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North Carolina Non-Motorized Volume Data Program (NC NMVDP)

Phase 1 Final Report

ITRE Bicycle & Pedestrian Program

BikePed PROGRAM

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NCDOT Project 2014-44

Bicycle and Pedestrian Data Collection

Phase 1 Final Report

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Abstract

This report documents the initial processes developed and tested to establish a common, consistent system for how NCDOT can quantifiably measure annual average daily non-motorized volumes based on sound methods. The following programmatic elements were piloted in the geographic region which comprises Divisions 7 and 9 (i.e., the Triad region): site selection; local agency coordination; equipment identification, procurement and installations; equipment validation; quality control/quality assurance checks; data management, monitoring, and reporting; and equipment maintenance and troubleshooting. As each element was implemented, the research team also identified recommendations for future process improvements as well as considerations for new or expanded programmatic elements, planning needs, and ongoing resources as NCDOT continues to expand the Non-Motorized Volume Data Program to other regions of the state.

Key Words	Distribution Statement
Bicycle, pedestrian, volume, AADT, site selection, continuous count, short-duration count, correction factor, adjustment factor	

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Executive Summary

The North Carolina Department of Transportation (NCDOT) is well practiced in collecting motor vehicle traffic counts and estimating annual average daily traffic (AADT) volumes for motor vehicles based on a wealth of knowledge founded on years of research and experience. When considering the prioritization and funding of projects, whether making the case for where new facilities are needed or where existing ones should be modified, transportation planning decisions are informed by understanding traffic volumes and future demands. NCDOT currently plans and programs bicycle and pedestrian project funds based on qualitative input and local priorities and some quantitative inputs, like crash data. As the state's population grows and urbanizes, the demand for pedestrian and bicycle facilities also grows. Therefore, there is a need for NCDOT to establish a non-motorized volume data program to complement the existing motorized traffic monitoring system to provide a full picture of how the state's transportation network is functioning for all users.

This report documents the initial processes developed and tested to establish a common, consistent system for how NCDOT can quantifiably measure non-motorized volumes based on sound methods. The following programmatic elements were piloted in the geographic region which comprises Divisions 7 and 9 (i.e., the Triad region):

- Site Selection
- Local Agency Coordination
- Equipment Identification, Procurement, and Installations
- Equipment Validation
- Quality Control/Quality Assurance Checks
- Data Management, Monitoring, and Reporting
- Equipment Maintenance and Troubleshooting

As each element was implemented, the research team also identified recommendations for future improvements and considerations for new or expanded programmatic elements, planning needs, and on-going resources as NCDOT continues to expand non-motorized volume data program to other regions of the state.

Establishing a bicycle and pedestrian count program will assist NCDOT in evaluating facility usage over time, inform the project prioritization process, and provide quantifiable evidence to support non-motorized facility inclusion through the Complete Streets process, thereby improving municipal and regional planning for active travel. In turn, these data can be fed into tools to measure existing trends and model future increases in non-motorized trips at site-, corridor-, and regional-levels.

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Chapter 1. Introduction

This report documents the development and piloting of a Non-Motorized Volume Data Program (NMVDP) for the North Carolina Department of Transportation (NCDOT). The pilot program (or Phase 1) specifically focused on establishing the continuous counting arm of the program through identifying sites and permanently installing automated equipment to count bicyclists and pedestrians. This report also provides recommendations for NCDOT to consider as it builds out the NMVDP through future phases. Future phases of the program will continue to expand the NMVDP in its geographic coverage of the state in two different ways – 1) to initiate the continuous count program other regions of the state; and 2) to develop and establish a short duration count program. Similar to motorized data collection monitoring programs, supplementing continuous count stations by adding a larger number of short-duration counters provides spatial and cost-effective representation within a non-motorized count program. While continuous count stations provide temporal coverage, short duration count stations provide spatial coverage. Therefore, the ultimate build-out of the NMVDP will include the establishment and management of data from a combination of the two count station types in a proportion similar to what is illustrated in **Figure 1** from the National Highway Institute's Traffic Monitoring Program: Guidance and Procedures Training Course Materials.

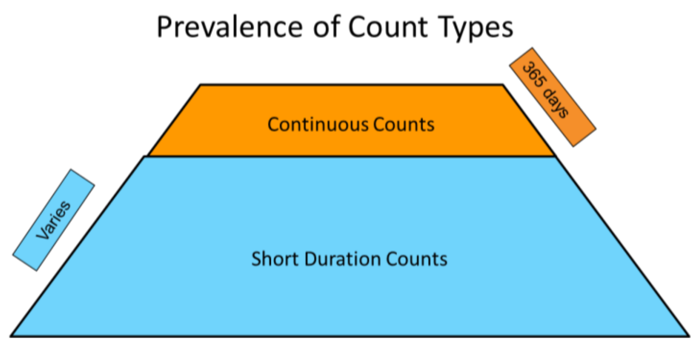

Figure 1. Type and proportional quantity of count collection types for estimating non-motorized volumes

Need for a Non-Motorized Volume Data Program

The North Carolina Department of Transportation (NCDOT) has vast experience collecting motor vehicle traffic counts and estimating annual average daily traffic (AADT) volumes for motor vehicles based on a wealth of knowledge. When considering the prioritization and funding of projects, transportation planning decisions are informed by understanding traffic volumes and future demands. NCDOT currently plans and programs bicycle and pedestrian project funds based on qualitative input and local priorities, with little quantitative inputs beyond crash data. As the state's population continues to grow and urbanize, the demand for pedestrian and bicycle facilities will also increase. It is therefore prudent to establish a volume data program to collect and monitor bicycle and pedestrian traffic to provide a more comprehensive transportation picture.

From the need to reduce air emissions to the need for additional exercise through active transportation, there is an increasing demand for understanding and evaluating agencies' bicycle and pedestrian infrastructure investments and project funding prioritization methods. Projects specifically targeted for bicycle and pedestrian travel struggle to compete for funding with other highway projects because they currently lack the necessary information to determine past, current, or future facility usage. Further complicating the challenge of obtaining the necessary information on volumes, very little information has been documented or published on implementing standardized methods for collecting these non-motorized volume datasets. However, the field is growing, and there are a few key references that serve as a start for building a data collection program. Additionally, agencies need bicycle and pedestrian volume data to report on established performance measures, enhance safety, provide for better operations and proper maintenance, and fulfill customer needs for non-motorized data. To that end, many governmental agencies have started to develop non-motorized count programs and have started purchasing automated counting equipment.

The North Carolina Non-Motorized Volume Data Program (NC NMVDP) establishes a consistent system for quantifiably measuring non-motorized volumes based on sound methods so that these data can ultimately feed into tools to measure existing trends and model future increases in non-motorized trips at site-, corridor-, and regional-specific levels. A bicycle and pedestrian count program will ultimately assist NCDOT in evaluating facility usage over time, better inform the project prioritization process and provide quantifiable evidence to support non-motorized facility inclusion through the Complete Streets process, improving municipal and regional planning for active travel.

Project Scope and Objectives

This report documents protocols that were designed and tested through a bicycle and pedestrian count collection pilot, resulting in recommendations and considerations for how to expand the program to conduct counts across the state. To initiate the research, the project team worked to create geographic sampling strata in the pilot region which covered NCDOT Division 7 and 9. Divisions 7 and 9, which includes the Piedmont or Triad Region of North Carolina, were chosen for the first phase of the project since the most comprehensive GIS dataset available on existing non-motorized facilities in the Pedestrian and Bicycle Infrastructure Network (PBIN), NCDOT's statewide geodatabase, was for this area at beginning of the project. The municipalities of Winston-Salem, Greensboro, Chapel Hill, Carrboro, High Point, Lexington, and Salisbury among others are located within the pilot region.

Local agencies involved in the pilot were trained on the basics of starting a non-motorized data collection program and best practices based on existing research. Sites were solicited through local agencies using an online survey tool. A site selection method was used to identify continuous and short-duration count sites. The research team worked with local agencies to permanently install and calibrate equipment at sites selected as Continuous Count Stations (CCSs). Data collected at these sites were checked for quality and data not meeting certain quality control thresholds were removed prior to creating quarterly data summary reports for project stakeholders. Counts at each site were validated to determine accuracy of counting equipment and derive site-specific error correction factors. After error correction factors were applied to the cleaned data, non-motorized activity in the pilot region was annualized to produce annual average daily bicyclist (AADB) and annual average daily pedestrian (AADP) traffic statistics.

Report Organization

This report consists of the following chapters:

- Chapter 1 – Introduction: provides background on the need for a non-motorized volume data program and outlines the project scope and objectives.
- Chapter 2 – Literature Review: summarizes the national state of practice through prominent and peer-reviewed research and guides and key takeaways from current premier regional and state program examples upon which we modeled and/or improved in developing NCDOT's program.
- Chapter 3 – Bicycle and Pedestrian Count Activities in North Carolina: summarizes the current state of practice in conducting counts within the state for a variety of uses and needs
- Chapter 4 – Establishing Count Stations: provides insight into the importance of local agency coordination to establish and build strong partnerships, lays out a series of steps taken in the site selection process, and offers considerations for determining whether a site should be prioritized for permanent equipment installation or temporary count needs. Additionally, this chapter outlines the steps taken to ensure new stations are properly identified and documented in appropriate records needed for data tracking and programmatic purposes.
- Chapter 5 – Continuous Count Sites: offers the research team's systematic approach used to manage and implement the installation of permanently installed count equipment, including equipment procurement, preparation for installation, in-field activities, and station maintenance.
- Chapter 6 – Short Duration Count Sites: identifies how SDCs were carried out in the pilot region.
- Chapter 7 – Validation, Accuracy, and Development of Correction Factors: provides the procedures used to conduct a validation study of each continuous count station and the analyses performed to develop appropriate, site-specific correction factors.
- Chapter 8 – Procedures for Obtaining Quality Data: lays out a series of quality control objectives and the protocol undertaken to check for and scrub invalid raw data.
- Chapter 9 – Data Storage, Reporting, and Sharing: gives an overview of the various data warehouses developed and maintained as well as how they relate to one another and discusses the processes used to prepare quarterly and annual reports as well as data sharing conducted through the pilot phase.
- Chapter 10 – Data Analysis and Generating Traffic Statistics: identifies a framework for assigning factor groups, developing adjustment factors, and the methods used to calculate annual average daily bicycle or pedestrian traffic volumes.
- Chapter 11 – Technical Transfer: describes three types of training developed and implemented in the pilot region to build program capacity and understanding at the local level.
- Chapter 12 – Recommendations for Phase 2: outlines key considerations for procedural modifications of existing program elements, the development of new program elements, and the need for an overarching strategic plan moving into future phases of the NMVDP.
- Chapter 13 – Appendices: includes a series of appendices that provide further details, analyses, or internal procedural documentation for various program elements; example checklists,

document templates, or forms used; and a compilation of the Site Narratives from the pilot region.

Finally, a list of references and appendices that support or expand upon content within the report are provided after Chapter 13. These include example checklists, templates, spreadsheets, and other more detailed documentation used in the initial launch of the North Carolina Non-Motorized Volume Data Program (NC NMVDP).

Chapter 2. Literature Review

North Carolina is on the forefront of work in the field non-motorized volume monitoring in the United States through this project. While some cities have worked to establish count programs to understand bicyclist and pedestrian volumes, very few state DOTs have model programs to look to for guidance. Nationally, research in this arena is currently a hot topic, and the current state of practice is a quickly changing landscape as new studies and reports inform and shape the body of knowledge on the subject.

This section provides some context regarding non-motorized count methods, equipment and technology, and uses of data based on the current body of knowledge available through the literature. Although minimal literature is available on the monitoring of non-motorized volume data, this field has recently generated interest and is expected to continue to grow. Local programs were also scanned for lessons learned and best practices.

National Research

The most pertinent research on the state of the practice for conducting bicycle and pedestrian counts and estimation methods for bicycling and walking are important to consider in the development of the NC NMVDP. Understanding known count technologies and having insight into transferrable methods for estimating and forecasting bicycling and walking trips informed the research tasks and supports the practices used in this project.

NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection

The guidebook describes applications for bicycle and pedestrian counts, methods, and technologies for counting pedestrians and bicyclists, offers detailed steps on planning for and implementing a non-motorized count program, describes approaches for selecting count locations, gives suggestions on selecting appropriate counting methods and technologies, and provides examples of how organizations have used non-motorized count data to better fulfill their missions. The guidebook also provides comprehensive definitions of numerous terms used in traffic monitoring, as well as detailed explanations of the processes involved in the collection of non-motorized data. The guidebook discusses the different strategies for selecting sites as representative count locations. Although these sites can be identified using a random sampling process, it is not a common method. To be representative, these locations should be in different geographic areas, surrounded by different land use types, found on different types of facilities, and are reflective of the range of socioeconomic characteristics in the community as a whole *(1)*.

Of specific interest to the NCDOT pilot project are topics related to quality control of the data, validation and adjustments that can be made to improve the accuracy of the count data being collected, and approaches to the development of factor groups. Validation involves testing the automated counter devices both on the installation day and also several days after the installation *(1)*.

The guidebook discusses examining count data for inconsistent or unusual data. It details processes for creating observation thresholds and comparing the differences in directional counts (e.g., eastbound vs. westbound) and describes how care must be taken in omitting or cleaning where anomalies are present in the data before it is corrected (i.e., adjusted for site-specific systematic errors based on count technology). Undercounting can and should be expected for even the most effective technologies. Correction factors are developed from validation counts and account for systematic inaccuracies in installed continuous count equipment. They are used to adjust the raw counts to represent more closely what is happening on the ground. Per Table 4-2 in *NCHRP Report 797*, inductive loops had the smallest correction factor for all sensor technologies tested by the researchers *(1)*.

Expansion factors are applied to short duration counts to estimate volumes for longer periods of time. These expansion factors can include temporal adjustments, environmental adjustments, and land use/facility type adjustments. Unless they are being used as an intermediate step in calculation, the guidebook recommends rounding volumes that are based on extrapolation because they are estimates. Section 4.6 of *NCHRP Report 797* details an example "Application of Factor Adjustment Methods" and includes step by step instructions for working with raw data to arrive at an estimate of annual volumes *(1)*.

Factor groups are count locations that experience similar daily, monthly, and annual pedestrian and bicycle traffic patterns and are used to expand short duration counts. The guidebook references three approaches for the development of factor groups that include a visual comparison, statistical comparison, or the application of criteria that describe characteristics of interest *(1)*.

NCHRP Web-Only Document 205: Methods and Technologies for Pedestrian and Bicycle Volume Data Collection

This report describes the research approach behind the development of *NCHRP Report 797: Guidebook on Pedestrian and Bicycle Volume Data Collection*. This project assessed existing, new, and innovative bicycle and pedestrian data collection technologies as an effort to provide guidance for transportation practitioners on to how to best collect non-motorized volume data. Test locations were selected to achieve a range of weather conditions, mix of facility types, and mix of road users. Selected hours from two weeks of video were manually counted to ground-truth the data. In addition to accuracy, the counting technologies were evaluated based on ease of implementation, labor requirements, security, maintenance, software, cost, and ease of data transmission. Product-specific accuracy varied significantly although the consistencies of the counted volumes were generally similar, meaning a correction factor could be applied to the tested products *(2)*.

The report recommends with emphasis that local correction factors (location- or device-specific) should be developed for automated counts. It states that a minimum of 30 time periods worth of ground-truth data (e.g., approximately 8 hours of counts when 15-minute interval data are collected or 30 hours of counts when 60-minute data are collected) are necessary to develop correction factors. Time periods should include a range of volumes, including some time periods when peak volumes occur. Significant site-specific factors influenced the accuracy of the counts stressing the importance of selecting sites to mitigate potential bypass error, proper installation, and calibration, as well as the recommendation to validate counts by site rather than more generally by the type of technology sensor used. The research reports no clear impact of temperature, snow, or rain on the accuracy any of the given count equipment *(2)*.

