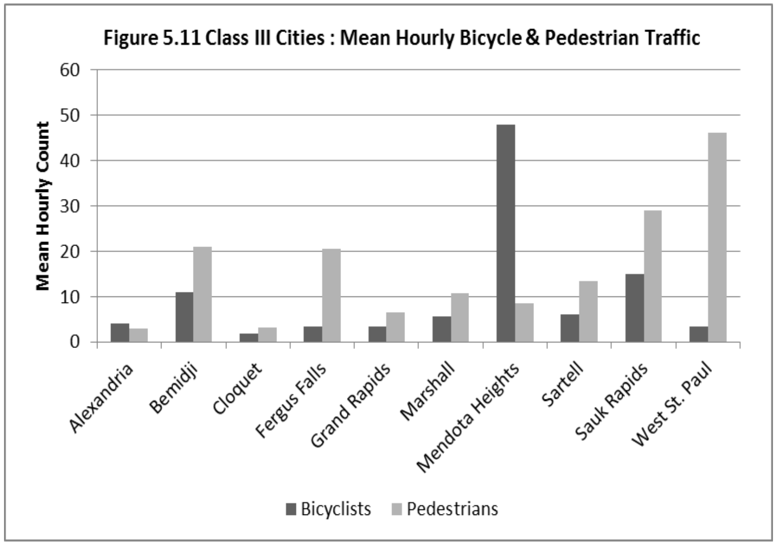


Figure 5.11 Class III Cities: Mean Hourly Bicycle and Pedestrian Traffic

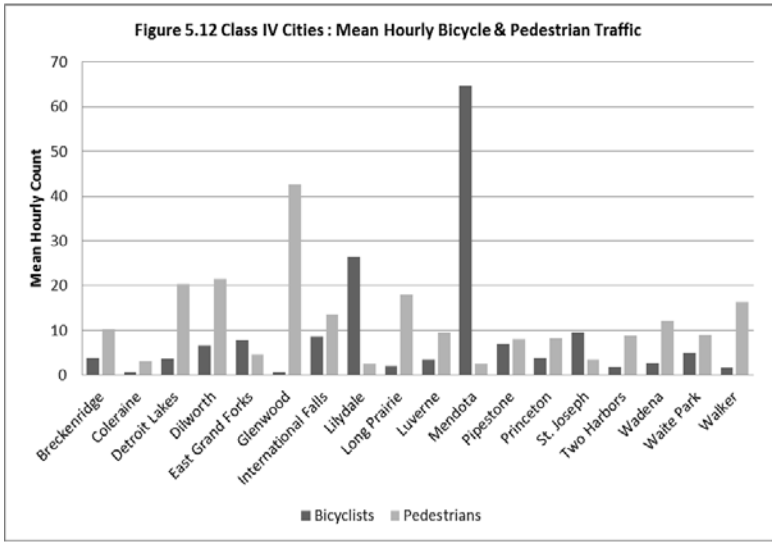


Figure 5.12 Class IV Cities: Mean Hourly Bicycle and Pedestrian Traffic

The Class II Cities that participated in the counts were Blaine, Bloomington, Coon Rapids, Eagan, Edina, Faribault, Fridley, Grand Forks, Richfield, Rosemount, South St. Paul, and St. Cloud (Figure 5.10). Among these cities, the largest average hourly volumes for both bicycle and pedestrian traffic were observed on multiuse trails, followed by volumes on minor collectors and minor arterials (Figure 5.6). Pedestrian volumes were greater than bicycle volumes on every type of road or infrastructure except multiuse trails. The highest average hourly bicycle volume was observed in Eagan on a multiuse trail (18 bicycles per hour; Figure 5.10); the highest average hourly pedestrian volume was observed in South St. Paul (35 pedestrians per hour; Figure 5.10).

The Class III Cities that participated in the counts were Alexandria, Bemidji, Fergus Falls, Grand Rapids, Marshall, Mendota Heights, Sartell, Sauk Rapids, and West St. Paul (Figure 5.11). Among these cities, the highest pedestrian volumes were observed on local streets and major collectors (Figure 5.7). Bicycle volumes exceeded pedestrian volumes on multiuse trails and minor collectors. The highest average hourly bicycle volume was observed in Mendota Heights on a multiuse trail (48 bicycles per hour; Figure 5.11); the highest average hourly pedestrian volume was observed in South St. Paul (46 pedestrians per hour; Figure 5.11).

The Class IV Cities that participated in the counts were Breckenridge, Coleraine, Detroit Lakes, Dilworth, East Grand Forks, Glenwood, International Falls, Lilydale, Long Prairie, Luverne, Mendota, Pipestone, Princeton, St. Joseph, Two Harbors, Wadena, Waite Park, and Walker (Figure 5.12). Among these cities, both pedestrian and bicycle traffic generally was higher greater on higher functional class roads, although observed bicycle traffic volumes on multiuse trails were substantially higher than pedestrian or bicycle volumes on roads (Figure 5.8). The highest average hourly bicycle volume was observed in Mendota on a multiuse trail (65 bicycles per hour; Figure 5.12); the highest average hourly pedestrian volume was observed in Glenwood (43 pedestrians per hour; Figure 5.11).

Across all population classes, the communities that participated in the MnDOT counts purposefully chose monitoring locations where they wanted estimates of bicycle and pedestrian traffic as part of planning for complete streets, to evaluate the need for safety controls, or to evaluate active living interventions. That is, the monitoring locations were not randomly selected to be representative of a community or to develop an estimate of average bicycle or pedestrian traffic for an average street. Interpreted another way, communities chose to count in locations where they thought, or hoped, there would be bicyclists and pedestrians. This fact means that the traffic volumes observed are likely to be at the higher end of distributions of traffic volumes that may exist in these communities for the time of day and year in which they were taken (i.e., peak hour in September). Knowing this fact – that these estimates, which are valid for the locations and time periods observed – are likely to be illustrative of the more heavily trafficked streets in these communities – helps to interpret them.

Overall, across cities of all sizes, across cities within population classes, and across street functional classes within cities, there are large, relative variations in traffic volumes and modal split. These variations may be explained by a number of different factors, including variations in land use near counting locations and possible errors in assigning street classifications to sample points. These variations also are a reason why any particular traffic count cannot be generalized to other locations, even within the same community on comparable types of streets. Additional counts will be needed to develop valid, reliable estimates of bicycle and pedestrian traffic. Analyses of future counts may provide additional insight into factors associated with variations in bicycle and pedestrian traffic volumes, particularly in smaller cities.

5.3 MnDOT Field Counts: Count Manager Survey

The MnDOT project manager conducted an informal telephone survey of 27 local count managers in the fall of 2012 following the pilot field counts. The purpose of the survey was to thank and affirm each manager for participation in the MnDOT Bicycle and Pedestrian Counting Initiative, to obtain feedback on MnDOT's protocols and efforts to coordinate the counts, and to identify issues to be addressed to strengthen future counts. The number of count managers surveyed was fewer than the number of communities where counts were taken because some count managers coordinated counts in several communities.

The MnDOT project manager followed a general interview guide but adapted it during interviews in response to issues raised or perspectives shared by participants. In addition to questions to confirm administrative information and to clarify the organizations that participated in the count, the project manager asked:

- Whether employees or volunteers conducted the counts and, if volunteers were engaged, issues in recruiting or training them;
- Why the organization chose to count and participate in the initiative;
- Why counting locations were chosen;
- Whether counts were taken on specific types of bicycle or pedestrian facilities;
- Whether the results were expected or surprising, and whether cultural factors in their community were relevant to the count or interpretation of results;
- Whether the count manager would participate again in future counts; and
- Whether the manager wanted to share anything else to inform or strengthen future counts.

The MnDOT project manager took notes on responses and summarized comments, but because of the qualitative nature of the survey and variations in discussions that evolved naturally, the results were not analyzed quantitatively. Key findings include:

- SHIP grantees were responsible for counting in 30 of 43 municipalities, and many of them would not have participated if not required to do so by MDH.
- Many different types of local agencies participated in the counts, including public health organizations, municipalities, local and regional planning agencies, parks and recreation departments, local law enforcement agencies, K-12 schools, higher education institutions, and advocates for bicycling and walking.
- Organizations participated in the counts for a variety of reasons, in addition to fulfilling the MDH requirement. These reasons included:
    - To assess recent or proposed infrastructure improvements;
    - To monitor Safe Routes to Schools; and
    - To increase understanding of bicycle and pedestrian traffic.

- Count managers recruited a mix of employees and volunteers to count, but recruitment of volunteers was difficult and challenging.
- Counts were taken mainly on streets and sidewalks, but also on facilities specifically for bicycles and pedestrians such as multiuse trails.
- The volumes of bicycles and pedestrians were about as expected.
- The MnDOT training materials were useful, but the spreadsheet for reporting totals was awkward to complete, and a better system for reporting should be developed.