Transportation Research Circular: Monitoring Bicyclist and Pedestrian Travel and Behavior (E-C183, March 2014)

Greg Griffin et al. give an overview of national baselines for non-motorized travel in the United States and a summary of the state of the practice on bicycle and pedestrian travel monitoring. The circular states that data collected using the methods from the National Bicycle and Pedestrian Documentation Project has limited value for systematic comparisons, and adjustment factors are not sufficient to derive a reliable nationwide model. One of the newer data collection techniques detailed in the circular is technology-assisted manual counting through an app called BikeCount which takes advantage of smartphone technology in an attempt at obtaining large numbers of short term counts, possibly through crowd-sourcing. However, this data collection technique is biased and requires all participating travelers to have a smartphone. Portable counters have flexibility to move counting devices as needed to different locations. Equipment adjustment factors can be used to correct the under-counting bias which can occur with portable counters. Permanent counters are useful to create factors that can then be applied to short-duration counts, including factors to account for local weather and seasonal variability. The circular discusses communication strategies that permanent sites are able to provide such as “bike barometers” that give real-time information to the public, and it highlights the importance of a strategy for quality assurance of the automatic count data *(3)*.

The circular also discusses the lack of national data standards for bicycling and walking. The Federal Highway Administration’s Travel Monitoring Analysis System (TMAS) promises to provide online data submittal (in the near future) by state departments of transportation and will be available publicly, but TMAS does not currently include bicycle and pedestrian data *(3)*.

National Bicycle and Pedestrian Documentation Project (NBPDP)

The National Bicycle and Pedestrian Documentation Project (NBPDP) was created in 2004 and is co-sponsored by Alta Planning and Design and the Institute of Transportation Engineers (ITE) Pedestrian and Bicycle Council as a nationwide effort to provide a consistent model of data collection and ongoing data for use by planners, governments, and bicycle and pedestrian professionals. The NBPDP was the first in the United States to create a standardized format for bicycle and pedestrian counts, and its website provides forms, instructions, and additional information for agencies interested in conducting short duration non-motorized counts *(4)*.

CDOT 2013-18: Development of Estimation Methodology for Bicycle and Pedestrian Volumes Based on Existing Counts

Colorado Department of Transportation released a report documenting their annual average daily traffic (AADT) methodology for non-motorized volume data from short term counts using a factoring method. This provides a process for the automated creation of annual average daily bicyclists and pedestrians (AADBP) statistics similar to calculating AADTs for motor vehicle traffic. By comparing time of day, weekly, and seasonal variations in volumes for both motorized and non-motorized travel, patterns of recreational vs. commute use became clear. These comparisons also allowed the team to develop a method for creating seasonal factors – the first step in calculating annual travel volumes for short-duration counts. These are the first known bicycle and pedestrian expansion factors developed by a state *(5)*.

For the cases examined, motorized and non-motorized travel in the same geographic area or corridor did not share the same patterns so applying motorized factors to non-motorized data is not expected to lead to accurate statistical calculations for non-motorized use. Non-motorized patterns were analyzed to reveal distinct travel patterns for non-motorized travel on a daily, monthly, and annual basis. Similar patterns were grouped together as factor groups and factors were developed to estimate an accurate annualized daily count based on the characteristics of the location and whether continuous counters or short-term counters were being used *(5)*.

Factoring methods were compared against statistical methods (incorporating hourly weather data) to calculate annual average daily bicyclists and pedestrians (AADBP). In doing so, the researchers found that including weather data into their statistical model increased the accuracy of the estimates but that there was a large tradeoff with the work required relative to the marginal increases in accuracy. The research team reported that simple factoring methods worked well with their data management system and required less effort to implement. Based on precision intervals from motorized vehicle counting program recommendations, the researchers recommend installing five to seven continuous counters for each factor group to achieve a reasonably accurate set of factors. This estimate was based on two factor groups (Commute and Non-Commute) from Boulder, CO for bicycle counts only *(5)*.

NCHRP Report 770: Estimating Bicycling and Walking for Planning and Project Development

When developing a count program, it is important to understand the purposes for which the data may be used, such as in modeling and estimating demand. This guidebook focuses on tools to estimate and forecast bicycling and walking activity at site, corridor, and regional levels based on contextual factors. It reviews analytic options and explains how count data feed into different models, while identifying the variables or factors that are important to consider for each model. To improve the overall caliber of bicycle/pedestrian planning tools, the research focuses heavily on forging a satisfactory choice-based approach (differentiated from a facility-based approach), both to provide needed illumination about the behavioral relationships in non-motorized travel and enabling planners to control for those variables in an analysis. Base data are provided so a user can test the assumptions of each model *(6)*.

The report notes that focusing the counts and models on a particular time period (e.g., A.M. weekday peak for work or mid-day weekend for recreation) can narrow the uncertainty as to the types of trips being observed, but, for other time periods, the mix of trips being modeled may be difficult to surmise. A review of this report reveals different modeling contexts in which count data is applied in combination with other source data to give a more holistic view of travel behavior. It also explains how the more local the context and data, such as observed counts, the less transferable the model is from one region or study area to another *(6)*.

FHWA *Traffic Monitoring Guide*

This guidebook was updated in 2013 and now includes a chapter on “Traffic Monitoring for Non-Motorized Traffic.” It provides a valuable review of existing techniques and guidance for implementation of a non-motorized transportation monitoring program. It includes recommendations for data to collect and related attributes for creating non-motorized count records as an attempt to standardize the collection of data. It also provides guidance on choosing methods for bicycle and pedestrian counts and steps for establishing a non-motorized traffic program which are summarized from the FHWA *Traffic Monitoring Guide (TMG)* in **Table 1** *(7)*.

Table 1. Key Steps in Establishing Non-Motorized Traffic Monitoring (Adapted from Figure 2-1 of the *Traffic Monitoring Guide*, 2013)

Continuous Data Management Program	Short-Duration Data Program
1. Review the existing continuous count program	1. Select count locations
2. Develop an inventory of available continuous count locations and equipment	2. Select type of count (segment and/or intersection)
3. Determine the traffic patterns to be monitored	3. Determine duration of counts
4. Establish seasonal pattern groups	4. Determine method of counting (automated and/or manual)
5. Determine the appropriate number of continuous count sites	5. Determine frequency of short-term counts per location
6. Select specific count locations	6. Evaluate counts (accuracy characteristics, variability)
7. Compute temporal factors	7. Apply factors (occlusion, time of day, day of week, monthly, seasonal)

The guide recommends three to five continuous count station groups for each factor group (based on trip purpose and seasonality) where budgets are not constrained. Continuous counters provide information on temporal variation from which hourly, daily, and monthly factors can be created and applied to short-duration counts. Short duration counts are collected as part of coverage programs (i.e., to provide geographic coverage across region) or for special study needs *(7)*.

Table 2 is taken from the *TMG* and provides a comprehensive summary of different technologies available to conduct bicycle and pedestrian counts. Agencies with manual observers are encouraged to count for longer periods (i.e., 4-6 hours minimum) at fewer locations due to the high error rates which have been found from annualizing 2-hour count data. Data extrapolated from 2-hour counts can lead to erroneous conclusions *(7)*.

Table 2. Bicycle and Pedestrian Counting Technologies (Table 4-1 in the *Traffic Monitoring Guide*, 2013)

Technology	Typical Applications	Strengths	Weaknesses
Inductance loop	Permanent counts Bicyclists only	Accurate when properly installed and configured Uses traditional motor vehicle counting technology	Capable of counting bicyclists only Requires saw cuts in existing pavement or pre-formed loops in new pavement construction May have higher error with groups
Magnetometer	Permanent counts Bicyclists only	May be possible to use existing motor vehicle sensors	Commercially available, off-the-shelf products for counting bicyclists are limited May have higher error with groups
Pressure sensor/ pressure mats	Permanent counts Typically unpaved trails or paths	Some equipment may be able to distinguish bicyclists and pedestrians	Expensive/disruptive for installation under asphalt or concrete pavement
Seismic sensor	Short-term counts on unpaved trails	Equipment is hidden from view	Commercially available, off-the-shelf products for counting are limited
Radar sensor	Short-term or permanent counts Bicyclists and pedestrians combined	Capable of counting bicyclists in dedicated bike lanes or bikeways	Commercially available, off-the-shelf products for counting are limited
Video imaging – automated	Short-term or permanent counts Bicyclists and pedestrians separately	Potential accuracy in dense, high-traffic areas	Typically more expensive for exclusive installations Algorithm development still maturing
Infrared – active	Short-term or permanent counts Bicyclists and pedestrians combined	Relatively portable Low profile, unobtrusive appearance	Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detection technology Very difficult to use for bike lanes and shared lanes May have higher error with groups

Technology	Typical Applications	Strengths	Weaknesses
Infrared – passive	Short-term or permanent counts Bicyclists and pedestrians combined	Very portable with easy setup Low profile, unobtrusive appearance	Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detector Difficult to use for bike lanes and shared lanes, requires careful site selection and configuration May have higher error when ambient air temperature approaches body temperature range May have higher error with groups Direct sunlight on sensor may create false counts
Pneumatic tube	Short-term counts Bicyclists only	Relatively portable, low-cost May be possible to use existing motor vehicle counting technology and equipment	Capable of counting bicyclists only Tubes may pose hazard to trail users Greater risk of vandalism
Video imaging – manual Reduction	Short-term counts Bicyclists and pedestrians separately	Can be lower cost when existing video cameras are already installed	Limited to short-term use Manual video reduction is labor-intensive
Manual observer	Short-term counts Bicyclists and pedestrians separately	Very portable Can be used for automated equipment validation	Expensive and possibly inaccurate for longer duration counts

Other Peer-Reviewed Research

Estimating Annual Average Daily Bicyclists: Error and Accuracy

Using bicycle counts from Boulder, CO, Krista Nordback et al. looked at the errors expected from various short-term bicycle counting scenarios to estimate annual average daily bicyclists (AADB). Often manual bicycle counting programs have been established that count cyclists for a few hours per year at each designated location, but the timing and frequency of the counts required to obtain a reliable estimate of AADB was unknown. AADB average estimation errors were found to range from 15% with four weeks of continuous count data to 54% when only one hour is counted per year. The study found that the most cost-effective duration for short-term bicycle counts is seven consecutive days when using automated counting devices such as a tube counter specifically calibrated to detect the presence of bicycles. Seasons with higher bicycle volumes were found to have less variation in bicycle counts and yielded more accurate estimates; therefore, short term counts should be conducted in seasons when variability is the lowest. For counts less than seven days of consecutive hourly count data, the study found it was difficult to understand the weekly travel pattern, and average absolute error is higher *(8)*.

Estimation of Annual Average Daily Bicycle Traffic Using Adjustment Factors

Using a full-year of daily bicycle volume data from twelve permanent count stations in the City of Vancouver, Canada from 2010, this study investigates the estimation accuracy of annual average daily bicycle (AADB) traffic volumes when using both daily and monthly adjustment factors. The study recommends that monthly factors be used to develop AADT as opposed to seasonal factors because they showed higher accuracy. It further indicates that factors calculated by straight average method are more accurate than factors computed through the harmonic mean method. The study also shows that factors are most accurate when applied to the volume data that is of the same year as the factor development data (i.e., factors derived from 2015 data should be applied to 2015 volumes) *(9)*.

Institutionalizing Bicycle and Pedestrian Monitoring Programs in Three States: Progress and Challenges

The paper summarizes lessons learned and identifies challenges state DOTs face in institutionalizing non-motorized traffic monitoring programs. Agency protocols for data collection, analysis, and management, including development of factors for purposes such as estimating average daily bicyclists or bicycle miles traveled are compared *(10)*. **Table 3** shows the states that are establishing non-motorized traffic monitoring programs adapted from this report to include North Carolina in the summary statistics.

This study illustrates that the key policy questions each state DOT faces is whether to initiate a comprehensive program that includes both continuous and short-duration counts designed to inform estimates of AADT and miles traveled on travel networks. Considerations such as the development of procedures or protocols for QA/QC, determination of factor groups, or application of factors stem from this decision. The Colorado, Oregon, and Minnesota DOTs are at the forefront of national non-motorized traffic monitoring, and each has answered this key question differently *(10)*.

Table 3. Comparison of States Establishing Non-Motorized Traffic Monitoring Programs

State	Area (Sq. Miles)	Pop. Est 2010	Bicycle Commute Share (2012 ACS)	Functional System Road Miles (2009 FHWA)	Annual Avg. Temp.
Minnesota	79,000	5.3 M	0.8%	137,000	41.2
Colorado	104,000	5 M	1.3%	88,000	45.1
Oregon	96,000	3.8 M	2.4%	59,000	48.4
North Carolina	48,000	9.5 M	0.2%	105,000	59.0

Day-of-Year Scaling Factors and Design Considerations for Nonmotorized Traffic Monitoring Programs

Unlike vehicular traffic, bicycle and pedestrian volumes are significantly influenced by weather. Steve Hankey et al. concluded day-of-year scaling factors for short duration counts had smaller error rates when computing non-motorized AADT as compared to day-of-week and month-of-year scaling factors *(11)*. Day-of-year factors are a collection of 365 factors which can be applied only for a specific year and in a specific region. This is because the factor accounts for events such as weather or holidays which are not captured when data are averaged over many weeks or months. Like day-of-week or month-of-year scaling factors, the day-of-year scaling factors are generated from multiple continuous count stations within a specific factor group. The difference in extrapolation error between the two methods increases as the duration of the count decreases, with significant difference for counts fewer than seven days. Counts taken on consecutive days save human resources but provide only marginally more accurate AADT estimates as compared to counts taking over the same number of days but nonconsecutively. The study also found that the acceptable error, equipment availability, and monitoring period duration all dictate the design of a monitoring program *(11)*.

The Association of Natural Elements and Trail Use by Adults

A study published by the Centers for Disease Control and Prevention (2012) examines the association between variations in natural elements on an urban rail-trail in South Carolina. The Mary Black Rail Trail connects the downtown business district of Spartanburg, SC to more rural areas, passing through diverse socioeconomic and demographic contexts. From Fall 2006 through Spring 2009, manual observations of adult travelers were made at ten-minute increments in the morning, at noon, and in the afternoon and in the evening at six access points on the trail using the 7-day version of the System for Observing Play and Recreation in Communities (SOPARC). The study documents describe how use of the shared use path is affected by seasons, weather, and temperature *(12)*.

Neighborhood Correlates of Urban Trail Use

In their 2006 study, Lindsey et al. illustrate weekday and weekend use by presenting daily traffic organized by day of week on the Monon Trail in Indiana, using data that were continuously collected from infrared sensors. They also provide evidence of variation in monthly and hourly traffic on four trail segments in Indianapolis, IN *(13)*.

Estimating Urban Trail Traffic: Methods for Existing and Proposed Trails

Using data from trails in Indianapolis, IN collected with infrared technology, Lindsey et al. (2007) present ratios that describe variations in traffic by month, day of week, and time of day. The study expands on previous research to estimate traffic on existing shared use paths using samples and monthly non-motorized traffic ratios for 30 locations across five shared use paths in Indianapolis. The study presents a regression model for estimating trail volumes that includes land use and weather variables *(14)*.

The Association of Trail Use with Weather-Related Factors on an Urban Greenway

In their 2012 study, Burchfield et al. conducted continuous counts using an infrared counter on the Third Creek Greenway in Knoxville, Tennessee for a period of nine months from August 2005 to April 2006. The 4.5-mile long greenway runs along Third Creek, connecting neighborhoods and parks in Knoxville. Weather related factors were documented, including temperature, humidity, and precipitation. Hourly weather-related measures explained nearly half (42%) of the variance in trail counts, while nearly one-fifth (18%) of the variance was explained by temperature alone. The study recommends considering the influence of the hour of day, day of week, air quality, and month of year when measuring physical activity on trails across time and seasons *(15)*.

Temporal and Weather Impacts on Bicycle Volumes

A report published by the Transportation Research Board (2011) analyzes five years of continuous count data at two permanent bicycle count locations on shared-use paths in Boulder, Colorado. The analysis demonstrates the effects of temperature and rain on user activity and indicates a decrease in counts at approximately 90 degrees Fahrenheit. In addition, higher weekday counts were found at three of the four stations. Tuesday had the highest average count, indicating that the locations where data were collected are possibly more commute-oriented paths *(16)*.