Some respondents volunteered that the data already were being used in grant proposals or for other purposes to improve opportunities for bicycling and walking. A few respondents noted that a “car culture” seemed prevalent in their communities and that bicycling and walking were not popular, even though people understood some of their benefits and that opportunities to bike and walk were available.

5.4 Potential Uses of Field Counts in Planning

As described in Section 5.3, local count managers participated in the pilot field counts to increase understanding of non-motorized traffic, assess infrastructure improvements or new programs, or to obtain information for planning and management of local transportation systems. Some managers also said they had begun to use the counts for in planning or in grant applications for active travel or other projects. Subsequent to the field counts and survey, a planner with the Arrowhead Regional Development Commission (ARDC) in Duluth contacted the MnDOT project manager and research team for assistance in interpretation of counts taken in Two Harbors and International Falls. The planner was working on a grant application for MnDOT’s Corridor Investment Management Strategy (CIMS) program, a program that encourages innovative intergovernmental investment in strategically important transportation corridors. The grant application required applicants to estimate bicycle and pedestrian miles traveled (i.e., BMT, PMT) in the corridor. Given the absence of methodological guidance in the application instructions, the planner asked if the counts obtained in the pilot field counts could be used to develop these estimates. The following example illustrates how the field counts for Two Harbors potentially can be used to estimate BMT or PMT. This example also illustrates the limitations associated with using the short-duration field counts.

This example follows the general approach used in motorized vehicle transportation monitoring for estimating average annual daily traffic and vehicle miles traveled, but adapts it for non-motorized traffic. The principal challenges in adapting this approach for non-motorized traffic are the small sample sizes and the fact that the historic databases required for deriving adjustment factors for extrapolation of short-duration counts do not yet exist. To use the field counts to estimate miles traveled thus requires a number of different assumptions, each of which limits the validity and increases the uncertainty of the final estimates. The following example lists these assumptions.

Prior to presenting the example, however, it is useful to reflect on the dilemma facing the ARDC planner because it is a dilemma that practitioners often encounter. The dilemma is that the planner is required to submit a quantitative estimate of a traffic indicator for programmatic purposes, but the data required for making the estimate following standard procedures do not exist. The planner’s options are to ignore the requirement or to use best professional judgment and develop an estimate, recognizing the severity of the assumptions that are implicit in the estimate. The assumptions here are (a) if the consequences of ignoring the requirement potentially are significant, it often will be unacceptable for a planner to ignore the requirement; and (b) an order-of-magnitude estimate with limitations presented transparently is better than no estimate. In this particular case, the consequences of failing to complete the application were unclear, but a risk-averse approach to competition for funding required development of an estimate. In other words, the rationale for this approach was pragmatic.

Following guidance in the FHWA Traffic Monitoring Guide (see Section 2.5.2), MnDOT, like other state DOTs, has developed procedures for (a) using adjustment factors derived from automated continuous monitoring sites to extrapolate short-duration counts to estimates of annual average daily traffic (AADT) and (b) using these estimates of AADT to estimate vehicular miles traveled. The following example follows this general approach but adapts it for bicycle and pedestrian traffic, taking into account data limitations.

The basic steps in the approach are to:

1. Use local short-duration (i.e., peak hour) counts to estimate daily traffic;
2. Use daily traffic to estimate annual average daily traffic;
3. Calculate annual traffic; and
4. Use annual traffic with segment length to calculate miles traveled.

The limitations of this approach include:

1. The available short-duration bicycle and pedestrian counts are for two hour, peak hour traffic, are not necessarily representative of typical traffic, and provide no information about traffic patterns throughout the day.
2. The state does not have historic monitoring data for bicycle and pedestrian traffic, so hourly, daily, monthly, and seasonal adjustment factors for non-motorized modes are not available.
3. The length of the segment in the transportation network that is represented by the traffic counts is not known.
4. Field counts are available for only a few hours, so meaningful estimates of the margin of error of the estimates cannot be made.

These facts limit the validity of estimates that can be derived, but if these limitations are noted, users can take them into consideration when using the estimate.

Volunteers from Two Harbors completed peak hour counts (4:00 p.m. – 6:00 p.m.) at one location on September 12, 13, and 14, 2012. They reported they observed 32 bicyclists and pedestrians but did not report mode split The ARDC planner estimated the counts were representative of a 1.5 mile corridor segment in Two Harbors.

Given this information, annual bicycle and pedestrian miles traveled can be estimated by:

1. Calculating average peak hour count:

   32 bikes and peds / 6 hours = 5.3 bikes and peds per hour

2. Using a peak hour adjustment factor to estimate average daily bicyclists and pedestrians. Because adjustment factors for bicycle and pedestrian traffic on streets and sidewalks have not been developed and published, assumptions about the proportion of daily traffic that occurs during peak hour must be made. As part of this project (see Section 6), the research team analyzed continuous counts of bicycle and pedestrian traffic on urban trails taken with infrared sensors in Minneapolis during 2011. These counts indicate that peak hour bicycle and pedestrian traffic on weekdays accounts for approximately 8.9% of daily (24 hour) traffic. Using this proportion, the average September weekday traffic in Two Harbors is estimated:

   Average September weekday traffic =

   5.3 bikes and peds/hour / 0.089 = 60 bikes and peds / day

3. Using a ratio of monthly average weekday traffic to average annual weekday traffic to estimate average daily bicyclists and pedestrians. Again, because of the lack of data, adjustment factors from the 2011 continuous trail counts must be adapted. These data show that average weekday bicycle and pedestrian traffic was 1.246 times average annual daily traffic. Average daily bicycle and pedestrian traffic in Two Harbors can be estimated using this ratio:

   Average daily bicycle and pedestrian traffic in Two Harbors =

   60 / 1.246 = 48 bicycles and pedestrians per day

4. Calculating average annual bicyclists and pedestrians:

   48 bicycles and pedestrians / day * 365 days / year =

   17,554 bicyclists and pedestrians per year

5. Using the estimated road segment length (1.5 miles) to estimate bicycle and pedestrian miles traveled:

   17,554 bicyclists and pedestrians / year * 1.5 miles / bicyclist and pedestrian =

   26,331 bicycle and pedestrian miles traveled per year.

Given these assumptions, an order-of-magnitude estimate of miles traveled by bicyclists and pedestrians annually in the Two Harbors corridor is approximately 26,000. If it is assumed that the counts are representative of only one mile (rather than 1.5 miles), then the estimate would be approximately18,000 bicycle and pedestrian miles traveled annually.

The purpose for presenting this example has been to illustrate both how practitioners can use available information to develop order-of-magnitude estimates and the importance of continued and expanded data collection so that better estimates can be developed in the future. It is taken as a given that demand for these types of estimates will continue to grow and that local planners will continue to be required to do their best to develop them.

The limitations of this approach are obvious but worth repeating:

- The estimate is based on a sample of only six hours;
- The counts are "mixed-mode" and do not distinguish between bicyclists and pedestrians;
- The peak hour proportion used to estimate September weekday traffic, and the ratio of average monthly to annual weekday traffic used to estimate average annual traffic, are from urban mixed-mode trail counts in a large city, not from counts on streets and sidewalks in a small town;
- The estimate assumes temporal traffic patterns are consistent over time (i.e., that 2012 patterns are consistent with those observed in 2011);
- The estimate assumes bicycle and pedestrian traffic is constant through the 1.5 mile segment.
- The approach does not characterize the inherent variability of traffic or the margin of error associate with the estimate.

Despite these limitations, this approach replicates the logic used in standard practice, can be implemented consistently, incorporates the best information available, and provides a foundation for further study and analysis. As continuous monitoring is implemented throughout the state, the approach can be refined and improved, and better estimates can be made. In addition, as monitoring continues, trends can be analyzed, and evaluations of investments and programmatic initiatives can be evaluated.

Chapter 6
Analyses of Continuous Counts

As noted in Chapter 1, one of the goals of this project was to collect automated, continuous counts of bicycle and pedestrian traffic that have been completed in Minnesota. The purpose of collecting continuous counts was to illustrate how they can be analyzed, used to develop adjustment factors for extrapolating short-duration counts, and integrated with data from vehicular monitoring programs.

The analysis of traffic counts and use of adjustment factors to extrapolate short-term counts is not new: the Federal Highway Administration (FHWA), state departments of transportation (DOTs), and local governments have developed routine procedures for analyzing counts, identifying traffic patterns, and estimating traffic volumes and vehicle miles traveled at locations where only short-duration counts have been taken. Continuous counts of bicycle and pedestrian traffic do not exist in most places, however, and the variability in patterns associated with bicycle and pedestrian traffic has yet to be described. This Chapter illustrates how procedures used routinely in analyzing vehicular traffic can be adapted for analysis of non-motorized traffic. The procedures, which generally following procedures recommended in the FHWA's Traffic Monitoring Guide, include collection and adjustment of count data, imputation of volumes for missing days, estimation of annual traffic and average annual daily traffic (AADT), derivation of day of week and monthly adjustment factors, and estimation of miles traveled on trail segments.