Assessing the Impact of Weather and Season on Pedestrian Traffic Volumes

In a report published by the Transportation Research Board (2009), Aultman-Hall et al. provide an analysis of twelve months of automated pedestrian counts from a single downtown sidewalk location in Montpelier, Vermont in regards to weather data to determine effects on count variability. They found that precipitation and season impact pedestrian levels even when controlling for time of day and day of week, but other unmeasured factors appear to account for a greater portion of the variability in the count volumes *(17)*.

Exploring Your Own Backyard: Measurement of Greenway Use in Cary, North Carolina

Another study published by the Transportation Research Board (2011) investigates pedestrian and bicyclist activity on greenways in Cary, North Carolina. The study found that temperature had a significant effect on non-motorized volume, while time period (during the weekend) did not *(18)*.

A Methodology to Characterize Ideal Short-Term Counting Conditions and Improve AADT Estimation Accuracy Using a Regression-Based Correcting Function

Figliozzi et al. propose a methodology that will enhance existing AADT estimation methods widely employed for motorized vehicle counts. The proposed methodology is based on the analysis of AADT estimation errors using regression models to estimate a correcting function that accounts for weather and activity factors. The methodology can be applied to any type of traffic with high volume variability. The correcting function is a function of the characteristics of the day of the count (and previous days if there are lagged variables) and includes not only weather variables (e.g., rain and temperature), but also activity or usage-based variables (e.g., holiday or school day) without adding new factors *(19)*.

Figliozzi et al. further show that three-day counts outperform counts conducted for durations of five, seven, and ten days for use in AADT estimation. They found that the estimation accuracy of three-day counts results from the exclusion of weekends and the presence of more stable high-volume days in the middle of the week. This finding is potentially significant for use in the design of cost-effective sampling strategies in areas where traffic is predominantly utilitarian (for the purpose of commuting). Future research efforts are needed to validate this finding across different urban areas *(19)*.

Existing Regional and State Program Examples

Delaware Valley Regional Planning Commission Travel Monitoring Program

The Delaware Valley RPC is the federally designated Metropolitan Planning Organization for the Philadelphia region. Travel data is collected and processed through a program developed by the DVRPC for both motorized and non-motorized modes. The data provides input to VMT forecasting, the Traffic Monitoring System (TMS), the Congestion Management System (CMS), travel simulation models, individual project level analysis as well as traffic monitoring and trend analysis *(20)*.

A map-based user interface provides public access to the bicycle and pedestrian counts collected using automated counter technologies in the greater Philadelphia region. Approximately seven days of consecutive hourly short-duration count data is available for each location and a summary is available by clicking on a Bicycle Count or Pedestrian Count location. This data can be accessed through a web viewer that is separate from the motor vehicle counts. The data can be downloaded from the site (see **Figure 2** of an example.) The site provides ADB (Annual Daily Bicycle) and ADP (Annual Daily Pedestrian) travel statistics *(20)*.

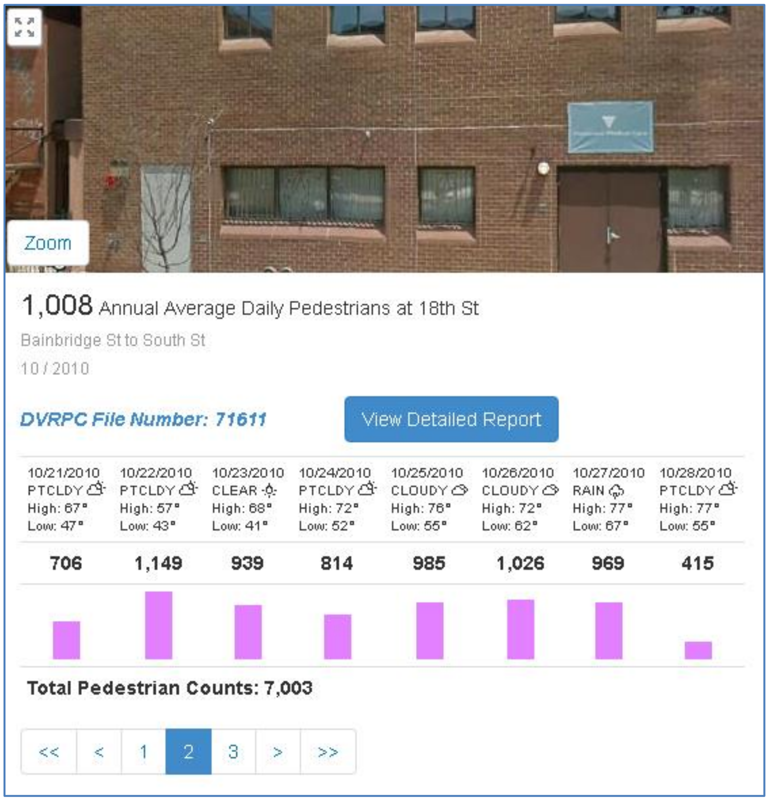

Figure 2. Example of pedestrian travel monitoring statistics from Delaware Valley Regional Planning Commission web viewer

The DVRPC currently employs infrared technology and pneumatic tube counters for collecting the short duration counts for pedestrians and bicyclists, respectively. There are also permanent locations for collecting continuous bicycle counts. The DVRPC uses volunteers from a local bicycle advocacy group to assist with calibrating the counters.

Arlington, Virginia Bike Pedestrian Automatic Count Technology Program

Arlington has been collecting bicycle and pedestrian counts at permanent locations since the first counter was installed in 2009. Counters came online gradually through 2012. The program employs a mix of Eco-Counter technologies and “double diamond” loop detectors that capture non-motorized volume activity on shared-use paths and bicycle lanes. Some counters do not include direction of travel; others cannot distinguish between bicyclists and pedestrians. One of the units is a MetroCount product which counts bicyclists only. The counters capture data that illustrates the effects of weather and seasonal variation on non-motorized travel. The data has shown that a single rainy day can discourage up to 75% of comminuting cyclists and that there is no significant drop in shared-use path usage during the hot humid summer months. Baseline patterns have been established (i.e., normal use) against which changes are detected and measured. Volunteer observations are conducted in the field to validate the machine counts *(21)*.

The raw data through May of 2013 is displayed through an online dashboard which was still under development as of January 2014. The user can select several parameters such as mode of transportation, weather factors, or day(s) of the week. The data can be exported to an Excel file and is also available to developers *(21)*.

Minnesota Bicycle and Pedestrian Counting Initiative

Greg Lindsey at the University of Minnesota began working on a project sponsored by the Minnesota Department of Transportation in 2011 to “define a consistent approach to integrating methodologies for measuring bicycle and pedestrian traffic on on-street and off-street facilities in Minnesota.” A pilot of manual field counts was conducted in 43 municipalities. Continuous count stations in Minneapolis were set up using six active infrared detectors (bicyclists, pedestrians, and mixed mode) and three inductive loops (bicyclists). The counters detect volume that can then be analyzed and summarized to measure and illustrate variability in bicycle and pedestrian volumes. These volume counts were used to calculate adjustment factors for applying to and calculating short duration annualized daily count statistics. An analysis of the automated, continuous non-motorized volume counts in Minneapolis was performed to calculate factors that help to develop annual average daily bicyclists, pedestrians, or mixed-mode volume statistics. Similar to the motorized traffic vehicle miles traveled (VMT) statistic, an estimate of annual non-motorized trail miles traveled was also performed by multiplying the volume estimates by the segment length. The estimate was based on a sample of only six hours and did not distinguish between bicyclists and pedestrians. Outcomes of the project include documenting the next steps to establish a network of permanent, automated continuous counting stations across the state to develop the data necessary to factor and calculate annualized short- duration counts, and to begin integrating non-motorized volume counts into new databases for vehicular traffic monitoring data *(22)*.

Colorado’s Statewide Bicycle and Pedestrian Count Project and Program

Colorado DOT (CDOT) worked with researchers at the University of Colorado-Denver to establish Colorado-specific methodologies for calculating bicycle and pedestrian volumes and patterns via a limited sample of existing counts (See Estimating Annual Average Daily Bicyclists: Error and Accuracy above). A grant was used to begin the program in 2010 with six permanent counting stations. Five mobile counters are also included in the program. CDOT has worked to create a Bicycle and Pedestrian Data Warehouse for the count location and volume data storage and is in the process of creating a data portal to access the data online. Local partners submit data in a variety of formats and CDOT is responsible for translating the data into a database software system which has been altered for bicycle and pedestrian counts *(23)*.

Oregon’s Statewide Bicycle and Pedestrian Data Collection System

A pilot study was conducted in 2014 by Portland State University to provide guidance to the State of Oregon as it seeks to develop a statewide data collection system for bicycle and pedestrian data. Currently, the Portland Bureau of Transportation conducts regular bicycle counts at locations throughout Portland, including the city’s four major bicycle-friendly bridges. However, a statewide initiative has not yet been fully implemented *(10)*.

Los Angeles County Bike Count Data Clearinghouse

The Los Angeles County Bike Count Data Clearinghouse is an online database for bicycle count data collected throughout the Southern California Association for Governments (SCAG) region, including Los Angeles County. Local agencies in the SCAG region can upload, download, and map data through the clearinghouse website, as well as access a bicycle count training manual, recommended count forms, and additional resources. The project began in 2012 and is co-sponsored by SCAG and the Los Angeles County Metropolitan Transportation Authority *(24)*.

San Diego Regional Bike and Pedestrian Counter Network

The San Diego Regional Bike and Pedestrian Counter Network began in 2012 as a grant-funded project through the Centers for Disease Control and Prevention in collaboration with the San Diego Association of Governments (SANDAG), San Diego State University, and the County of San Diego Health and Human Services Agency. The counter network consists of 54 counters installed at 37 sites across 15 jurisdictions in the San Diego region, making it one of the largest non-motorized counting programs in the country. The program uses Eco-Counter technology to measure pedestrians-only, bicycles-only, and mixed traffic. Data from 2012 to present is publicly accessible through Eco-Counter's Eco-Public web portal which provides basic data analysis and mapping for all their count locations *(25)*.

Chapter 3. Bicycle and Pedestrian Count Activities in North Carolina

A summary of the state of the practice of bicycle and pedestrian count collection activities within North Carolina was conducted at the beginning of the Pilot project in 2014 to inform the types of local data collection processes currently being undertaken both regionally and on a statewide level, to provide a synopsis of the technologies and methods currently being deployed, and to assist in identifying future training needs. Understanding current and planned count activities in the state sheds light on potential opportunities or barriers for NCDOT as it establishes and builds a non-motorized travel monitoring program.

Local Agency Non-Motorized Count Activities

In late 2013, ITRE surveyed agencies across the state known to have conducted bicycle and pedestrian counts based on knowledge from the project team as well as input from the steering and implementation committee. To gain a more comprehensive picture, an email was sent out to all Metropolitan Planning Organizations (MPOs) and Rural Planning Organizations (RPOs) requesting any contacts or information on known non-motorized count activity in their region. Although the list may not be exhaustive, a summary of the known counts conducted by agencies within North Carolina is given in **Appendix A**. A total of 17 agencies are known to have conducted counts in the past, are currently conducting counts, or have purchased equipment to begin a counting program. Phone interviews were conducted with each agency. The findings from these interviews are provided here to demonstrate the current state of the practice of non-motorized count activities in North Carolina.

According to survey and interview responses, the vast majority of bicycle and pedestrian counts occurring in North Carolina were either project-specific short-duration counts completed on an as-needed basis or as part of peak-hour intersection counts as an "add-on" when collecting data to study motorized vehicle turning movement volumes. These counts were typically collected from two to twelve hours (reported in 15-minute increments) and either done manually or through video recording contracts with a vendor. Outsourcing data collection activities was typical for agencies seeking motor vehicle turning movement counts, and some agencies in NC requested the non-motorized volumes for an additional fee.

Volunteer efforts or university assisted manual counts were also common among these agencies for one-time or project-specific data needs. Some of these programs were relatively well established. For example, Asheville and Cary have organized and sustained large-scale multi-year volunteer count programs of their greenway systems. The Durham-Chapel Hill-Carrboro (DCHC) MPO employed a standalone intersection count program which has been operating for over 10 years and developed the most thorough data collection protocol discovered in North Carolina. While the DCHC MPO used their count data to produce Mobility Report Cards for Chapel Hill and Carrboro, limitations in the usefulness of the data collected by all agencies within the state were identified due to the current count methods being employed.

Count programs with the most potential to complement or supplement data that may be collected through NCDOT's non-motorized traffic data collection program are those from agencies that have access to or that employ equipment that allows for short-duration counts for a minimum of seven consecutive days, 24 hours a day, with maximum intervals of one-hour time periods. While a handful of agencies surveyed had equipment that could be utilized in this manner, none were currently conducting short duration counts long enough to allow for variability analyses in the data collected. At the time of the survey, permanently installed infrared counters were only known to exist on trails in Greensboro, North Carolina.

The City of Greensboro Parks and Recreation Department has been performing counts using infrared equipment on their trail system since 2008. The agency had seven infrared TRAFx counters that were continuously counting users on the trail. The counters did not distinguish between bicycle and pedestrian modes or direction of travel and the agency had not checked the quality of the data collected through this count technology, nor developed correction factors for stations that may consistently over- or undercount.

The City of Winston Salem began a bicycling count program with five hand-built devices created by connecting pneumatic tubes to a programmed Arduino board at a very low cost. The device was tested and calibrated and was ready for deployment in January 2014. Although the agency intended to conduct twelve-hour counts due to the concerns for vandalism or theft, there is potential for the devices to be left out for longer periods of time. The pneumatic devices require manual data uploads and may require special monitoring but may be able to provide bicycle-specific data for non-motorized traffic monitoring.

The two agencies employing infrared sensors and/or inductive loop count technology offered through Eco-Counter were in the process of beginning to conduct counts at the time of interview, and neither had a well-developed count program.

Many of these agencies were still in the beginning stages of testing equipment and assessing staffing needs for rotation of mobile equipment in the field. Some agencies surveyed had ordered counters but were still waiting to receive them. For example, the Town of Cary budgeted for and planned to order three automated counters (two of which will have the capability of distinguishing between bicyclists and pedestrians). The Gaston Cleveland Lincoln MPO also ordered three counters which were to arrive in January 2014. Though these agencies would have the most automated equipment assets in NC, they had not developed implementation methods (such as developing site selection criteria, standardized site selection steps while on-site, storing data in integrated formats, etc.) for how they would be employed. Additional count program protocols might be developed from these agencies as the technology is tested and implemented and as procedures for using the technology matures.

As of early 2014, the Land of Sky Regional Council employed an infrared counter in conjunction with a pneumatic tube and was interested in the findings of this project to guide the use of their equipment through a more formalized protocol. The Capital Area MPO had started collecting seven days of consecutive count data but their equipment did not have the capability to distinguish bicyclists from pedestrians.

Several of the agencies that had or were planning to order automated equipment indicated that they could benefit from training to educate staff and learn more about developing a bicycle and pedestrian count program for their area.

Existing NCDOT Activities

NCDOT Transportation Mobility and Safety is a data supplier to other NCDOT unit customers requesting traffic data. This division contracts with 13 different vendors to collect various types of data. Data contracted out to obtain information on non-motorized users in the past includes turning movement counts, pedestrian crossing corridor studies, and site-specific evaluations of traffic control devices such as a Pedestrian Hybrid Beacon (PHB). The duration and protocol for the counts depends solely on the customer requesting the data and is flexible depending on the needs of the requester. Divisions and other units within NCDOT can work with Transportation Mobility and Safety on their program-specific data collection needs. It should be noted that bicycle and pedestrian data to-date has not been provided in a searchable or database-friendly format.

Research Projects and University-Based Activities in NC

In addition to these efforts, five known projects have been conducted in North Carolina that included non-motorized counting through research or classroom-based efforts at state universities (See **Table 4**). None of the counts conducted were either of long enough duration or current enough to complement the project. It is expected that there are additional counts conducted through universities as a part of coursework not included in this list. These studies were all conducted on an individual shared use path or greenway system.

Table 4. List of Research Through Which Non-Motorized Count Data Were Collected in NC

Research Project / Paper Title	Lead / Author	University / Center	Date	Location / Trail / Area Studied	Count Sensor Technology Used
A Tale of Two Trails: Exploring Different Paths to Success	Walker	Citadel	2007	American Tobacco Trail	Infrared
Behavioral Effects of Completing a Critical Link in the American Tobacco Trail	Cook	ITRE	2013, 2014	American Tobacco Trail	Manual
Economic Impact Assessment	Worthington	Research Fellowship	2013	Carolina Thread Trail	Manual
Exploring Your Own Backyard: Measurement of Greenway Use in Cary, North Carolina	Bush	N/A	2011	Cary Greenway System	Manual
What's on Your Greenway? People & Nature on Raleigh's Greenway System	Hess	NCSU	2014-2016	Raleigh Greenway System	Motion camera

Chapter 4. Establishing Count Stations

The NC NMVDP will ultimately have two primary count programs within it: a continuous count program that manages the permanently installed equipment and data collected from these sites, and a short duration count program to expand the geographic coverage of the NC NMVDP and possibly manage future temporary counts conducted for project study needs. Regardless of which type of count, the location where a count is conducted is called a “station.” Stations may be comprised of multiple sites where equipment is installed to fully capture the screenline count of a given location. For example, to capture pedestrian activity on sidewalk on both sides of a street, two separate counters may be installed. Each counter is considered a “site” that comprises the pedestrian count station for that segment of the street.

Chapter 4 lays out the general process involved for establishing a count station, regardless of whether permanent or mobile count equipment is used to collect volume data at the station. Chapter 5 further explains how CCSs were handled, while Chapter 6 explains details of the SDC stations.

Local Agency Coordination

For the program to be successful and sustainable, a great degree of agency coordination is required to install, monitor, and maintain Continuous Count Stations (CCSs). Training for agencies, installation coordination, agreements to define equipment responsibilities, encroachment agreements, and maintenance requests are all elements of the NC NMVDP that require communication between agencies.

Site Selection Survey

To be included in the NC NMVDP, prospective partner agencies completed a survey developed and administered by ITRE that was distributed within the pilot region. The survey requested candidate sites for collecting bicycle and pedestrian counts. Contact was made with communities with populations of 5,000 persons or more in the target region in addition to agencies with regional jurisdictions such as Metropolitan Planning Organizations (MPOs) and Rural Planning Organizations (RPOs). An attempt was made to find the most appropriate contact(s) with knowledge of the area’s bicycle and pedestrian activities for these agencies. The survey gathered recommended site locations for pedestrian, bicycle, or shared use counting. Additional information could be entered on maintenance, volumes, user type, and a description about why the site was important to counting non-motorized users. Respondents could also report their willingness to participate in maintenance aspects. The results from this survey were used to kick off the Site Selection Process, described in more detail on page 4-3. Over 100 sites were submitted in Phase 1 of the NC NMVDP through the agency survey.

Volume Monitoring Training

For the NC NMVDP, ITRE offered a customized one-day workshop developed to give planners, engineers, and transportation professionals a solid foundation for being a part of the program and an introduction to traffic monitoring. The following topics were covered in the workshop:

- Introduction to the NC Program
- Bicycle/Pedestrian Volume Data Fundamentals
- Non-Motorized Counting Equipment and Installation
- Data Needs and Uses
- Site Selection Methods
- Data Management and Reporting

In addition to the in-class portion, participants also did field visits to examine potential counting sites and educate participants on how to make observations specific to the site selection process. See page 11-1 for more workshop details.

Agreement Execution

The NC NMVDP relies on relationships between entities for implementation. This section outlines the two types of agreements that were facilitated to establish definitions, responsibilities, or terms of ownership to the partnering organizations prior to the installation of count equipment.

Memorandum of Agreement

To give more definition to the responsibilities of each agency, Memorandums of Agreement (MOA) were initiated between the North Carolina Department of Transportation (NCDOT) and the local agency receiving count equipment. The MOA provides details related to equipment specifications, responsibilities, timeline for installation, maintenance, equipment access, and data. The research team helped facilitate local agency understanding of the provisions of the agreement and paid attention to key dates such as monthly Board of Transportation (BOT) meeting dates and agency committee dates to ensure timely execution. The following is the process for which MOAs are fully executed for agency participation in the NC NMVDP:

1) NCDOT initiates MOA and puts it on the BOT agenda.
2) The MOA is reviewed by the BOT.
3) The document is mailed to the local agency, signed by the responsible party, and returned to NCDOT.
4) The document is signed by NCDOT and fully executed.

Encroachment Agreement

Where necessary, an encroachment agreement was executed between the NCDOT division responsible for the roadway right of way where equipment was to be installed and the local agency to allow the local agency to install the counter equipment on a state-maintained road. Encroachment agreements were not necessary on city-maintained facilities.

For reference, a sample of each type of agreement between NCDOT and the local agency can be seen in Example Memorandum of Agreement used in Phase 1. Once the MOA has progressed to the latter stages of the execution pipeline and encroachment agreements were secured (where necessary), an installation date was scheduled.

Installation

ITRE scheduled meetings with each agency to bring together the correct stakeholders participating in the oversight, installation, and maintenance prior to site installation. Roles and responsibilities were explained regarding agreements, installation processes and each site is reviewed. An opportunity was given for discussion of pre-installation needs, installation techniques, or traffic control scenarios. This meeting allowed stakeholders an opportunity to ask questions, disclose concerns, and to meet with and begin the coordination with external departments for equipment installation. For more information on the specifics of scheduling and installing continuous count stations, see Chapter 5 – Continuous Count Sites.

Responsibilities for installation of the equipment fall to the local agency receiving the equipment, with technical assistance and quality assurance oversight from ITRE. ITRE provides facilitation assistance to meet project timelines due to their own contractual requirements with NCDOT and ensures that pre-installation, installation, and onboarding protocols are met. The responsibilities for the installation of count equipment in Phase 1 of the NC NMVDP are outlined in CCS Installation: Agency Roles and Responsibilities.

Maintenance

According to the MOA, maintenance responsibilities are shared during the first two years of the NC NMVDP. The agency takes care of routine maintenance while ITRE, as NCDOT's agent, is responsible for all non-routine maintenance. Routine maintenance includes battery replacement, removing obstructions or hazards on or near the equipment, and monitoring equipment security. Maintenance issues are discovered through both the QA/QC of data (see page 8-7) and equipment validation (see page 7-1) and could be the result of routine or non-routine events. ITRE investigates and coordinates maintenance, using the vendor as a sounding board to troubleshoot issues and determine how to proceed with maintenance requests and obtain replacement parts where necessary or covered by warranty during the first two years of the life of the equipment.

Site Selection Process

There are many steps to follow to strategically and optimally select Continuous Count Stations (CCSs) that will provide the most effective data collected and potentially used many times. Site selection steps include contacting agencies, developing site selection criteria, evaluating and prioritizing site selection recommendations, and conducting virtual and on-site audits. Numerous site-level considerations need to be analyzed such as whether a site should be a continuous or short-duration counting (SDC) location, whether a site can provide data that represents a factor group, whether a site provides the necessary geographic representation desired in the counting program, etc. This section documents the site selection methodology followed in Phase 1 to yield viable and effective data collection locations for the NC NMVDP. Different programs may have different goals, such as trying to target a specified subset of factor groupings, but ultimately a fully built out bicycle and pedestrian counting program that is representative of non-motorized travel across a geographic area will have sites that represent all factor groups for non-motorized travel. The NCDOT pilot project aimed to spread newly installed CCSs across a variety of site types to not over-saturate any factor group.

Background and General Approach

To select fruitful sites, one must have a sense of where bicyclists and pedestrians are to count them. It is reasonable, therefore, to begin with the existing bicycle and pedestrian facilities network to identify where active travelers may be. Given that the most comprehensive GIS dataset available on existing non-motorized facilities in North Carolina was for Divisions 7 and 9, this area was identified as the pilot region.

If all facilities had an equal demand and seasonality profile, it would suffice to observe one facility to infer what is happening on all other facilities. However, given that there are variations in bicycle and pedestrian demand, the next question to consider is how non-motorized travel varies in space and attempt to quantify that variation in order to develop a sampling plan across these variations (see Research Methods to Determine Baseline Data Needs for more details on this sampling plan). This approach is consistent with FHWA's *Traffic Monitoring Guide*, where factor groups are identified based on similar patterns of demand and seasonality. The recommendation (page 3-10 of the TMG) is to use local expertise, cluster analysis, or the volumes based on the HPMS functional classification to bin all facilities and develop a count location sampling plan. Divisions 7 and 9 lack reliable continuous pedestrian and/or bicycle count location so, as a result, the research team inferred current pedestrian and bicycle demand to identify the factor groups (or strata). These strata are groups of locations with relatively homogenous patterns of demand. Pedestrian and bicycle demand were examined separately at the census tract level.

Ultimately, this process resulted in the identification of census tracts within Divisions 7 and 9 where the variation in pedestrian and bicycle trips can be best explained. While calculations suggested a sample size of between seven and 28 tracts for walking and six and 28 tracts for cycling to ensure statistical rigor, cost constraints prohibited us from following the sampling plan as a criterion for the site selection process. Selected sites are concentrated in these strata but were ultimately selected using the site-level characteristics, observations, and prioritization processes further described in this section below. This approach yielded the installation of twelve continuous count stations by the research team spread across the pilot region. An additional 22 locations were identified for short-duration counts. In the pilot region, the blue, teal, and light green shaded census tracts shown in **Figure 3** are where a higher sampling is needed to understand variability in walking and bicycling trips across the region.

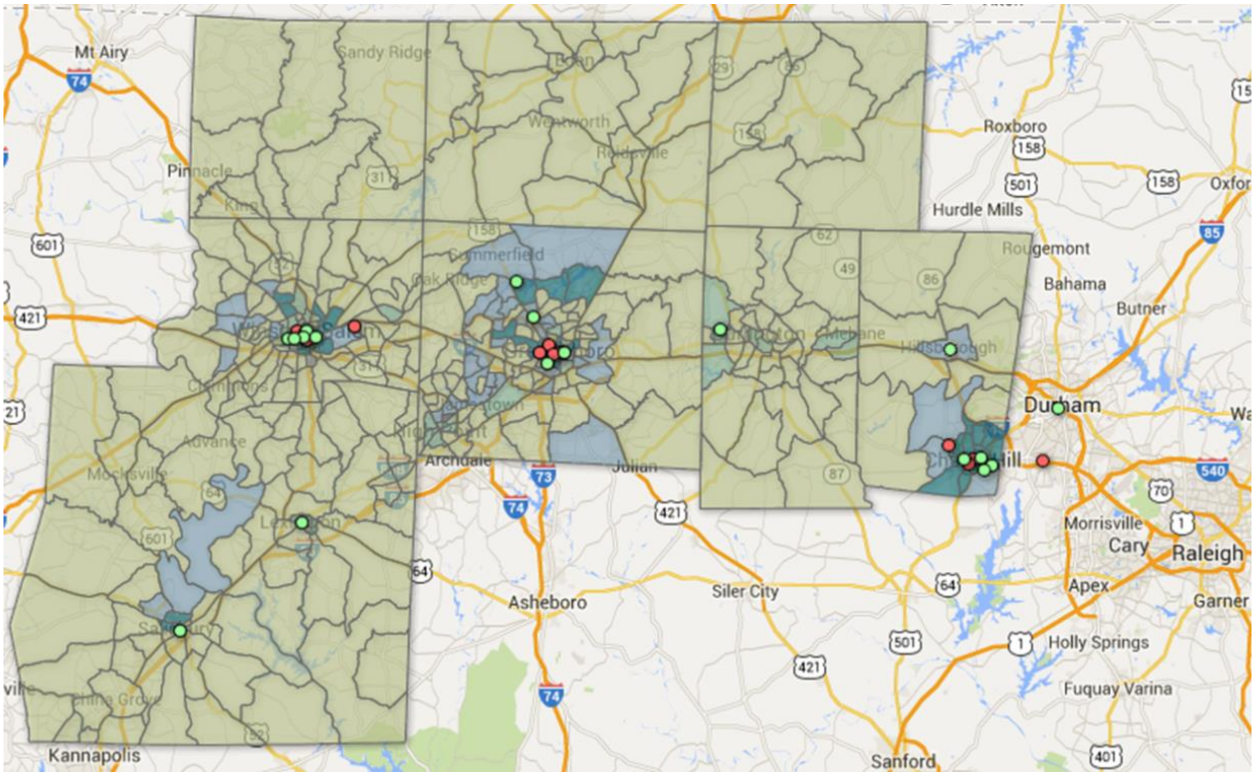

Figure 3. Locations of continuous count stations (red) and short duration count locations (green) selected for the NC NMVDP pilot

Site Selection Objectives

The site selection process developed and implemented in the Pilot region met the following objectives:

- Objective #1 – It complies with nationally accepted methods for calculating annualized traffic statistics, following the TMG to the extent possible based on feasibility and fiscal resources.
- Objective #2 – It is standardized and can be replicated by other agencies.
- Objective #3 – It founded a living document for iteratively prioritizing sites over time. This document maintains a consistent, transparent means by which new sites for consideration in the region may be added and ranked. This is important given the reality of fiscal constraints, which preclude NCDOT or a given local agency from counting at all the sites identified upfront.
- Objective #4 – Stakeholders are engaged early on in process, and partnerships are cultivated to ensure and encourage data sharing, encroachment access, and good stewardship of the equipment through coordinated installation and maintenance.
- Objective #5 – The process ensures data collected can serve a variety of purposes and optimizes the funds and resources NCDOT has for the region in terms of technologies and equipment used and data managed.

Site Selection Methodology

When evaluating and selecting sites for non-motorized data collection, it is critically important to understand the need for continuous counting stations. Lindsey defines the backbone of a continuous count program as a system of automated traffic recorders that are used to determine travel patterns by purpose (e.g., recreational, commute) and variability over time (hourly, daily, or seasonal) *(10)*. Ultimately these elements inform the development of daily and seasonal factors which are used to calculate annual volumes for counts of shorter durations. Continuous counts may be ideal at any station; however, it is not financially practical to install permanent equipment everywhere an agency may want to count bicyclists and pedestrians. While CCSs provide temporal coverage, short-duration count stations (SDCs) provide geospatial coverage.

The site selection process is used to determine locations for installing a CCS followed by efforts to identify other locations which are more appropriate for an SDC. Continuous count stations are permanent counting sites that provide counts 24 hours a day, 7 days a week, typically over an entire year.

The goal of the site selection effort is to create a prioritized list of recommended CCSs that results in a mix of sites across travel patterns, volume groups, and other factor group characteristics. For Phase 1, sites were also prioritized to utilize the sensor technology and equipment already identified and to pick sites where both bicycle and pedestrian type counts could be collected. The process was somewhat iterative, practical in nature, driven by budgetary restrictions, and took into consideration the local agency's and NCDOT's confidence and comfort with making a long-term investment. Locations for conducting SDC sites are a natural by-product of the CCS selection process and are discussed in more detail on page 12-1. **Table 5** shows the twelve CCSs recommended and ultimately installed for the pilot region spread across a variety of anticipated site types. Sites with higher rankings have a higher likelihood of representing discrete patterns and are preferred for installation over lower ranking sites given budgetary constraints. Note, for example, that stations ranked 1 through 4 are spread among the area types with differing anticipated patterns. Working through the site selection process provides a way to gather more information about each site prior to ordering or installing exact configurations of equipment. The information gathered was analyzed to posit what factor group(s) a given site may represent. The TMG recommends three to five CCSs per factor group, based on motor vehicle travel monitoring best practices. Due to funding constraints of this pilot program phase, no factor group was saturated.