6.1 Continuous Bicycle and Pedestrian Counts

As noted in Chapter 3, the Humphrey School of Public Affairs is collaborating with the Minneapolis Department of Public Works (MDPW) and the Minneapolis Park and Recreation Board (MPRB) to collect and analyze continuous counts of bicycle and pedestrian traffic at six locations on multiuse trails in Minneapolis (Table 3.1, Figure 6.1). MDPW has been collecting counts of bicycle traffic with inductive loop detectors at three locations on the Midtown Greenway since 2007. Researchers at the Humphrey School installed active infrared counters at these same locations in 2010 and added counters at three additional locations on MPRB trails, including counters on separated bicycle and pedestrian paths around Lakes Calhoun and Nokomis.

The inductive loop detectors register an event or count when a bicycle passes over an electric wire embedded in the asphalt, thereby changing the current. The loop detectors do not count pedestrians. The infrared monitors register an event or count when a bike or pedestrian passes by and breaks the infrared beam; the counts from the monitors therefore are estimates "mixed-mode" traffic: undifferentiated bicyclists and pedestrians. The purpose for co-locating the infrared monitors by the loop detectors was to assess whether estimates of pedestrians on the Greenway could be obtained by subtracting the bicycle counts from the mixed-mode counts.

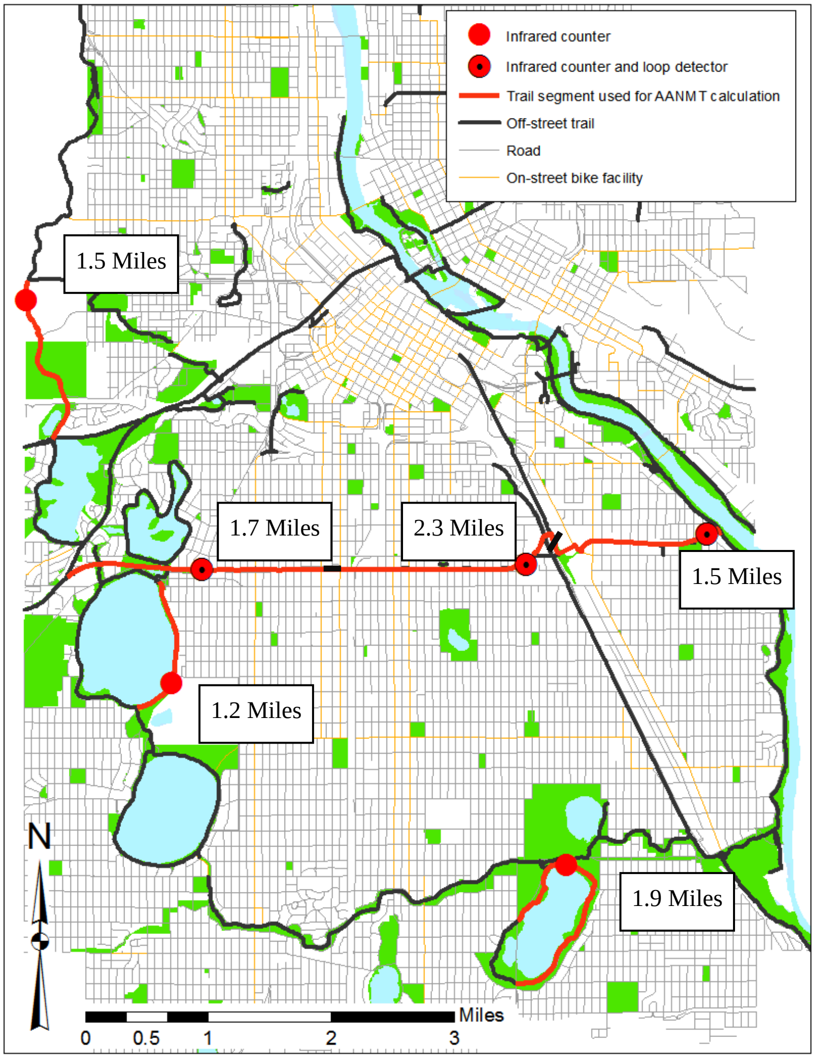


Figure 6.1 Automated, Continuous Non-motorized Traffic Monitoring Sites in Minneapolis

6.2 Analytic Methods

6.2.1 Collection and Adjustment of Count Data

The research team obtained a copy of the counts from each automated counter for 2011. The percentage of valid counts ranged between 35% and 98% of the possible days across the six locations (Table 6.1). The reasons for missing observations vary by type of counter. For the battery-operated infrared monitors, the reasons include lack of power, traffic volumes higher than maximum storage capacity (16,000 events), censoring of days with abnormal counts (e.g., blizzards during winter), vandalism, and human error in downloading data from the monitors. Reasons for missing observations from the loop detectors include loss of power, counter malfunction, exceedance of capacity, and human error downloading data. Days with only partial counts also were censored from the dataset. With the exception of the MDPW's loop detector at the Cedar Avenue location on the Greenway, which malfunctioned for most of the year, counts for more than 83% of all possible days were obtained from each monitor. At the two locations with separate paths for bicyclists and pedestrians (Lake Calhoun and Lake Nokomis), the total number of possible days of counts for separate bicycle and pedestrian traffic is 244 rather than 365 because the pedestrian path is not plowed or maintained during winter, and the bicycle path then becomes a shared use path for both bicyclists and pedestrians.

Table 6.1 Summary of Available Data from Automated Counters in Minneapolis

Location	Possible Days of Counts	Valid Days	Valid Days of Counts (%) in 2011	Method of Estimating Missing Counts
Active Infrared (Bikes, peds, and mixed-mode)				
(1) Hennepin Ave. & Midtown Greenway (MGW)	365	347	95.1	Location specific regression model
(2) West River Pkwy & MGW	365	325	89	Location specific regression model
(3) Cedar Ave. & MGW	365	335	91.8	Location specific regression model
(4) Lake Calhoun Parkway*				
Pedestrian path	244	204	83.6	Mode Share
Bicycle path	244	204	83.6	Mode Share
Mixed-mode	365	319	87.4	Location specific regression model
(5) Lake Nokomis Parkway*				
Pedestrian path	244	213	87.3	Mode Share
Bicycle path	244	213	87.3	Mode Share
Mixed-mode	365	304	83.3	Location specific regression model
(6) Wirth Parkway	365	345	94.5	Location specific regression model
Inductive Loop Counters (Bikes only)				
(1) Hennepin Ave. & Midtown Greenway (MGW)	365	358	98.1	Monthly mean weekday and weekend daily traffic
(2) West River Pkwy & MGW	365	339	92.9	Monthly mean weekday and weekend daily traffic
(3) Cedar Ave. & MGW	365	127	34.8	Monthly mean weekday and weekend daily traffic

The infrared monitors systematically undercount traffic because of occlusion – the monitors register only a single event when the bicyclists and/or pedestrians pass simultaneously. Researchers found that the MDPW loop detectors both systematically undercount and over-count depending on the location. To correct for these systematic errors, the team aggregated the raw counts by hour, and then estimated location-specific correction equations by regressing the relevant field counts on the counts from the automated monitors. The hourly correction equations used for the monitors are presented in Table 6.2. Because the accuracy rates of the infrared monitors were similar, a single equation was used to adjust the data from each of the eight monitors. Separate equations were estimated for counts from each of the loop detectors because of their accuracy rates were dissimilar. After the hourly totals were adjusted, they then were aggregated to obtain 24-hour daily totals.

Table 6.2 Hourly Traffic Correction Equations

Monitoring Location(s)	Type of Monitor	Mode	Hours of Validation	Hourly Traffic Adjustment Equations*
All six locations	Active infrared	Mixed	130	$y=0.0002x^2+1.0655x-1.2937$
Lakes Calhoun and Nokomis	Active infrared	Pedestrian	20	$y=1.2920x$
Lakes Calhoun and Nokomis	Active infrared	Bicycles	19	$y=1.078x$
Midtown Greenway: Hennepin	Inductive Loop	Bicycles	86	$y=0.7018x$
Midtown Greenway: Cedar	Inductive Loop	Bicycles	8	$y=0.9451x$
Midtown Greenway: W. River Parkway	Inductive Loop	Bicycles	51	$y=1.0328x$

*Adjustment equations
y = estimated hourly traffic
x = hourly count from automated monitor.