Table 5. Continuous Count Stations Recommended by Site Type for NC NMVDP Pilot

Site Type		Site Type Example	Pilot Project Recommended Continuous Count Stations (Ranking)	Proposed Factor Group
Area Type	Travel Pattern Anticipated			
Urban	Commute	Urban sites with weekday volumes highest, primarily journey to work trips expected	W-S_4TH (1) GSO_ELM (9)	Urban Commute
	Recreation	Greenway trail or street/sidewalk network within city limits not generally used for commuting or other trip purposes. This pattern may be found around urban parks or bodies of water.	W-S_END (5) W-S_STR (7)	Urban Recreation
	Mixed	Urban site with varied trip purposes and volumes	GSO_WAL (3) GSO_LDG (8) DRH_ATT (12)	Urban Mixed
Rural	Commute	Large employer generating trips to work in rural area		Rural Commute
	Recreation	Greenway trail or rural bicycling/jogging route with primarily recreation-oriented users, weekend users. This pattern may be found around lakes or other natural attractions.	W-S_SLG (2)	Rural Recreation
	Mixed	Rural facility that receives both recreation and journey to work trips, such as a rail trail in a rural area that connects to employment centers in an urban area	CRB_OLD (10)	Rural Mixed
University	Commute	Facilities that primarily serve to connect student and staff residences to university areas	CHL_MLK (11)	University Commute
	Recreation	A location near campus that does not connect to destinations, such as a long distance walking or running loop.		University Recreation
	Mixed	A location adjacent to a university that captures a variety of trip purposes, such as a mixed use area or connector between university and downtown.	CRB_LCB (4) GSO_SPR (6)	University Mixed

The mix of sites recommended in Phase 1 was identified by implementing the following steps:

a. Gather Potential Site Locations
b. Conduct a Site Visit
c. Select CCS Sites
d. Select Short Duration Count Sites

Each of these methodological components is further explained below with details for how each was performed.

A. Gather Potential Site Locations

Step 1 – Assign a Data Wrangler and Contact Agencies

For the NC NMVDP, ITRE served as the data wrangler. In this capacity, the research team provides an avenue for outreach, communication, and coordination with local agencies within the state, and specifically within the pilot region for this Phase 1 of the project. The data wrangler works as a multiple-agency resource to coordinate, gather, and update the agencies on bicycle and pedestrian data collection activities. The data wrangler's responsibilities include but are not limited to: helping agencies coordinate schedules, resources (including equipment and staff), and installations; providing access to data; and developing regionally adopted data collection standards.

When contacting agencies who may wish to participate in the NC NMVDP, the following informational gathering techniques and tools are offered as examples that have been used:

- Analyze data from site locations where counts have been conducted in the past,
- Survey agencies within the geographic region for sites of interest (phone, electronic, in-person surveys),
- Discuss opportunities with the count program sponsor, and
- Investigate new count sites that arise during a site visit.

Step 2 – Develop a Tracking System

It was critical to develop a site tracking system from the very beginning of the site selection process. The spreadsheet system that has worked very well for the Colorado Department of Transportation (CDOT) and the Atlanta Regional Commission (ARC) was also used by the research team. This spreadsheet includes columns with headers that represent the selection criteria described in the next step.

The following fields are listed as either critical or valuable to the process of prioritizing potential sites, and the research team made every effort to obtain each of the below when investigating a candidate site:

Critical

- Ranking
- Site Location (coordinates make it easy to map the locations)
- Area Type (Urban, Suburban, Rural)
- Anticipated User Type (Mixed/Everyday, Recreation/Weekend, Commuter/Weekday)
- Install Type (Paved Path, Unpaved Path, Roadway, Bike Lane, Sidewalk)
- Type of Count (Bicycle, Pedestrian, Both)
- Ownership (Municipal, County, State)
- Duration (Short, Continuous)
- Notes from Virtual Site Audit
- Volume Potential (High, Medium, Low)

Valuable

- Existing Count Data (where available) or Estimate of Hourly Volume
- Number of Lanes
- Sidewalks (One Side, Two Sides, None)
- Agency Submitting Location
- Local Contact Information
- Notes from Agency

Step 3 – Develop, Evaluate, and Update Site Selection Criteria

This step creates a foundation upon which all sites are compared. The results of completing this step provide an objective way to prioritize and select sites for collecting data. Establishing site selection criteria is a dynamic process and is subject to change over time with new technology, staff, and regional agency priorities or policies.

The site selection criteria used in the Pilot region provided a way to regionally evaluate and prioritize requests for bicycle and pedestrian volume data. The criteria listed below are not meant to be all-encompassing, but they provide general guidance for identifying sites suitable for monitoring bicycling and pedestrian traffic:

- **Location** - Location should be within a defined area. In Phase 1, this was represented by the pilot region, and specifically the census tracts identified through our sampling plan (see page B-1).
- **Duration** - Sites should include prospective continuous count sites as well as those that may fill short-duration count needs.
- **Factor Group Designation** - Sites should include a relatively even distribution of factor groups. **Table 5** provides the proposed factor groups used for this pilot project.
- **Equipment Feasibility** - Sites must have appropriate conditions to count bicyclists and pedestrians at the same station using infrared sensors and inductive loop sensor technology, to optimize the number of units of equipment to be procured.

Step 4 - Evaluate and Prioritize Recommendations

Evaluating and prioritizing recommended sites should begin with conducting virtual site audits using GIS-based mapping software, internet tools (e.g., Google Maps, Google Street View, Google Earth), or crowdsourced GPS Data (e.g., heat map/aggregate application data from Strava, Garmin, or MapMyRide). This is done prior to in-person site visits to ensure that staff resources are used efficiently. The research team conducted a virtual site audit to filter all recommended sites into an initial ranking order that was prioritized according to a number of different variables such as factor group, geographic area type, anticipated travel pattern, etc. To conduct a virtual site audit in Phase 1, we used Google Maps, and Google Street View to inspect the site locations recorded in the site selection tracking system outlined in Step 2. During the visual inspection of the site, the following features were documented in the tracking system:

- Is the site near any bodies of water?
- Is the site near bicycle or pedestrian generators such as a hospital, transit station, events center, grocery store, or shopping mall?
- Is the site on a roadway or trail? Note the surface condition.
- Are pedestrians/bicyclists present? Note any observations.
- Is the site near overhead power lines that may cause interference? (if considering bicycle loop detection)

We then ranked sites according to the selection criteria. The resultant recommendations in the tracking spreadsheet were used to drive the next steps in the site selection process.

B. Conduct a Site Visit

Conducting a site visit helps to further refine and prioritize recommended sites for those which should be a CCS versus a SDC site. Not every site on the list remained, and new sites were added based on local knowledge received during the site visit. Equipment to have on hand during the site visit is outlined below. In some cases, it was not necessary to make more detailed site observations (Step 5) or spend extra time on-site conducting testing for interference (Step 6) for sites that were not appropriate for CCS or SDC data collection.

Site Visit Equipment Checklist

- **List of Sites and Contacts:** Prioritized list of sites to visit, broken down by geography to minimize travel time between sites. Include local and/or regional contacts to meet at each site.
- **Local Maps or Data:** Maps are helpful in orienting to a site and searching for adjacent sites when necessary. GPS Application Data, local bicycling routes, and any previously collected count data can also be useful while on site. Load maps and/or data on a smart phone or laptop that can be accessed in the field.
- **Safety Vest:** Worn when working in the roadway right-of-way.
- **Camera:** Used for taking site specific photos, especially to reorient to site locations during prioritization of sites and installation. Photograph any relevant bicycle or pedestrian behaviors or observations (i.e., bicycle placement in travel lane, goat trails/desire lines from pedestrians,

transit stop placement). Photos are referenced when creating equipment orders and to discuss installations with contractors and agencies.

- **Interference tester:** Used to determine interference from overhead or buried utilities at locations where loops will be installed. Photograph and document the specific site location where the interference testing is conducted for reference.
- **Tape measure:** Used to measure the width of the path or street to determine equipment needs (i.e., configuration and number of loops or approximate cone of detection).

Step 1 – Notify Local Contacts

Before visiting a potential site, arrange to meet the local contacts, if possible. Local knowledge is invaluable in assessing sites and a large amount of knowledge transfer and stakeholder buy-in can occur during the site visit. This contact can also be a point person through the process of developing the site into a CCS.

In most cases, the pilot region contacts had a background in planning or public works. We also worked with agency Bicycle and Pedestrian Coordinators or parks and recreation staff, depending on the site location. We ensured that local contacts understood the NMDVP's goals, highlighted the agencies' responsibilities should a site be selected in their jurisdiction, and pointed out that the site visit was a step in the process but did not guarantee the installation of a CCS.

Step 2 – Review Site Recommendations Ranking and Develop Site Visit Schedules

Based on the site tracking spreadsheet, the team developed a site visit schedule from the highest ranked sites to the lowest ranked sites in the spreadsheet. This schedule considered drive/walk/bike times to each location and whether local agency contacts would be met on-site. The site visit schedule and site locations changed when meeting with local stakeholders since some agencies did not have a full comprehension of the site selection process or larger picture of a non-motorized count program. This initial meeting represented a significant learning curve, and changes occurred due to agencies' better understanding of program goals.

Step 3 – Determine Baseline Activity Levels and Evaluate Site Conditions

Once on-site, the team evaluated conditions and baseline activity levels. If the site had no bicycle and/or pedestrian activity during the site visit and there was no evidence to substantiate activity may occur at other time periods at the site, we noted that further investigation would be needed before investing in it as a CCS and its ranking was subsequently lowered. Some observations of activity at the site increased its ranking such as a diversity of users from differing perceived socioeconomic status to a diversity of bicyclist types.

Step 4 – Look at Origins and Destinations

Finding where trips begin and end can help to determine the anticipated pattern (e.g., Recreational, Commuting, or Mixed) for assigning a factor group. Even general observations such as bicyclists wearing backpacks or having saddle bags, the type of bicycle utilized, or the clothing type are good indications of traveler type. Making such observations of environment or users helps locate specifically where equipment should be placed to capture these trips. The team looked for downtown business districts, hospitals, transit stops, major employers, universities, public recreation lands, and bodies of water as examples of non-motorized travel generators. The research team ultimately looked for sites to populate all factor groups with an emphasis on finding sites uniquely qualified to capture those patterns.

Step 5 – Make Additional Site Observations

Additional observations of bicyclists and pedestrians and the surrounding environmental conditions were noted in the tracking spreadsheet to keep track of potential issues and opportunities that cannot be ascertained from the virtual audit.

For some sites, specific factors that would make it a complicated install such as proximity to transit stops, no funneling point, etc. meant that the team either refined the site location (i.e., moved up, down, or over a block), or dropped the site lower in rank. A list, while not exhaustive, is provided in **Table 6** below and includes the type of observations that ultimately increase (+) or decrease (-) a site's viability or ease in counting, based on the technology expectation of using infrared sensors to count pedestrians and inductive loop sensors to count bicyclists:

Table 6. Examples of Site Visit Observations and Site-Specific Factors That Affect Site Ranking

Pedestrian		Bicycle	
Poles and Bollards	(+) Assists with funneling (+) Attachment surface (-) May be an obstacle or change behavior	**Parallel Parked Vehicles**	(+) Assists with funneling (-) Cause avoidance behavior (-) Low parking utilization may make it difficult to predict bicyclist travel path
Landscape Buffer	(+) Block sensor's cone of detection (+) Assist with funneling	**Bike Lane**	(+) Assist with predictability of travel path
		Turning Lanes	(-) Decrease predictability of travel path (-) Limits placement of loop detectors
Transit Stop	(-) Changes in pedestrian behaviors, especially street crossing (+) Increased pedestrian activity		
		Bike Parking Areas	(-) Changes in bicyclist behavior to access parking
Sidewalk One Side	(+) May assist with funneling	**Sidewalk Riding**	(+) May represent differing age groups (-) Difficult or more costly to place detectors in sidewalk
Goat Paths	(+) Indication of travel path		
Walls	(+) Block sensor's cone of detection	**Interference**	(-) Increase chances for loop detector error
Outdoor Seating Areas	(-) May increase chances for sensor errors, detection of milling pedestrian causes false counts	**Vehicles Queuing in Roadway**	(-) Decrease predictability of travel behavior, especially in short links between closely space signals
Windows	(-) Infrared sensor may pick up thermal glare	**Steep Hills and Curves**	(-) Decrease predictability of travel behavior
Bridges and Underpasses	(+) Assists with funneling	**Bridges and Underpasses**	(+) Assists with funneling

Step 6 – Testing for Interference

Given that NCDOT planned to use inductive loop technology to count bicyclists, it was critical to test for interference from sources that may affect the accuracy of the equipment such as underground utilities or overhead power lines. An inductive loop tester linked to an actual loop made of coiled wire (configured in the shape of a diamond) was used to test electromagnetic interference from nearby objects – interference that could cause false counts with actual CCS installs. It should be noted that a small shift of a few feet can dramatically affect the amount of interference indicated by the testing unit.

We tested for interference in the general area where bicycle loops may be installed. These areas are defined by where bicycling activity was observed or known to occur. For instance, bicyclists may use bike lanes exclusively (if available), a portion or the entire width of a vehicle lane, or even sidewalks in certain areas. In addition to bicyclists travel paths, locating where inductive loops should be installed was also dependent on several supplemental factors, including: the available options for also locating a pedestrian detector at the same site (the loops must be installed within close proximity), channelization, and potential interference with nearby utilities or other metallic objects.

The predominant location for bicycle loop installation was in the roadway or along shared use paths (both paved and unpaved); however, a few applications required us to consider bicycle detection along sidewalks. In general, less interference was acceptable for sites where bicyclists would be counted in the vehicle travel way. The primary reason for this is that the algorithm developed to distinguish between motor vehicles and bicycles is more complex; therefore, the sensitivity of the loop needs to be higher (and thus less interference can be tolerated). In contrast, the sensitivity of the loop can be tuned down on shared use paths or sidewalk, reducing the likelihood of nearby utilities inadvertently being counted.

Figure 4 provides a street-level view showing interference testing (A) and an aerial diagram (B) of recommended equipment placement at a station being considered for a CCS. Initial observations and discussions with locals indicate that pedestrians tend to funnel between an upstream bridge location and the nearby train depot driveway just downstream. Observations of bicyclist showed that many tend to use the road lanes outside of on-street parking, while some bicyclists were preferred to ride on the sidewalk. The diagram shows how pedestrian counters could be installed on both sidewalks in addition to the roadway. The sidewalk to the south had no obvious concerns for detecting pedestrians; however, the north sidewalk requires that the pedestrian detector oriented to face the office building. This will reduce false detection of vehicles or people moving in the adjacent parking lot. Based on observations of bicyclist lane positioning and on-street parking utilization, two loops per direction of travel are needed to capture bicyclists traveling in the roadway where bicyclists track through the site. This does not cover the full roadway but maximizes the placement of the equipment. Although this site ranked highly prior to a field visit, it was ultimately not chosen for continuous monitoring due to issues with interference from underground utilities.

Example Application of Site Visit and Recommendations for Detection Location

Initial tests using the interference tester indicated very little interference for loops on the north side of the roadway (westbound lanes and northern-most sidewalk); however, substantial interference was found on the south side (eastbound lanes and southern-most sidewalk) where it was believed that underground utilities are located. The team tested interference at several locations along the eastbound approach, finding that the interference adjacent to the train depot driveway was acceptable for the roadway and sidewalk. Therefore, recommendations were made to install loops along this approach as close to the driveway as possible while mitigating potential for conflict from right turning buses. The team recommended installing the bike loops as close as possible (but staying within the acceptable distance to the pedestrian detector) to the other bike detectors to reduce the risk of double-counting bicycles that cross the street between the two units.

Figure 4. Example of aerial view showing interference testing at a site under consideration for a continuous count station (A) and aerial diagram showing recommended placement of bicycle and pedestrian equipment at a continuous count station (B)

C. Select Continuous Count Stations

Based on the information gathered from discussions with the local contacts, observed or recorded baseline activity levels, and the origins and destination information, sites were re-evaluated and assigned as a CCS or SDC in the tracking spreadsheet. Due to their longevity, data from CCSs provide opportunities to analyze additional elements important to the NC NMVDP. For example, a site may be able to satisfy one or more of the conditions listed below while still maintaining representation of a factor group.