6.2.2 Imputation of Volumes for Missing Days

To obtain estimates of annual traffic volumes at each location, it was necessary to impute or estimate daily totals for days when observations were missing. The team used different approaches for different modes and locations, depending on the availability of information and location (Table 6.1). For mixed-mode traffic volumes at each site, the team used location-specific negative binomial regression models to estimate the daily count. Independent variables in the models included weather conditions (temperature, precipitation, and wind) and day of week (weekday vs. weekend). Development of the models is described in Wang at al. (2012). For bicycle and pedestrian volumes at two locations (Lake Calhoun and Lake Nokomis, the mode share for winter months (December – March) when only a single, shared-use path was open was set to the mean mode share for the two fall and spring months preceding and following this period (October-November, April-May). This heuristic was adopted because inspection of counts indicated mode share between bicyclists and pedestrians varied seasonally. For the Lake Calhoun location, the winter mode-share split was: bicycles (31%) and pedestrians (69%). For the Lake Nokomis location, the winter mode-share split was: bicycles (29%) and pedestrians (71%).

Statistical models of bicycle traffic analogous to those for mixed-mode traffic for each of the three locations with inductive loop detectors have not been estimated. Therefore, to obtain bicycle volumes for days when counts were unavailable at these locations, the missing volumes were estimated as the mean weekday or mean weekend bicycle traffic for the respective month of the year. If data were missing for an entire month (e.g., at the Cedar Avenue location), data from 2010 mean daily traffic estimates from 2010 for the same location were used to impute values.

From a methodological viewpoint, the use of the regression models as described above is preferred because it takes into consideration weather and day of week – factors known to be correlated with use. The use of mean mode-share ratios or mean day of week factors is routine practice but does not incorporate the variability in non-motorized traffic known to be associated with weather. The process of estimating traffic for missing days resulted in estimates of daily traffic volume for 365 days at each site that can be totaled to obtain estimates of daily traffic and analyzed to derive general adjustment factors for use in monitoring programs.

6.2.3 Estimation of Annual Traffic Volumes

The research team summed actual, adjusted, and imputed daily traffic totals for the relevant modes (i.e., mixed-mode, bicycle, pedestrian) to obtain annual totals. For the two lake locations, where there are separate bicycle and pedestrian paths for eight months of the year, the mode-specific totals were summed to obtain total mixed-mode.

For the three Greenway locations where both infrared and inductive loop detectors were located, the bicycle totals were subtracted from the mixed-mode traffic totals to obtain estimates of pedestrian traffic. This step in the process revealed challenges in integrating two types of automated counting technologies, especially when traffic volumes are low and underscores the importance of validating automated counts. For a number of days during the year, particularly at the West River Parkway site, subtraction of bicycle daily volumes recorded by the inductive loop detectors from the mixed-mode daily traffic volumes recorded by the active infrared monitors resulted in negative estimates of daily pedestrian volumes. This result occurred even though counts had been adjusted for systematic error (i.e., up for the infrared counters and either up or down for the inductive loop monitors). Because of this outcome, the disaggregated day of week estimates of pedestrian volumes at the West River Parkway site are not deemed reliable and are not presented.

Only mixed-mode traffic estimates are available for the Wirth Parkway location. Separate bicycle and pedestrian counts are not presented for the Cedar Avenue location because of the inductive loop monitor at that location malfunctioned for nearly two-thirds of the year.

6.2.4 Derivation of Day of Week and Monthly Adjustment Factors

Daily counts were used to estimate day of week, weekend, and weekday traffic ratios for each month of the year and for the entire year for each location and mode, where possible. Mixed-mode ratios are available for all six locations. Separate ratios for bicycles and pedestrians are available for four locations.

6.2.5 Estimation of Miles Traveled

To illustrate how traffic counts can be used to estimate miles traveled the team estimated the length of trail segment each traffic count likely represented and multiplied the annual traffic volumes times the segment length.

6.3 Average Daily Traffic and Miles Traveled

Estimates of annual mixed-mode traffic, average annual daily traffic, and miles traveled for each of the six locations are presented in Table 6.3, including, where possible, separate estimates for mixed-mode, bicycle, and pedestrian traffic. Total annual traffic, annual average daily traffic, mode share, and miles traveled vary significantly across locations.

Table 6.3 Estimated Total Annual Traffic, AADT, and Miles Traveled

Location / Mode	Estimated Total Annual Traffic	Estimated AADT	Percent of Non-Motorized Traffic at Site	Estimated Segment Length (miles)	Estimated Annual Miles Traveled
(1) Hennepin Ave. & Midtown Greenway (MGW)					
a. Bicycle	629,262	1,724	87.30%	1.7	1,069,745
b. Pedestrian	91,451	251	12.70%	1.7	155,467
c. Total – mixed-mode	720,714	1,975	100%	1.7	1,225,214
(2) West River Pkwy & MGW					
a. Bicycle	320,198	877	96.00%	1.5	480,297
b. Pedestrian	13,196	36	4.00%	1.5	19,794
c. Total – mixed-mode	333,395	913	100%	1.5	500,093
(3) Cedar Ave. & MGW					
a. Total – mixed-mode	738,336	2,023	100%	2.3	1,698,173
(4) Lake Calhoun Parkway*					
a. Bicycle (outer)	494,209	1,354	37.80%	1.2	593,051
b. Pedestrian (inner)	814,434	2,231	62.20%	1.2	977,321
c. Total – mixed-mode	1,308,643	3,613	100%	1.2	1,570,372
(5) Lake Nokomis Parkway*					
a. Bicycle (outer)	193,843	531	36.00%	1.9	368,302
b. Pedestrian (inner)	344,604	944	64.00%	1.9	654,748
c. Total – mixed-mode	538,448	1,475	100%	1.9	1,023,051
(6) Wirth Parkway – mixed-mode	116,765	320	100%	1.5	175,148
Six Location Mixed-Mode Total	3,756,301	10,291	100%	10.1	6,192,049

6.3.1 Variation in Annual and Monthly Traffic and Miles Traveled

Non-motorized, mixed-mode annual traffic and AADT vary by an order of magnitude across locations, from a low of nearly 117,000 at Wirth Parkway (AADT=320) to 1.3 million at Lake Calhoun (AADT=3,613; Table 6.3). Mode share also varies significantly between the lake locations and the Greenway locations (Table 6.3). At Lake Calhoun and Lake Nokomis, pedestrians account for nearly two-thirds of total traffic, while at the Hennepin and West River Parkway locations, pedestrians account for only 13% and 4%, respectively, of total traffic. Miles traveled (the product of mixed mode annual traffic and segment length) range from 175,000 at Wirth Parkway to nearly 1.6 million at the Lake Calhoun site. Total non-motorized miles traveled during 2011 on the 10.1 miles of shared-use paths monitored in this study are estimated to be 6.2 million.

Non-motorized traffic at the six locations varies by season at all locations, with higher average daily traffic in summer (Figure 6.2; Table 6.3). For example, average daily mixed mode traffic at the highest volume site (Lake Calhoun) ranged from 373 in January to more than 7,800 in July. While monthly average daily traffic (MADT) varies significantly across locations, the ratios of MADT to AADT generally are consistent across locations throughout the year (Figure 3), indicating that the effects of weather are consistent and independent of location characteristics. For mixed mode traffic in peak summer months, the MADT/AADT ratio exceeds two at five of the locations; in winter months (e.g., December), the MADT/AADT ratio drops to between 0.2 and 0.4 at all locations. At the Greenway Cedar Avenue location, the MADT/AADT ratios in June and July are somewhat lower than at the other locations, although they also reflect seasonality (Figure 6.2).

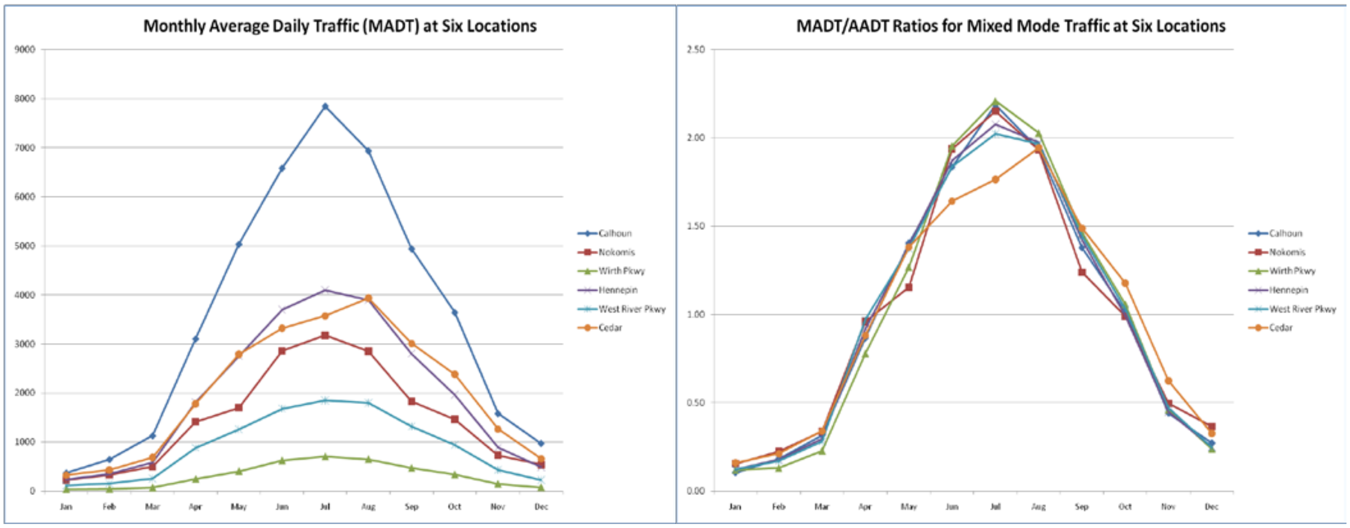


Figure 6.2 Monthly Average Daily Mixed Mode Traffic (left panel) and MADT/AADT Ratios for Mixed Mode Traffic (right panel) at Six Locations

The MADT/AADT ratios for mixed mode traffic mask differences in MADT/AADT ratios for bicycles and pedestrians. Figure 6.3 presents MADT/AADT ratios by month for bicycle and pedestrian traffic at the two lake locations (Calhoun and Nokomis) where pedestrians account for more than 60% of mode share. While the seasonality in traffic is not significantly different between the two locations, the seasonality is different between modes, with bicycle traffic reflecting greater seasonality than pedestrian traffic. For both locations, the July MADT/AADT ratio is 2.6 for bicycles and approximately 1.9 for pedestrians. These differences suggest that recreational bicycle traffic around these lakes is affected more by weather than is pedestrian traffic.

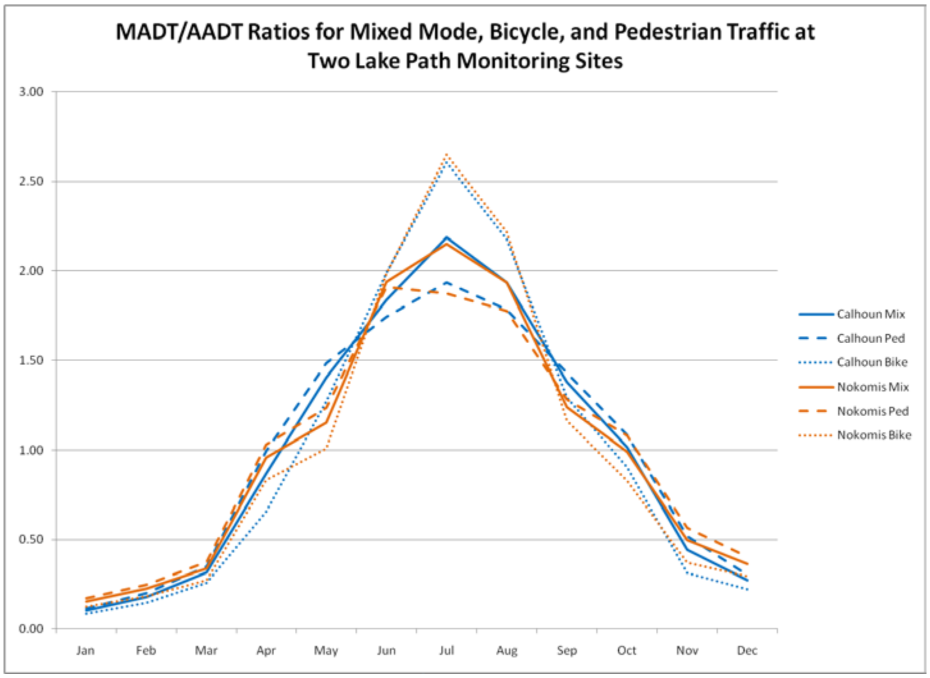


Figure 6.3 MADT/AADT Ratios for Mixed Mode, Bicycle, and Pedestrian Traffic at Two Lake Path Monitoring Sites

6.3.2 Variation in Daily Traffic

Non-motorized traffic at the six locations also is characterized by consistent patterns in daily or day of week traffic (Figure 6.4, Table 6.4). Mixed mode traffic is higher on weekends than weekdays at five locations. The Saturday, Sunday, and Weekend average daily traffic/AADT ratios for these five sites range from approximately 1.2 to 1.4, with Sunday average traffic generally higher than Saturday average traffic. Average weekday traffic is characterized by slight rises on Wednesdays; traffic is on average lowest on Fridays. The exception to these general patterns occurs at the Greenway Cedar Avenue location where mixed mode traffic is relatively consistent throughout the week, with the highest traffic on Wednesdays, and weekend daily traffic essentially equal to AADT.

Table 6.4 MADT/AADT Ratios for Each Location (MADT = Monthly Average Daily Traffic; AADT = Annual Average Daily Traffic)

Location / Mode	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
(1) Hennepin Ave. & Midtown Greenway (MGW)												
a. Bicycle	0.09	0.13	0.23	0.69	1.38	1.91	2.12	2.05	1.50	1.10	0.50	0.24
b. Pedestrian	0.34	0.54	0.74	2.48	1.53	1.63	1.77	1.46	0.86	0.25	0.09	0.30
c. Total – mixed mode	0.12	0.18	0.30	0.92	1.39	1.87	2.08	1.97	1.42	0.99	0.45	0.25
(2) West River Pkwy & MGW												
a. Bicycle	0.06	0.10	0.22	0.96	1.33	1.81	2.09	2.04	1.50	1.13	0.50	0.21
b. Pedestrian	1.58	1.92	1.82	1.29	2.60	2.65	0.42	0.20	0.09	-1.43	-0.26	1.20
c. Total – mixed mode	0.12	0.17	0.28	0.97	1.38	1.84	2.02	1.97	1.44	1.03	0.47	0.25
(3) Cedar Ave. & MGW												
a. Total – mixed mode	0.16	0.21	0.34	0.88	1.38	1.64	1.77	1.94	1.49	1.18	0.62	0.33
(4) Lake Calhoun Parkway*												
a. Bicycle	0.08	0.14	0.24	0.66	1.28	2.00	2.62	2.19	1.30	0.91	0.32	0.21
b. Pedestrian	0.12	0.21	0.36	0.99	1.48	1.74	1.93	1.78	1.43	1.08	0.52	0.31
c. Total – mixed mode	0.10	0.18	0.32	0.87	1.41	1.84	2.19	1.94	1.38	1.02	0.44	0.27
(5) Lake Nokomis Parkway*												
a. Bicycle	0.13	0.19	0.29	0.83	1.00	1.97	2.64	2.21	1.16	0.82	0.37	0.31
b. Pedestrian	0.17	0.24	0.37	1.03	1.24	1.92	1.88	1.78	1.29	1.09	0.57	0.31
c. Total – mixed mode	0.16	0.22	0.34	0.95	1.15	1.92	2.14	1.92	1.23	0.98	0.49	0.36
(6) Wirth Parkway – mixed mode	0.12	0.13	0.23	0.78	1.27	1.95	2.21	2.03	1.46	1.06	0.46	0.24
Mean Bicycle Ratio	0.09	0.14	0.25	0.79	1.25	1.92	2.37	2.12	1.37	0.99	0.42	0.24
Mean Pedestrian Ratio	0.55	0.73	0.82	1.45	1.71	1.99	1.50	1.31	0.92	0.25	0.23	0.53
Mean Mixed Mode Ratio	0.13	0.18	0.30	0.90	1.33	1.84	2.07	1.96	1.40	1.04	0.49	0.28

Table 6.5 ADT/AADT Ratios for Each Location (ADT = Average Daily Traffic; AADT = Annual Average Daily Traffic)