The following are additional site selection considerations discussed with the local agency that elevated a site's ranking:

- **Before and After Count Location** – A suitable location where obtaining "before and after" counts are possible. A location where a proposed bicycle and/or pedestrian improvement is already funded such as a new bicycle/pedestrian bridge, segment linking two greenway trails, road diet, or other "Complete Streets" improvement.
- **Choke Points** – A natural funneling point such as a bridge, tunnel, or overpass. This location could be for bicycle and pedestrians only, or an on-street location where bicyclists and pedestrians are channeled to get across a waterway, railroad, interstate, or other barrier. The facility typically separates a downtown from neighborhoods or other important destinations and is a relevant location to document overall trends in bicycle and pedestrian volumes over time.
- **Special Events** – Bicycle and pedestrian activity may be influenced substantially by special events. A site near a regular special event generator (but ideally just outside of the street closure areas for such events) can assist with understanding the level of activity that is related to such events. This could include locations near a stadium, baseball field, concert venue, or festival locations. These sites could be primarily tourism-based and/or adjacent to nearby neighborhoods. Obvious counting locations within the street network may be difficult to pinpoint due to difficulty in finding a funneling point into and out of the special event area or an area where no milling of pedestrians takes place, but shared-use path locations are often appropriate.
- **National / State / County Park** – This location would likely capture non-motorized volumes from a large recreational activity generator, especially where residential areas are adjacent. It may be difficult to find a location that captures the different subsets of recreational bicycle and pedestrian users which include, but are not limited to, mountain bikers, road bicyclists, hikers, walkers, and joggers.
- **Schools and Universities** – A location that captures elementary and middle school children walking and bicycling to and from school. Universities can also be large bicycle and pedestrian attractors; however, facilities at universities are not particularly unique and are easy to populate as a factor group. Instead, unique sites near a university setting should be the target for a CCS. For instance, a site on a roadway connector into a University that includes residential road users coming from a large residential area, a central business district connection, a connection to a heavily used recreational route, or even a train or bus depot.

D. Select Short Duration Count Sites

Through the process of conducting virtual and on-site visits and ranking recommended sites as discussed, some sites naturally lend themselves to being considered as a SDC sites as opposed to a CCS. For example, sites where inductive loops cannot be installed, due either to the intrusiveness of the equipment or high interference, may be suitable for an SDC.

New Station Integration into NC NMVDP (Onboarding)

Whenever a new count station is established, regardless of whether it is a permanent or temporary count location, it needs to be integrated into the non-motorized volume data collection program via a series of “onboarding” steps. These steps include establishing the station ID and logger names for the count location and creating new records in the data tracking systems.

Establish Station ID and Logger Names

For CCS and SDC locations, ITRE assigned a station ID to the point location that represents where count data is collected. This establishes a unique record for each count collection location regardless of the station type (i.e., continuous or short duration), number of counters, or method of collection (e.g., manual or automated). The formatting for the station ID is consistent across all count locations. For the NC NMVDP, the station ID naming convention follows what is used on the motor vehicle side of the house: a two-digit NCDOT county code (00 to 99) plus the next available four-digit identification code unique within that county at the time the station was first established. For example, the first station where equipment was installed in Durham County is assigned the station ID 310001, where 31 is the NCDOT county code and 0001 is the identification code.

Each piece of count equipment was also assigned a logger name (Error! Reference source not found.) to facilitate the identification of each data stream received from a location. For example, at a location where pedestrian and bicycle counts are collected on both sides of a north-south roadway, a separate logger name was assigned for the equipment capturing travel on the east side of the roadway and for the equipment capturing travel on the west side of the roadway. Logger names assist in establishing tracking inventories based on station type and number of counters used at a station.

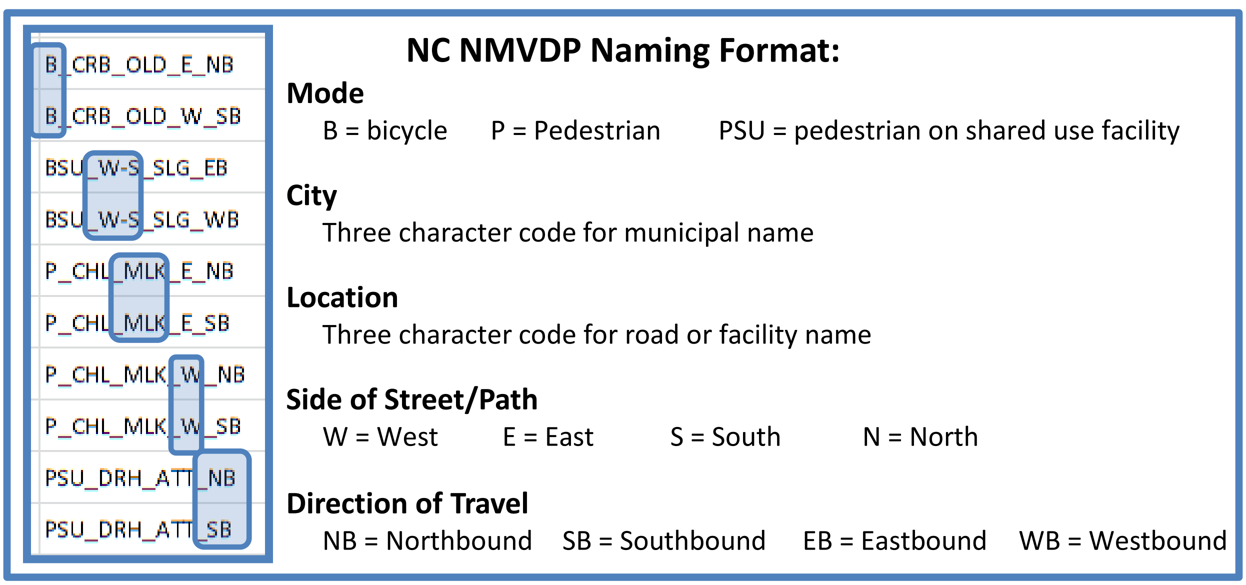

Figure 5. Example of logger name is created based on the type of count collected, name of municipality in which the station is located, name of facility being counted, location of station equipment on that facility, and direction of travel collected

Create New Records in Data Tracking Systems

After the station ID and logger names were established for a new count location, ITRE created new records in the data tracking systems used in the NC NMVDP. This included the collection of files that store the count data in its various forms, including raw, processed, and published data, as well as files that store information on equipment inventory, validation, and troubleshooting. Additional information on how the equipment inventory was developed is provided on page 5-1.

Figure 6 provides a general schematic that the research team used to organize the various station inventories necessary for tracking count locations and equipment. At the highest level is the System Station Inventory (SSI) which is organized based on Station ID. At the next level are inventories based on station type, whether continuous or short duration. Each station type inventory is linked to its own equipment inventory and count database that are organized by the established logger names. It is important to note that the Continuous Station Inventory (CSI) lists all CCS locations, whereas the Coverage Event Inventory (CEI) lists the locations where short duration counts were collected for an individual year. The stationing format was designed to allow the finest level of data, the individual count, to be linked back up to the general count collection location.

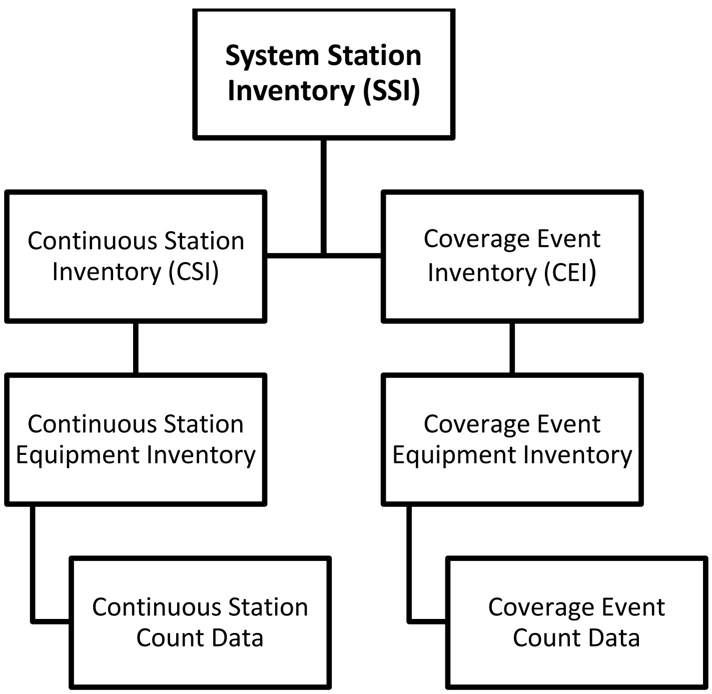

Figure 6. Schematic of station inventories developed and used in the NC NMVDP

Chapter 5. Continuous Count Sites

As further discussed in Chapter 8 in regards to data handling, processes for obtaining quality data are put in place even before stations are installed. This section focuses on the elements and procedures ITRE developed and/or implemented when procuring and preparing to install equipment, general information on installation, and quality control procedures related to other program elements. Proper installation and testing of equipment may eliminate the need for costly maintenance or data correction later and is of high importance for creating and sustaining quality data. Key inputs obtained during installation of equipment go into the Onboarding Process described on page 4-17.

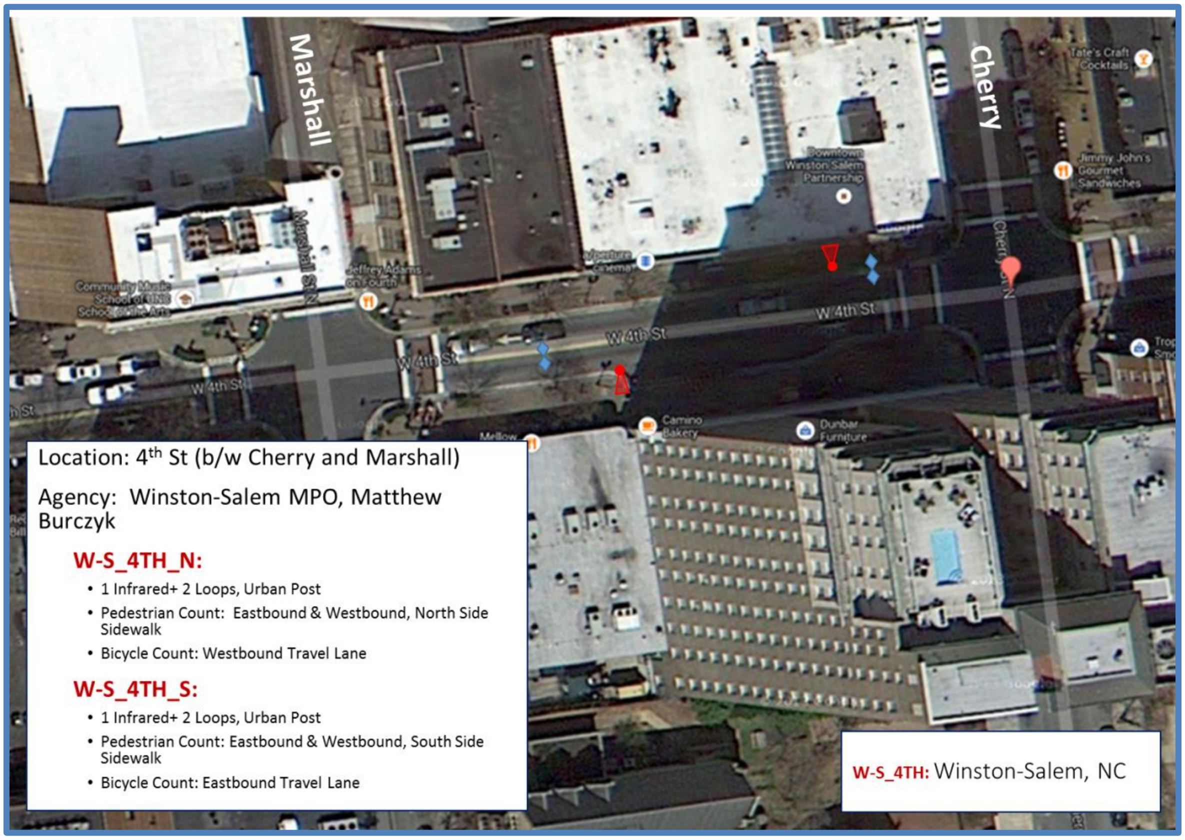

Figure 7. Example site diagram: aerial image shows location of equipment and sensors, labeled facilities, and is oriented north

Procurement of Equipment

For Phase 1, NCDOT was responsible for purchasing equipment. ITRE assisted by providing a list of equipment needs based on the sites selected. ITRE created site diagrams to use when consulting and negotiating with an equipment vendor to identify site-specific equipment needs for Phase 1 and ensure that NCDOT procured the appropriately configured units. An example site diagram is shown in **Figure 7**. Equipment needs were then summarized from these diagrams and used for developing a bid document to procure equipment based on NCDOT's financial constraints. The product specifications used in Phase

1 of the NC NMVDP to develop a vendor bid is shown in **Appendix F** on page F-1. Manuals, customer service information, and warranties were also included with the equipment order.

Equipment Inventory

As soon as equipment has been received, it should be inventoried. Initial fields for the inventory and those completed after installation are shown in **Table 7** below.

Table 7. List of Information Tracked in Equipment Inventory Spreadsheet

Initial Inventory Fields	Fields Completed After Installation
Location (Municipality)	Installation Date
Site Name	Serial Number
Logger ID	GPS Coordinates
Serial Number	Battery Life
Agency (Memorandum of Agreement)	Logger Side
Logger Type	Bike Direction*
County Code	Number of Inductive Loops
NC NMVDP ID	Pedestrian Direction*

*Detail may include Inbound and Outbound directional assignment, depending on equipment configuration

This inventory spreadsheet was modified as the equipment was received and installed prior to set-up in the software so that the appropriate information got assigned to the data bins that the equipment logger stores for the QA/QC and reporting elements of the program. The Phase 1 equipment inventory for the NC NMVDP is shown in Equipment Inventory on page G-1 and the fields that are used in relationship to equipment onboarding are discussed on page 4-17.

Pre-Installation Procedures

A great degree of agency coordination is required for the installation of CCSs in the NC NMVDP. These agency coordination efforts are outlined on page 4-1 and ensure efficient installation with the right equipment on the scheduled installation date. Training opportunities (page 11-1) and agreements (page 4-1) are key components as well as the clarification of roles and responsibilities prior to installation. The site selection process (page 4-3) ensures that overall program objectives are met, resources are not wasted on sites, and equipment and manpower are used efficiently when deployed.

Ultimately, the local agency was responsible for installation of CCSs. In some cases, agencies used a contractor to handle the work. ITRE reminded local contacts of the pre-installation tasks they needed to complete prior to the install date, which included marking utilities, acquiring tools/materials, coordinating traffic control, and any field set-up required in advance for equipment to be mounted (i.e., setting concrete). A checklist outlining installation roles and responsibilities for the NC NMVDP is given in **Appendix D** on page D-1. A more general description is given in this section.

Surface or Mounting Preparation

For the CCSs, intrusive equipment was used, so ITRE requested that the local agency mark utilities along the entire block where the equipment was scheduled to be set. The reason for marking the entire block is that minor modifications to equipment placement may occur on the day of installation. In some locations such as downtown business districts or where special circumstances dictated, it was prudent to mark several blocks. ITRE called for utilities to be marked well in advance of the installation, as it sometimes took several business days to complete, depending on the agency.

Some posts required a mounting cage to be set in concrete prior to the actual installation. In these cases, ITRE shipped the mounting cage and instructions to the agency, to ensure the cage was secured prior to the installation date. Site diagrams were sent to each agency showing the desired equipment placement so they could adequately prepare the site.

Materials, Tools, and Equipment

A variety of tools and materials are needed, depending on the equipment that is being installed at each site. It is best practice to review the site diagrams in advance and keep a kit of basic maintenance tools, electrical tools, and a spare set of special wiring components. For the NC NMVDP, a list of the materials, tools, and equipment needed at the site and the party responsible for bringing them to installation was given to the local agencies (see page C-1). Additionally, ITRE developed and used an internal checklist to gather materials for both installation and validation prior to going out in the field (see page H-1.)

Scheduling an Installation Timeframe

The scheduled installation dates took into consideration the time needed for agencies to mark utilities and acquire materials. In the best-case scenarios where all site locations, materials, equipment, crews, and contractors are coordinated effectively, multiple installations were accomplished on one day.

Installation Resources

The site diagrams were a critical installation resource. Additionally, ITRE consulted the vendor manuals and user guides for stepwise instructions, exact tolerances/specifications and to gain knowledge of on-site procedures in advance of installation. These manuals are typically shipped with the equipment, but ITRE also provided them electronically to the local agency.

Data Gathering for Onboarding

The NC NMVDP Installation Onboarding Checklist (see page D-1) was developed to ensure that that important steps are not left out, best practices are performed, and all of the correct information is collected. This checklist was created and refined based on the experience and knowledge learned through the installation process in the pilot region. The site name, interference reading, serial number, NCDOT ID number, agency/vendor contacts, cell phone numbers and loop diagram (if applicable) should all be documented prior to going into the field. The installation date, start time, end time, verification of serial number, and interference reading, installer, and GPS coordinates are recorded at the installation.

Some information on the Onboarding Checklist was not gathered during Phase 1 installations due to the nature of it being the pilot phase of the process where procedures were still being tested; however, some data, like the performance of equipment-specific pairing tests and the directionality of the count, were recorded. The data gathered during installation was saved and used for updating the equipment inventory and onboarding the equipment into the software which is explained on page 4-17.

Equipment Installation Procedures

This section gives a general idea of the stepwise process used when installing a logger that collects bicycle data (loops) and pedestrian data (infrared sensor) as a component of North Carolina's Non-Motorized Volume Data Program. Not every step is outlined, and configurations differed depending on the site-specific variables which determined the type of equipment post, logger housing, and surface material where the equipment was to be mounted or inlaid. Each site was unique, so actual installation processes varied slightly. ITRE provided oversight and monitoring of the installation processes to ensure data quality.

Prepare Site

Before installation begins, the site is prepped. For installations with a metal post, the agency set the conduit and base in advance to allow enough time for the concrete to cure. For installations with a wooden post, holes for the post and irrigation valve box (which houses the logger, battery, and GSM components) were dug on installation day.

Set up Traffic Control

The local agency set up traffic control before installation began to ensure motorists, bicyclists, and pedestrians could travel through the work zone safely. In the case of shared use paths, trail users were alerted that work was being done. In the case of installing bicycle loops in the roadway, the work zone needed to be shifted from one side of the street to the other after one side was completed.

Install Bicycle Count Equipment (Inductive Loops)

In Phase 1 of the NC NMVDP, inductive loops were installed to detect cyclists and an infrared sensor mounted in a post was installed to detect pedestrians. Each site was selected and identified to count both pedestrians and bicyclists, so the logger was configured to accept inputs of these different count types and by direction through multiple channels. To locate the loops, ITRE used an interference tester to determine placement. The location for the logger was selected based on the distance to the inductive loops and an ideal place where the infrared beam could be oriented to detect pedestrians. ITRE ensured that the loops were cut to vendor specifications by drawing a template of the loop in the optimal place in the roadway or path to guide exact location of the pavement cuts and measuring channel depths of each cut as they were made. ITRE monitored the work to verify that the loop channels were cleaned out before wiring.

To complete the loops, ITRE wrapped eight turns of wire around each of the loops, per vendor specifications. The wire leads were then twisted together and fed through the cut channel back to the post or irrigation valve box. ITRE tested the connections to ensure the loops function properly. ITRE then connected the wire to the data logger ensuring that the correct loop wires were connected to the proper channel and sealed using waterproof electrical connectors.

Install Pedestrian Count Equipment (Infrared Sensors)

ITRE monitored the installation of the posts that house the infrared sensors to ensure each was level, pointing in the correct direction, and at the correct height to detect pedestrians. Where the wooden post and irrigation valve box configuration was used, ITRE connected the sensor leads to the logger using a waterproof electrical connection.

Equipment Testing and Troubleshooting

ITRE tested each unit to make sure it functioned properly. In some cases, sites had to be rewired, reconfigured, or abandoned. To test the sensors, an ITRE researcher or local agency staff rode over the loops on a bicycle and walked in front of the infrared sensor while another ITRE researcher monitored the counts and direction of travel logged into the data collection software.

Complete Installations

Once the equipment was set up, confirmed as functional, and correctly logging using a Bluetooth enabled device, ITRE signaled the local agency to seal the loops. ITRE monitored to ensure the seal was flush with the pavement and then secured the equipment with theft resistant hardware.

Maintenance of Stations

Maintenance needs may be identified at different instances during the life of a CCS from the testing and troubleshooting that occurs during on-site validation, the validation study, visually inspecting the data, or when running one or more QA/QC checks on the data. Once the issue has been raised, maintenance to a station is deployed in as timely a manner as possible given program constraints, since obtaining complete and quality data from the continuous count program is the backbone of any traffic monitoring program.

Phase 1 Issues

The following types of maintenance issues were discovered through quality control assessments of the data throughout Phase 1 the project.

Site/Context Related – Many considerations were given to mitigate site related issues by working closely with the vendor during the site-selection phase and during placement of equipment in Phase 1. Through quality control protocols, we identified one station where the direction of travel had been switched and incorrectly assigned for both logger sites on each side of the road. At another location, we ultimately pulled the equipment because the daily bicycle volume was so low, it could not establish travel patterns.

Equipment Malfunction – The equipment is made up of many parts that work together to create a count. During Phase 1, care was taken through installation and utilization of best practices to mitigate equipment malfunctions, but some still occurred. For example, we had to replace faulty parts in three different units.

Damage/Vandalism – There are numerous ways in which the equipment can be damaged, either by accident or by intention. In Phase 1, sealant pulled out of the pavement by a street sweeper caused loop wires to be damaged. Objects pushed inside the posts such as a cigarette butt, gum, tack, or bits of paper caused loggers to skew the directional distribution of data or stop collecting it entirely depending on which sensor was obstructed. The pedestrian sensor can also be obstructed due to spider egg sacs. This occurred at one location.

Transmission Related – Cellular signal transmission can be impeded for a variety of reasons. Often a logger will resume data transmission on its own, usually within a few days; however technical issues occurred with the SIM card in a few of the loggers, and replacement was necessary to successfully retrieve the data. Fortunately, in most cases the logger was still collecting and storing the data which was eventually retrieved.

Sensitivity – Overcounting or undercounting is a potential issue with a sensor. If the sensitivity is too high, a system may double or triple-count. If the sensitivity is too low, it may not detect a user at all. These settings were adjusted after consultation with the vendor on several sensors in Phase 1.

Battery Replacement – When the battery for the logger is running low, the logger will start to miscount. This can occur if the battery replacement interval is missed but may also occur due to issues that may have to do with warranty or overdraw of the battery. Both issues occurred on some loggers during Phase 1.

Occasionally, the cause of an issue could not be determined, and the equipment returned to functioning normally without maintenance. Special events may sometimes look liked a malfunction when reviewing daily data but were determined to have a normal “ramping up” or distribution across multiple hours when the same data was reviewed at the hourly level.

Chapter 6. Short Duration Count Sites

Short duration counts are collected on less than a continuous basis. FHWA's 2014 *Traffic Monitoring Guide (TMG)* recommends counting (at a minimum) 24 hours a day for seven continuous days so that weekend and weekdays are represented. While SDCs may be needed and useful for different aspects of the NC NMVDP as it grows, the purpose of collecting them during Phase 1 of the project was to provide additional geographic coverage of the pilot region while developing and testing a method for collecting SDCs.

Through the site selection process (see page 4-3), some sites naturally lend themselves to being considered as SDC sites. Since SDC equipment is typically non-intrusive, installing the equipment to collect data from SDC sites requires fewer resources. It was still important to evaluate site conditions when choosing a SDC location for a few reasons. First, for the purpose of travel monitoring, ITRE still attempted to prioritize a mix of sites with different travel patterns and characteristics. Secondly, for the test sites where ITRE installed equipment, site selection was further constrained based on the type of sensor technology being used to ensure that its installation was feasible.

ITRE collected SDCs at a few different sites during the pilot phase. These test sites were all located near the team's office in Raleigh. Portable infrared sensors were used to collect pedestrian volume data and pneumatic tubes were used to collect bicyclist volume data. Based on current research, the team collected a minimum of seven consecutive days of data so the SDCs can ultimately be extrapolated to produce accurate annual average daily pedestrian and bicycle traffic volume estimates (AADP and AADB, respectively).

Utilize NCDOT's Existing Data Collection Program

NCDOT's Transportation Mobility and Safety Division existing data collection program (see page 3-3) provided an opportunity to establish a partnership with the Division of Bicycle and Pedestrian Transportation. ITRE encouraged the Division of Bicycle and Pedestrian Transportation to work with the Traffic Safety Unit to expand the type of traffic data they collect to include non-motorized volume data and to improve the specifications for how these data are collected. This partnership resulted in new specifications to be written into on-call contracts that NCDOT uses to collect traffic data to ensure that all bicycle and pedestrian count data collected will require seven consecutive days of 15-minute interval count data at a minimum and data formats and metadata that conforms to FHWA's TMG requirements. By capitalizing on the existing administrative functions of the data collection services the department provides, ITRE helped NCDOT begin to institutionalize a means to gather short duration non-motorized counts and ensure these counts are collected in a consistent, standard way.

Develop Data Entry Template

To ensure the consistency and accuracy of SDC data across all data collection locations, SDC contractors were furnished with a data entry template that ITRE specifically designed for the SDC collection task. This template was set up to collect data using FHWA's TMG format, which include fields for capturing the count data as well as the descriptive information specific to the data collection location. Count data was required to be reported in 15-minute intervals as part of the count description record. The template also included fields to comprise a station description record. ITRE requested the following supplemental documentation be submitted by the SDC contractors in addition to the count data:

- An aerial image of the site showing the exact placement of equipment and detection zone captured
- Images of the street view both up- and downstream from the site.
- Images of the installed equipment

Acquire Contractors

ITRE worked with NCDOT to prepare data collection specifications to be used in the Invitation for Bid (IFB) by reviewing draft specs, modifying provisions, and adding new ones. The specifications did not limit the type of sensors or technologies a contractor could use to collect the data or exact dates for conducting the count, but they did require that the contractors collect counts for a minimum number of consecutive days, conduct the collection within 30 days from assignment, and document a variety of contextual data, like weather, special events, and other information to supplement the count.

A member of ITRE's research team also participated in the bid review process and reviewed proposals with NCDOT. NCDOT awarded contracts in compliance with the IFB to vendors pre-qualified to collect statewide traffic data. For NCDOT's IFB process, all qualified bids are evaluated, and award(s) are based on lowest responsive bid meeting specifications, requirements, and terms and conditions of the IFB.

Assign Count Locations

ITRE assembled Site Diagrams including location information and GPS coordinates for each SDC station as a batch of PDFs. These stations were then assigned to the contractors at NCDOT's discretion. For example, NCDOT assigned work to the lowest accepted bids based on how many counts they could handle. The highest accepted bids were expected to do more data processing post-collection, including QA/QC. NCDOT intentionally assigned a certain number of sites to each contractor to test their performance in successfully completing assignments and allow ITRE to see how data collection methods may have varied across stations and/or contractors.

Table 8 provides a list of the station locations where SDCs were conducted during Phase 1. While existing research suggests that seasons with higher bicycle volumes have less variation in bicycle counts and yield more accurate estimates, due to project timeline constraints and funding constraints within NCDOT's traffic data collection program, all the contractor-collected SDCs were conducted between late September and late November of 2014. Currently, the NC NMVDP does not have sufficient data to determine if this late fall/early winter timeframe impacted the usability of these SDCs.

Table 8. SDC Stations Collected in Phase 1

City	Location	Count Day Start	Count Day End
Winston Salem	Brookstown Avenue, West of Main Street	10/14/2014	10/20/2014
Winston Salem	Martin Luther King Jr Drive, South of Cromartie Street	10/14/2014	10/20/2014
Winston Salem	Clover Avenue, East of Miller Street	10/14/2014	10/20/2014
Reidsville	South Scales Street, South of Morehead Street	10/15/2014	10/22/2014
Salisbury	South Main Street, South of Council Street	10/26/2014	11/2/2014
Lexington	North Main Street, South of 1st Street and North of Center Street	11/12/2014	11/19/2014
Chapel Hill	Manning Drive, East of Skipper Bowles Drive	10/3/2014	10/10/2014
Chapel Hill	Raleigh Road, East of Hamilton Road	9/30/2014	10/7/2014
Chapel Hill	Franklin Street, East of Columbia Street	9/30/2014	10/7/2014
Durham	American Tobacco Trail, Off of Blackwell Street	9/29/2014	10/6/2014
Hillsborough	South Churton Street, South of Margaret Lane	9/29/2014	10/6/2014
Elon	North Williamson Avenue, South of College Road	10/2/2014	10/9/2014
Carrboro	North Greensboro Street, West of Pleasant Drive and East of Oak Avenue	9/30/2014	10/7/2014
Carrboro	West Main Street, West of North Greensboro Street	9/30/2014	10/7/2014
Winston Salem	Hawthorne Road, South of Queen Street	10/14/2014	10/21/2014
Winston Salem	Miller Street, North of Silas Creek Parkway	10/14/2014	10/21/2014
Winston Salem	Muddy Creek Greenway	10/24/2014	10/31/2014
Summerfield	Atlantic and Yadkin Greenway, Behind Applebee’s	10/26/2014	10/31/2014
Summerfield	Atlantic and Yadkin Greenway	11/13/2014	11/20/2014
Greensboro	East Washington Street, West of South Lyndon Street	11/13/2014	11/20/2014
Greensboro	Spring Garden Street, West of Chapman Street	11/12/2014	11/19/2014
Greensboro	Florida Street, East of Lovett Street	11/12/2014	11/19/2014

Review and Store Data

Upon completing their assigned data collection tasks, contractors transmitted their data to NCDOT, who, in turn, sent it to ITRE. The data was reviewed to ensure there were no obvious issues with the descriptive and count information provided. Due to the short duration of the data collection periods, it was not necessary to perform extensive QA/QC to the level that it is performed on CCS data. The data was inspected for obvious data entry and equipment error, including missing descriptive information and blank count cells. ITRE developed a file structure and filename convention to store the data as a part of the overall data management protocol for the NC NMVDP. Two files are kept for each SDC. The raw data submitted by the contractor is retained “as-is” in their provided data collection template. The data was also transformed and stored in the TMG format specified by the FHWA to facilitate federal data reporting requirements.

Chapter 7. Validation, Accuracy, and Development of Correction Factors

While every effort is made during tool selection and installation to faithfully measure pedestrian and bicycle data along the routes of interest, there is still some error present. Errors can be systemic or random. Validation is the process by which tools are checked for errors and adjusted to reflect the ground truth more accurately. The goal of validation is to develop a correction factor unique to each machine which reflects the systemic errors for each site and adjusts the tool's count accordingly.

Validation Study

In the pilot phase, the validation process was conducted by collecting video of activity at each count location, manually counting walkway users or bicyclists for a period of no less than 22 hours over two days of footage (one weekday and one weekend day), comparing those counts to the tool's self-reported counts, and developing a correction factor to be applied to the tool's raw count.

Video Collection Process

Battery powered bullet cameras were set up at each count location to record activity. For locations with multiple counters, two sets of cameras were used if one set could not provide a visual of both sites. Equipment was installed such that at least one weekday (excluding Monday and Friday) and one weekend day could be captured. To provide the best validation, periods of high and low volumes are desired. Therefore, equipment was deployed when there were no poor weather conditions forecasted as well as no unusual events scheduled. Unusual events may include parades or bicycle or pedestrian races if in a downtown area, or school holidays or early release days if near a school. Agencies were notified of the timeframe the cameras would be in the field. When equipment and time allowed, and when there were multiple sites to be validated in one geographic location, multiple video collection installations were conducted on one day.