Location / Mode	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Weekday	Weekend
(1) Hennepin Ave. & Midtown Greenway (MGW)									
d. Bicycle	117%	101%	91%	100%	92%	88%	109%	95%	113%
e. Pedestrian	120%	85%	107%	90%	96%	107%	94%	97%	107%
f. Total – mixed mode	118%	99%	93%	99%	93%	91%	108%	95%	113%
(2) West River Pkwy & MGW									
d. Bicycle	121%	98%	95%	98%	90%	87%	111%	94%	116%
e. Pedestrian	309%	90%	-25%	47%	37%	-4%	242%	29%	275%
f. Total – mixed mode	128%	97%	90%	96%	88%	84%	116%	91%	122%
(3) Cedar Ave. & MGW									
b. Total – mixed mode	100%	100%	100%	109%	99%	89%	103%	99%	101%
(4) Lake Calhoun Parkway*									
d. Bicycle	140%	94%	86%	92%	83%	82%	122%	87%	131%
e. Pedestrian	132%	94%	89%	93%	82%	78%	132%	87%	132%
f. Total – mixed mode	135%	94%	88%	92%	82%	79%	128%	87%	132%
(5) Lake Nokomis Parkway*									
d. Bicycle	143%	94%	86%	94%	83%	79%	121%	87%	132%
e. Pedestrian	129%	96%	91%	97%	87%	77%	123%	90%	126%
f. Total – mixed mode	134%	95%	89%	96%	86%	78%	122%	88%	128%
(6) Wirth Parkway – mixed mode	134%	94%	87%	95%	83%	85%	121%	89%	128%
Mean Bicycle Ratio	130%	97%	90%	96%	87%	84%	116%	91%	123%
Mean Pedestrian Ratio	173%	91%	66%	82%	76%	65%	148%	76%	160%
Mean Mixed Mode Ratio	125%	97%	91%	98%	89%	84%	116%	92%	121%

Table 6.6 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

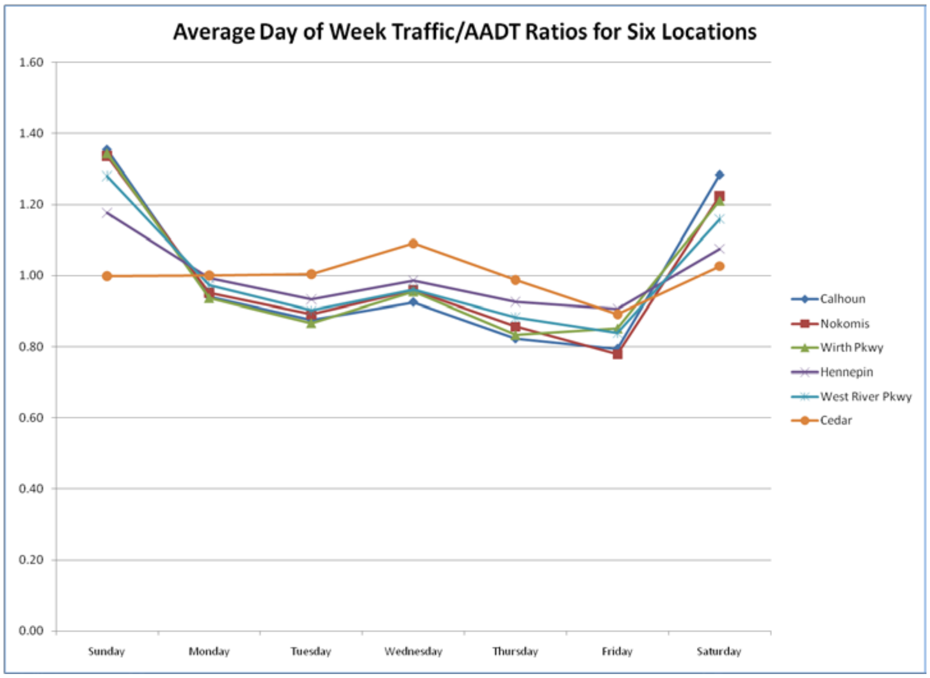


Figure 6.4 Average Day of Week Mixed Mode Traffic/AADT Ratios for Six Locations

Daily bicycle traffic patterns generally are similar to mixed mode traffic patterns, but weekend traffic is disproportionately higher at the two lake path monitoring locations relative to the two Greenway path locations (Figure 6.5, Table 6.5). At Calhoun and Nokomis, for example, the Sunday average daily traffic/AADT ratio is 1.4, while the same ratio for the Greenway sites is 1.2. These differences are likely due to increases in recreational cycling around the lakes on weekends and a higher proportion of utilitarian cycling on the Greenway.

Daily pedestrian traffic patterns differ from mixed mode and bicycle traffic patterns, with a smaller range in the daily average traffic/AADT ratios (Figure 6.5, Table 6.5). Figure 6.5 does not include day of week/AADT ratios for pedestrian traffic at the West River Parkway site because the pedestrian volumes, which were estimated by subtracting bicycle traffic volumes from mixed mode traffic volumes, are so low that the ratios are deemed unreliable.

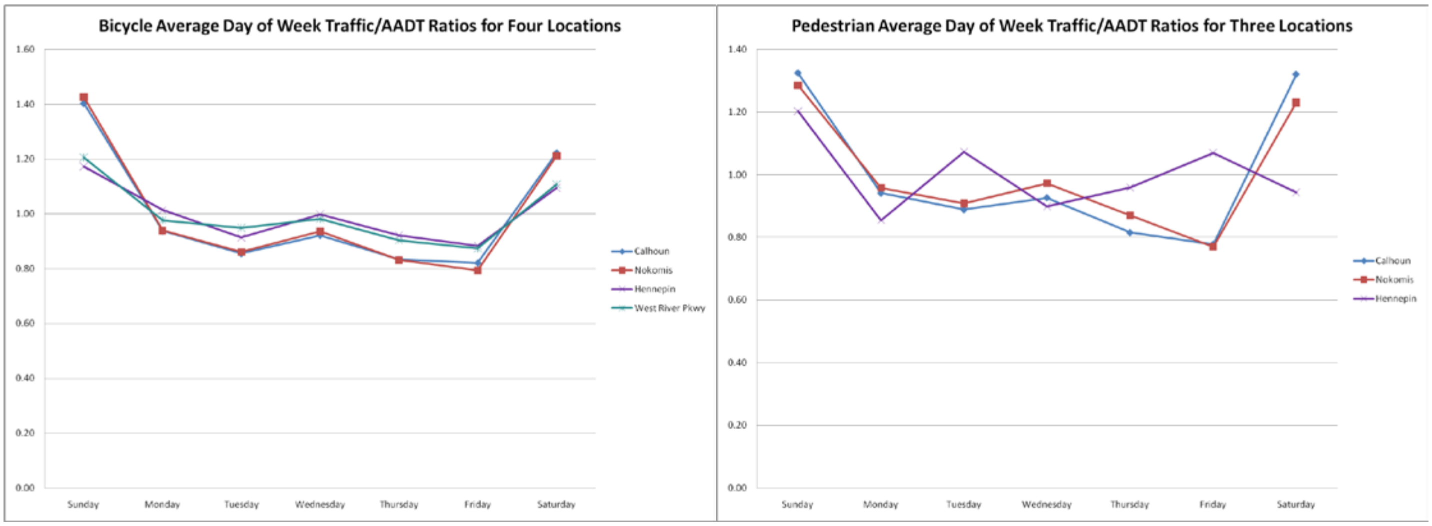


Figure 6.5 Bicycle (left panel) and Pedestrian (right panel) Average Day of Week Traffic/AADT Ratios

6.4 An Application: Using Daily and Monthly Adjustment Factors to Estimate AADT

The FHWA's Traffic Monitoring Guide recommends both continuous (i.e., 365 day) and short-duration (e.g., 48 hour) traffic counts as components of a comprehensive traffic monitoring program. We illustrate here how the adjustment factors derived in this paper can be used to estimate annual traffic and AADT at a site from a short-duration count. This example is for mixed mode traffic but the same procedure could be followed for bicycle or pedestrian modes. The example uses ratios developed from the counts at the Greenway Hennepin Avenue location, including AADT, monthly average daily traffic (MADT), ratios of mean day of week traffic to MADT for each month, and ratios of MADT to AADT for each month (Table 6.6).

Assume that MDPW installed a temporary infrared monitor to count traffic for 48 hours on a Friday and Saturday in February, 2012 on a different shared use path where no monitoring previously had occurred (Monitoring Site A). Suppose further that the 24-hour mixed mode traffic count for Friday was 175 and that the 24-hour count for Saturday was 250. Annual traffic and AADT at Site A can be estimated by:

1. Using the 2011 Friday and Saturday mean daily traffic ratios for February to calculate an average adjustment factor for the February 2012 48-hour monitoring period.
2. Estimating the MADT for February 2012.
3. Using the MADT/AADT ratio from February 2011 to estimate the 2012 AADT and 2012 annual traffic.

From Table 6.5, the average Friday traffic in February, 2011 was 1.04 times February average daily traffic, and the average Saturday traffic was 1.27 times February average daily traffic. Therefore, for the Friday-Saturday monitoring period, the average daily traffic was 1.16 times the February average daily traffic. Using this ratio, the 2012 February average daily traffic can be calculated from the 2012 48-hour traffic count:

$$\text{2012 February average daily traffic} = \frac{(175 + 250)}{1.16} = 183$$

From Table 6.6, the February MADT/AADT ratio is 0.18 (i.e., February average daily traffic is 18% of annual average daily traffic). This factor then is used to calculate AADT and annual traffic for 2012 for Site A:

$$\text{Site A AADT} = (183 / 0.18) = 1{,}023$$
$$\text{Site A annual traffic} = 1{,}023 \times 365 = 373{,}422$$

This example could be extended for counts of different duration (e.g, daily or weekly or peak hour).

Chapter 7
Conclusions and Recommendations

7.1 Conclusions

This research project included:

- A focused review of the literature on bicycle and pedestrian monitoring;
- An inventory of bicycle and pedestrian monitoring programs in Minnesota and collection of continuous monitoring data from Minneapolis;
- Development of general guidance for manual, field counts of non-motorized traffic;
- Pilot counts of bicycle and pedestrian traffic in 43 Minnesota communities; and
- Analyses of automated, continuous non-motorized counts to illustrate how engineers can develop estimates of average daily bicyclists and pedestrians and miles traveled.

The project was supported by members of an active technical advisory committee who encouraged pilot field counts and, in many communities, participated in the counts.

Several observations can be drawn from overview of research and trends in non-motorized traffic monitoring. Demand for information about bicycle and pedestrian traffic is growing rapidly, technologies for counting bicyclists and pedestrians are improving rapidly, and governments at all levels and nonprofit organizations are initiating or supporting counting programs. Local governments and nonprofit organizations have led efforts nationally to begin counting, but state departments of transportation and the FHWA also are taking important steps to institutionalize monitoring of non-motorized traffic. Among the most important initiatives, the National Bicycle and Pedestrian Documentation Project (NBPDP) has served as a catalyst for counting, developing protocols for field observations, and engaging dozens of communities, including Minneapolis, Minnesota, in counting. Recognizing the importance of counting, the need to integrated vehicular and non-motorized traffic monitoring, and the statistical limitations of the short-duration counts typically taken in the NBPDP, the Federal Highway Administration (FHWA) has included a chapter on non-motorized traffic monitoring in its authoritative Traffic Monitoring Guide, the standard for traffic monitoring in all 50 states. The FHWA also has indicated it will begin collection and archiving of non-motorized traffic data. Along with Colorado, Oregon, Vermont, and Washington Departments of Transportation, MnDOT is among state leaders with its efforts to support local agencies in non-motorized monitoring.

The inventory of counting initiatives in Minnesota identified several municipalities, recreational agencies, and nonprofits engaged in counting. The Minneapolis Department of Public Works, which has conducted both manual field counts and operated three inductive loop detectors on a multiuse path since 2007, is a leader in the state. Transit for Livable Communities, a nonprofit advocate for sustainable transportation that administered the national Non-motorized Transportation Pilot Program, also has conducted manual field counts and both continuous and period automated counting of bicycle and pedestrian traffic. Recreational agencies, including the Minnesota Department of Natural Resources (DNR), the Metropolitan Council, the Three Rivers Park District, and the Minneapolis Park and Recreation Board, are participating in counting on multiuse trails, but the field methods used by the DNR and the Metropolitan Council differ from those used by transportation agencies. Both the local park districts are gaining experience with automated, continuous monitoring of mixed-mode trail traffic using infrared sensors. In sum, most state and local agencies involved in non-motorized traffic monitoring follow protocols analogous to those recommended by the NBPDP, but local jurisdictions have some experience with inductive loop detectors and both active and passive infrared sensors. To date, deployment of these sensors has been limited to multiuse trails and sidewalks. No jurisdiction in Minnesota apparently has yet experimented with automated, continuous counting of bicycles on streets. State and local agencies expressed interest in working with MnDOT to deploy new technologies.

In collaboration with the MnDOT project leader and the technical advisory committee, the research team developed training materials and standard forms for manual counts of bicycle and pedestrian traffic. The guidance and protocols were based on protocols followed by the Minneapolis Department of Public Works and Transit for Livable Communities that originally were based on NBPDP protocols. Following review and approval of the materials and protocols by the technical advisory committee, the MnDOT project leader and research team held a webinar and workshops in Alexandria, Bemidji, Duluth, Marshall, and Rochester in the summer of 2012 to train people in counting and to recruit participants for pilot field counts in September 2012. Seventy-five people attended the training sessions.

In September 2012, the project officer and the research team coordinated the first MnDOT statewide bicycle and pedestrian counts. The Minnesota Department of Health collaborated in the counts and required recipients of State Health Improvement Program (SHIP) grants involved in active travel interventions to participate in the counts. Counts were undertaken at 133 locations in 43 communities, including approximately 25% of all communities in Minnesota with populations greater than 10,000. In addition, the MDPW and Transit for Livable Communities conducted counts at several hundred locations as part of their ongoing monitoring programs. Most counts were taken during evening peak hours (4:00 p.m. and 5:00 p.m.) on mid-week days (Tuesday, Wednesday, and Thursday). Across all cities at all times, mean hourly bicycle and pedestrian traffic was 7.5 and 19.3 respectively. Mean hourly bicycle and pedestrian traffic was substantially higher in Class I cities with populations greater than 100,000 than in Class II, III, and IV Cities with lower populations. Across Class II, III, and IV Cities, mean hourly bicycle and pedestrian traffic was comparable, although there were substantive variations within class sizes depending on the locations where counts were undertaken. In general, across cities of all sizes, pedestrian traffic was greater than bicycle traffic, except on multiuse trails. In addition, non-motorized traffic also seemed to be associated with street functional class, although there were variations across communities. A post-count survey of count managers by the MnDOT project officer found that many communities participated because of MDH requirements, that traffic volumes recorded were comparable to those expected, that the MnDOT guidance was helpful but that methods for reporting counts need to be improved, that data collected during the counts was already being used, and that some jurisdictions, but not all, would participate again if MnDOT held additional counts.

Analyses of automated counts from six locations on eight paths in Minneapolis with inductive loop detectors and active infrared monitors demonstrated the limitations of these technologies; hourly, daily, and monthly patterns in bicycle, pedestrian, and mixed-mode traffic; and the feasibility of estimating average annual daily traffic and miles traveled on segments of multiuse trails using procedures outlined in the FHWA's Traffic Monitoring Guide. The automated continuous monitoring showed that annual trail traffic in Minneapolis is substantial but varies significantly across locations; that hourly, daily, and monthly patterns are comparable despite variation in volumes, and that adjustment factors developed from continuous counts can be used to extrapolate short-term counts to obtain estimates of annual traffic.

7.2 Recommendations

Given these findings and conclusions, the research partners (i.e., the MnDOT project officer, the researchers, and the technical advisory committee) have several recommendations:

1. MnDOT should continue and institutionalize coordination of annual statewide bicycle and pedestrian counts using the new MnDOT forms. Continuation of counting will provide useful information about local conditions, build support for automated continuous counting, and engage citizens in activities that will increase their understanding of the complexities and challenges of planning bicycle and pedestrian systems.

2. MnDOT should improve methods for reporting results of field counts and explore web-based programs for data reporting and analysis, including opportunities to integrate short-duration field counts into databases used to archive vehicular monitoring data.

3. MnDOT should lead efforts to deploy and demonstrate the feasibility of new automated technologies for bicycle and pedestrian counting, focusing on new technologies not presently used in Minnesota. New technologies that have not yet been deployed in Minnesota include inductive loop detectors for counting bicycles in streets, pneumatic tubes for short-duration continuous counting of bicycles on streets, infrared counters for counting pedestrians on sidewalks, and integrated loop detectors and infrared monitors for differentiating and counting both bicycles and pedestrians on multiuse trails.

4. MnDOT should begin integration of non-motorized traffic counts from existing automated, continuous counters in Minneapolis into its new databases for vehicular traffic monitoring data. Experimentation with existing data will be useful in establishing protocols for quality control and analysis essential for integration of non-motorized and vehicular data and use of standard procedures for factoring and extrapolation.

5. MnDOT should work with local governments and explore institutional arrangements for (a) establishing a network of permanent, automated continuous monitoring sites across the state to develop the data necessary for factoring and extrapolating short-duration counts and (b) sharing and deploying new technologies for short-duration monitoring to generate traffic counts that provide a more comprehensive understanding of spatial variation in non-motorized traffic volumes. To help local jurisdictions implement counting programs MnDOT should work with them to estimate program costs, including capital equipment and staff time. Special effort should be made to work with the State's smallest jurisdictions to develop cost-effective strategies for acquiring information about bicycle and pedestrian traffic.

References

AMEC E&I, Inc. and Sprinkle Consulting, Inc. (December 2011) *Pedestrian and Bicycle Data Collection*, For Federal Highway Administration, Washington, DC.

Aultman-Hall, L., D. Lane, and R. Lambert, (2009) "Assessing impact of Weather and Season on Pedestrian Traffic Volumes. *Transportation Research Record*. 2140, 35-43.

Baker, M., P. Jannett, A. Lee, and L. Mitchell, (2012) "MnDOT Support for Monitoring Bicycle and Pedestrian Traffic." Hubert H. Humphrey School of Public Affairs, Minneapolis, MN.

Behnam, J., and B.G. Patel, (1977) "A method for estimating pedestrian volume in a central business district." *Transportation Research Record*. 629, 22-26.

Bike Walk Twin Cities Available: http://www.bikewalktwincities.org/, accessed Sep. 2011.

BTS (Bureau of Transportation Statistics), (2002) *Bicycle and Pedestrian Data: Sources, Needs, and Gaps*. Publication BTS00-02. Bureau of Transportation Statistics, U.S. Department of Transportation, Washington, DC.

Cao, X., S. Handy, and P. Mokhtarian, (2006) "The Influences of the Built Environment and Residential Self-Selection on Pedestrian Behavior: Evidence from Austin, TX." *Transportation*, 33(1), 1-20.

City of Minneapolis Department of Public Works. Bicycle and Pedestrian Counts. Available: http://www.ci.minneapolis.mn.us/bicycles/bicycle-counts.asp, Sep. 4 2011.

Dharmaraju R., D.A. Noyce, and J.D. Lehman, (2001) "An Evaluation of Technologies for Automated Detection and Classification of Pedestrians and Bicycles" University of Massachusetts, Massachusetts Highway Planning, Amherst, MA.

Federal Highway Administration (FHWA). *Traffic Monitoring Guide*. Federal Highway Administration, U.S. Department of Transportation, http://www.fhwa.dot.gov/ohim/tmguide/, accessed July 12, 2012.

Greene-Roesel, R., M.C. Diogenes, D.R. Ragland, and L.A. Lindau, (2008) *Effectiveness of a Commercially Available Automated Pedestrian Counting Device in Urban Environments: Comparison with Manual Counts*, Institute of Transportation Studies, Berkeley, CA.

Guo, J., C. Bhat, and R. Copperman, (2007) "Effect of the built environment on motorized and non-motorized trip making: substitutive, complementary, or synergistic?" *Transportation Research Record*. 2010(1), 1-11.

Handy, S. L., M.G. Boarnet, R. Ewing, and R.E. Killingsworth, (2002) "How the Built Environment Affects Physical Activity: Views From Urban Planning." *American Journal of Preventive Medicine*, 23(2, Supplement 1), 64-73.

Hankey, S., G. Lindsey, X. Wang, J. Borah, K. Hoff, B. Utecht, and Z. Xu. "Estimating use of non-motorized infrastructure: Models of bicycle and pedestrian traffic in Minneapolis, MN." *Landscape and Urban Planning*. (in press).

Haynes, M., and S. Andrzejewski, (2010) GIS Based Bicycle and Pedestrian Demand Forecasting Techniques. Fehr & Peers. TMIP Webinar. Available: http://tmip.fhwa.dot.gov/webinars/nonmotorized, accessed May 2010.

Holmes, A., G. Lindsey, and C. Qiu, (2009) "Ambient Air Conditions and Variation in Urban Trail Use." *Journal of Urban Health*. Vol. 86, No. 6: 1099-3460 (Print) 1468-2869 (Online).

Hudson, J., T-B. Qu, and S. Turner, (2010) *Forecasting Bicycle and Pedestrian Usage and Researching Data Collection Equipment*. Capital Area Metropolitan Planning Organization by the Texas Transportation Institute, Austin, TX. December.

Hunter, W., and H.F. Huang, (1995) "User counts on bicycle lanes and multiuse trails in the United States." *Transportation Research Record*. Vol. 1502, p. 45-57.

Jones, M., S. Ryan, J. Donlon, L. Ledbetter, D.R. Ragland, and L. Arnold, (2010) *Seamless Travel: Measuring Bicycle and Pedestrian Activity in San Diego County and Its Relationship to Land Use, Transportation, Safety, and Facility Type*. UC Berkeley Safe Transportation Research & Education Center. UC Berkeley.

Lee, C and Moudon A, (2012) Correlates of Walking for Transportation or Recreation Purposes. Journal of Physical Activity & Health [serial online]. January 2, 2006; 3: S77-S98. Available from: SPORTDiscus with Full Text, Ipswich, MA. http://activelivingresearch.org/node/9981 Accessed January 6, 2012.

Lindsey, G., Y. Han, J. Wilson, and J. Yang, (2006) "Neighborhood correlates of urban trail traffic." *Journal of Physical Activity and Health*. 1, S134-S152.

Lindsey, G., J. Wilson, E. Rubchinskaya, J. Yang, and Y. Han, (2007) "Estimating urban trail traffic: methods for existing and proposed trails." *Landscape and Urban Planning*, 81, 299-315.

Lindsey, G., J. Wilson, E. Rubchinskaya, J. Yang, and C. Alexa, (2008) Urban form, trail characteristics, and trail use: implications for design." *Journal of Urban Design*. 13(1), 107-132.

Minneapolis, MN Bicyclist Counts Available: http://www.minneapolismn.gov/bicycles/data/WCMS1P-088370, accessed July 2012.

Moudon, A.V., C. Lee, A.D. Cheadle, C.W. Collier, D. Johnson, T.L.Schmid, and R.D. Weather, (2005) “Cycling and the Built Environment, a US Perspective.” *Transportation Research Part D: Transport and Environment*, 10(3), 245-261.

National Bicycle and Pedestrian Documentation Program (2012). Available: http://bikepeddocumentation.org/, accessed Sep. 4 2011.

NBPDP (National Bicycle and Pedestrian Documentation Project). http://bikepeddocumentation.org/, accessed July 30, 2012.

Nordback, K., and B.N. Janson, (2011) “Automated bicycle counts: Lessons from Boulder, Colorado.” *Transportation Research Record*. Vol. 2190, p. 11-18.

Papanikolopoulos, N.P., (2010) *Practical Methods for Analyzing Pedestrian and Bicycle Use of a Transportation Facility* University of Minnesota, Department of Computer Science and Engineering, Minneapolis, MN.

Porter, C. and J. Suhrbier, (1999) “Forecasting Bicycle and Pedestrian Travel: State of the Practice and Research Needs.” *Transportation Research Record: Journal of the Transportation Research Board*, 1674, 4-101.

Pratt, R., J. Evans, H. Levinson, S. Turner, C.Y. Jeng, and D. Nabors. “Traveler Response to Transportation System Changes,” (December 2011) Chapter 16, *Pedestrian and Bicycle Facilities*; Revised final report (Prepared for Transit Cooperative Research Program, Transportation Research Board, National Research Council and Centers for Disease Control and Prevention.).

Pushkarev, B., and J.B. Zupan, (1971) “Pedestrian travel demand,” *Highway Research Record*. 377, 37-53.

Rodriguez, D.A. and J. Joo, (2004) “The Relationship between non-motorized Mode Choice and the Local Physical Environment.” *Transportation Research Part D: Transport and Environment*, 9(2), 151-173.

Schneider, R., R. Patton, J. Toole, and C. Raborn, (2008) *Pedestrian and Bicycle Data Collection in United States Communities: Quantifying Use, Surveying Users, and Documenting Facility Extent*. U.S, Department of Transportation. Federal Highway Administration, Washington, DC.

Schneider R., L. Arnold, and D. Ragland, (2009) “Methodology for Counting Pedestrians at Intersections: Use of Automated Counters to Extrapolate Weekly Volumes from Short Manual Counts.” *Journal of Transportation Research Board*, 2140:1-12.

Senn, A. and A. Anderson, (2010) Technical Memorandum. “Manual Validation of Automatic Bicycle and Pedestrian Counters. Humphrey School of Public Affairs, PA4290-5290 Practicum in Non-motorized Transportation.” Transit for Livable Communities and Minneapolis Department of Public Works. Minneapolis, MN.

Transit for Livable Communities. Bicycling and Walking Counts. Available: http://www.bikewalktwincities.org/about-us/funding-process-and-history/projects/bicycling-walking-counts accessed Sep. 4 2011.

Turner**,** S., Q. Tongbin, and P. Lasley, (2012) *Strategic Plan for Non-Motorized Traffic Monitoring in Colorado*. Texas Transportation Institute. Prepared for Colorado Department of Transportation, Denver, CO.

US DOT, (1999) *Guidebook on Methods to Estimate Non-Motorized Traffic: Supporting Documentation*. Federal Highway Administration, U.S. Department of Transportation, Washington, DC.

Wang, X., G. Lindsey, S. Hankey, and K. Hoff, “Estimating Mixed-Mode Urban Trail Traffic Using Negative Binomial Regression Models.” Submitted to *Journal of Urban Planning and Development* (in review).