Before going into the field, installation photos were reviewed to determine the exact placement of the CCS equipment and how many cameras would be needed to capture the station. Shared use paths typically required one camera while roadway installations required up to two cameras because there were multiple sites (typically one on each side of the road) and there could be a distance (one to three blocks) between them. Installation pictures as well as online street-viewing tools assisted in identifying locations where camera equipment could be mounted.

Once in the field, cameras were mounted to poles, signs, or trees such that the viewing angle was large enough to capture the entire site, but not so far away as to make visual confirmation of pedestrians and bicycles difficult. Additional considerations were given to events that may obstruct the view of the detectors including passing or parked vehicles, outdoor restaurant seating with large umbrellas, sun angle changes throughout the day, etc. After beginning to record, the installer walked to the infrared sensor to note its location and, if safely possible, walked to the edges of the bicycle loops. This assisted the data processer watching the video in the office in identifying the extents of the detection zones. Finally, the counting system clock and the recording video clocked were synched.

Three to five days following video installation, crews returned to remove the recording devices. SD cards which were used to store the video were removed and downloaded for processing.

Video Review Process

Once video from a site was downloaded, review of the video could begin. Data from two days were reviewed for each site (either a Tuesday, Wednesday, or Thursday, and either a Saturday or Sunday). Analysts selected a day to review and consulted historical weather data to ensure no significant precipitation events occurred on the day of interest. A presence of precipitation did not eliminate the day from consideration if there was still significant pedestrian and bicycle traffic. This was determined by comparing the volumes to those of other, non-weather event days. The threshold for an acceptable volume was left to the discretion of the analyst.

Analysts then binned the machine's count data for the site and day of interest in 15-minute increments. Video counts were collected from the day of interest from 6 AM or when there was enough sunlight to observe pedestrians and bicycles until 8 PM or until there was not enough sunlight to observe pedestrians and bicycles. Most sites were observed for 12 or more hours, but a few sites (particularly those validated in the winter) only had enough sunlight to validate 11 hours in a day.

Analysts manually counted pedestrian and bicycle users in the same 15-minute bins that were used in the machine's count. Pedestrians were always separated by direction of travel. Bicycles were separated by direction of travel when the equipment installed at that site had the capability to distinguish direction of travel for bicycles.

It is important to understand that the primary goal of validation is to ascertain that the equipment is correctly counting objects that pass through its detection zone. Bypass error, where a pedestrian or bicyclist passes through the corridor's screenline but is outside of the equipment's detection zone, is not considered a faulty count based on equipment performance. Analysts noted where bypass errors occurred since these errors may suggest poor placement of equipment to capture true screenline volumes.

Equally important, is understanding what object each type of sensor should count. For inductive loops, the equipment should count any bicycle that passes over a loop (but not motor vehicles, including motorcycles). For the infrared sensor, any user that passes through the cone of detection should trigger a count. Video analysts counted all users who passed through the detection zone. Users who entered the detection zone in one 15-minute bin and exited in the following 15-minute bin were counted in the bin in which they entered the detection zone. Classification of users was critical and generally followed the rule that counts on the walkway were of pedestrian counts, called "sidewalk users" while counts on the roadway were of vehicles counts, assumed to be bicycles. **Table 9** provides how users were classified.

Table 9. Validation Classification for Different Users

User	Location	Validation Classification	Count
Independent pedestrian	Walkway	Walkway User	1
Pedestrian pushing a bicycle	Walkway	Walkway User	1
Bicyclist bicycling	Walkway	Walkway User	1
Tandem Bicyclists	Walkway	Walkway User	2
Tandem Bicyclists	Roadway	Bicycle	1
Pedestrian carrying another pedestrian (child)	Walkway	Walkway User	2
Pedestrian pushing one or more pedestrians (wheelchair, stroller, etc.)	Walkway	Walkway User	2+
Pedestrian walking an animal	Walkway	Walkway User	1
Bicycle with child in a rear seat	Roadway	Bicycle	1

Where binning for a user group was separated by direction, the analyst separated the 15-minute bins by direction. These bins were then compared against the machine's count bins of the same direction.

Comparative Analysis of Manual and Equipment Counts

Manual hourly count data was plotted versus automated hourly count data (a scatterplot), along with a 45^{o} line to confirm that the automated counters were not overcounting, and that there were no other unexpected irregularities in the data. In some cases, after comparing equipment with manual counts, it was clear that the equipment was malfunctioning. This triggered the need to address a maintenance issue (see page 5-5) and then potentially re-validate the equipment. Some equipment malfunctions were fixed remotely by the vendor, who also corrected the associated data without the need for re-validation.

Development of Correction Factors

Beyond the simple comparison of manual vs. equipment hourly counts, the following error metrics were calculated for each set of data: average percentage deviation (APD), average of the absolute percent difference (AAPD), weighted average percentage deviation (WAPD), Pearson's correlation coefficient (r), and average hourly volume.

Several linear regression models were run on each set of manual hourly count vs. automated hourly count (AHC) data to determine an equation for corrected hourly counts:

- Regression Model 1: Corrected Hourly Count = b_1(AHC)
- Regression Model 3: Corrected Hourly Count = b_1(AHC) + b_2(AHC)^2
- Regression Model 4: Corrected Hourly Count = b_1(AHC) + b_2(AHC)^2 + b_3(AHC)^3

The Akaike information criterion (AIC) values for each regression were compared, with the lower AIC value indicating the best model of the three. A model summary table for each mode shows the R^2 values for each regression, with a higher R^2 value indicating a better fit (See **Table 10** and **Table 11**).

Table 10. Pedestrian Model Summary

Station Name	City	Direction	Model 1 $Y=B*Auto$	Model 3 $Y=B*Auto+B_2*Auto^2$	Model 4 $Y=B*Auto+B_2*Auto^2+B_3*Auto^3$
MLK Jr Boulevard	Chapel Hill, NC	East Side	0.9930	0.9935	0.9935
		West Side	0.9826	0.9826	0.9827
Libba Cotten Bikeway	Carrboro, NC	N/A	0.9053	0.9237	0.9253
Old NC 86	Carrboro, NC	East Side	0.9916	0.9932	0.9932
American Tobacco Trail	Durham, NC	N/A	0.9863	0.9865	0.9874
S Elm Street	Greensboro, NC	East Side	0.9940	0.9956	0.9959
		West Side	0.9980	0.9983	0.9984
Lake Daniel Greenway	Greensboro, NC	N/A	0.9878	0.9898	0.9917
Spring Garden Street	Greensboro, NC	North Side	0.9979	0.9979	0.9979
		South Side	0.9972	0.9972	0.9973
Walker Avenue	Greensboro, NC	North Side	0.9931	0.9942	0.9943
		South Side	0.9972	0.9976	0.9976
West End Boulevard	Winston Salem, NC	East Side	0.9946	0.9950	0.9955
		West Side	0.914	0.9283	0.9283
Strollway at Academy Street	Winston Salem, NC	N/A	0.9929	0.9935	0.9937
W 4th Street	Winston Salem, NC	North Side	0.9885	0.9885	0.9886
		South Side	0.9977	0.9982	0.9983
Salem Lake Greenway	Winston Salem, NC	N/A	0.9907	0.9925	0.9925

Table 11. Bicycle Model Summary

Station Name	City	Direction	Model 1	Model 3	Model 4
MLK Jr Boulevard	Chapel Hill, NC	East Side	0.8414	0.8694	0.8936
		East Sidewalk	1.0	--	--
		West Side	0.8064	0.8066	0.8346
		West Sidewalk	0.9543	0.9596	0.9655
Libba Cotten Bikeway	Carrboro, NC	N/A	0.9907	0.9939	0.9954
Old NC 86	Carrboro, NC	East Side	0.9888	0.9955	0.9956
		West Side	0.9197	0.9311	0.9319
American Tobacco Trail	Durham, NC	N/A	0.9946	0.9947	0.9947
S Elm Street	Greensboro, NC	East Side	0.9615	0.9690	0.9771
		West Side	0.9903	0.9906	0.9906
Lake Daniel Greenway	Greensboro, NC	N/A	0.9989	0.9990	0.9990
Spring Garden Street	Greensboro, NC	North Side	0.9561	0.9623	0.9624
		South Side	0.9444	0.9445	0.9491
Walker Avenue	Greensboro, NC	North Side	0.9960	0.9962	0.9963
		South Side	0.8570	0.9402	0.9722
West End Boulevard	Winston Salem, NC	East Side	0.7348	0.7647	0.8101
		West Side	0.9391	0.9461	0.9477
Strollway at Academy Street	Winston Salem, NC	N/A	0.9811	0.9826	0.9813
W 4th Street	Winston Salem, NC	North Side	0.9183	0.9253	0.9301
		South Side	0.8864	0.8876	0.9013
Academy Street*	Winston Salem, NC	Eastbound	0.636	0.756	0.755
		Westbound	No model		
Salem Lake Greenway	Winston Salem, NC	N/A	0.9988	0.9989	0.9989

*The CCS at Academy Street was ultimately uninstalled due to very low counts of bicyclists; and therefore, no correction factors were developed to adjust the data at that station.

Only in a handful of instances does Model 3 improve the fit more than 10% from Model 1. As such, Model 1 was selected for parsimony as the consistent approach for error correction. After examining the results of all of the regressions, and taking into account parsimony, it was determined that Regression Model 1 would be used to develop the correction factors, summarized in **Table 12**, for all locations and modes.

Table 12. Summary of Site Correction Factors

Count Location	Phase 1 Correction Factor	Count Location	Phase 1 Correction Factor
B_CHL_MLK_E_NB	0.954	P_GSO_SPR_N	1.048
B_CHL_MLK_E_SW	1	P_GSO_SPR_S	1.022
B_CHL_MLK_W_SB	0.61	P_GSO_WAL_N	1.165
B_CHL_MLK_W_SW	0.865	P_GSO_WAL_S	1.11
B_CRB_OLD_E_NB	1.017	P_W-S_4TH_N	1.32
B_CRB_OLD_W_SB	0.845	P_W-S_4TH_S	1.186
B_GSO_ELM_E_NB	1.129	P_W-S_END_E	1.025
B_GSO_ELM_W_SB	1.018	P_W-S_END_W	1.378
B_GSO_SPR_N_WB	0.924	PO_CRB_OLD_E	1.057
B_GSO_SPR_S_EB	1.155	BSU_CRB_LCB	1.059
B_GSO_WAL_N_WB	1.004	BSU_DRH_ATT	1.031
B_GSO_WAL_S_EB	1.397	BSU_GSO_LDG	0.993
B_W-S_4TH_N_WB	1.1	BSU_W-S_SLG	0.981
B_W-S_4TH_S_EB	1.222	BSU_W-S_STR	0.981
B_W-S_END_E_NB	0.65	PSU_CRB_LCB	0.789
B_W-S_END_W_SB	0.945	PSU_DRH_ATT	1.243
P_CHL_MLK_E	1.067	PSU_GSO_LDG	1.163
P_CHL_MLK_W	1.097	PSU_W-S_SLG	1.346
P_GSO_ELM_E	1.345	PSU_W-S_STR	1.158
P_GSO_ELM_W	1.176		

Validation, Accuracy Analyses, and Correction Factors Results contains further details of the accuracy analyses performed for each site, including the:

- manual vs. automated scatter plots
- table of error metrics
- desired regression model (Model 1)

The regression equations developed were used to correct the automatic counts for each direction and mode before generating the annual report (see Creating Annual Reports).

Chapter 8. Procedures for Obtaining Quality Data

The accuracy of non-motorized data collected by Continuous Count Stations (CCSs) is important to be able to create sound estimates of walking and bicycling volumes and factor data from Short Duration Count (SDC) sites. Data quality is important for any application, as it affects the credibility and usability of the data for agency decisions. In a volume data program, there are numerous points at which quality assurance and quality control (QA/QC) processes or procedures can be applied during project implementation. QA/QC is the combination of quality assurance, the process or set of processes used to measure and assure the quality of a product, and quality control, the process of meeting products and services to consumer expectations. Key quality assurance principles and their application to pedestrian and bicycle count data have been documented by Turner *(26)*.

A flowchart detailing points at which QA/QC processes were performed in the NC NMVDP for obtaining quality data and the interrelationships between these processes are shown in Parts A and B of **Figure 8** and **Figure 9**, respectively.

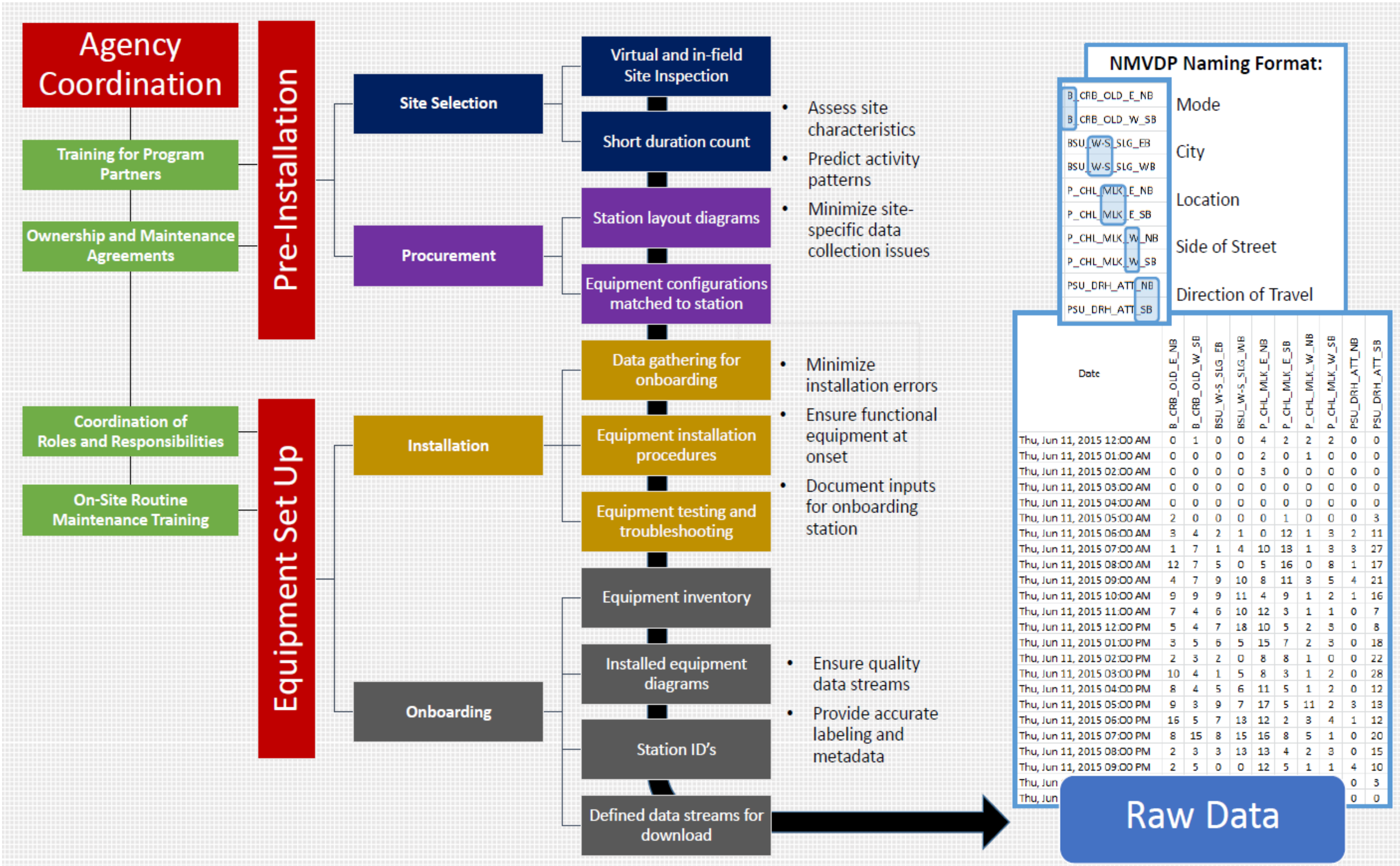

Figure 8. Part A of flowchart of QA/QC Process showing the interrelationship among the NC NMVDP elements (indicated in red) and their internal processes to generate raw data

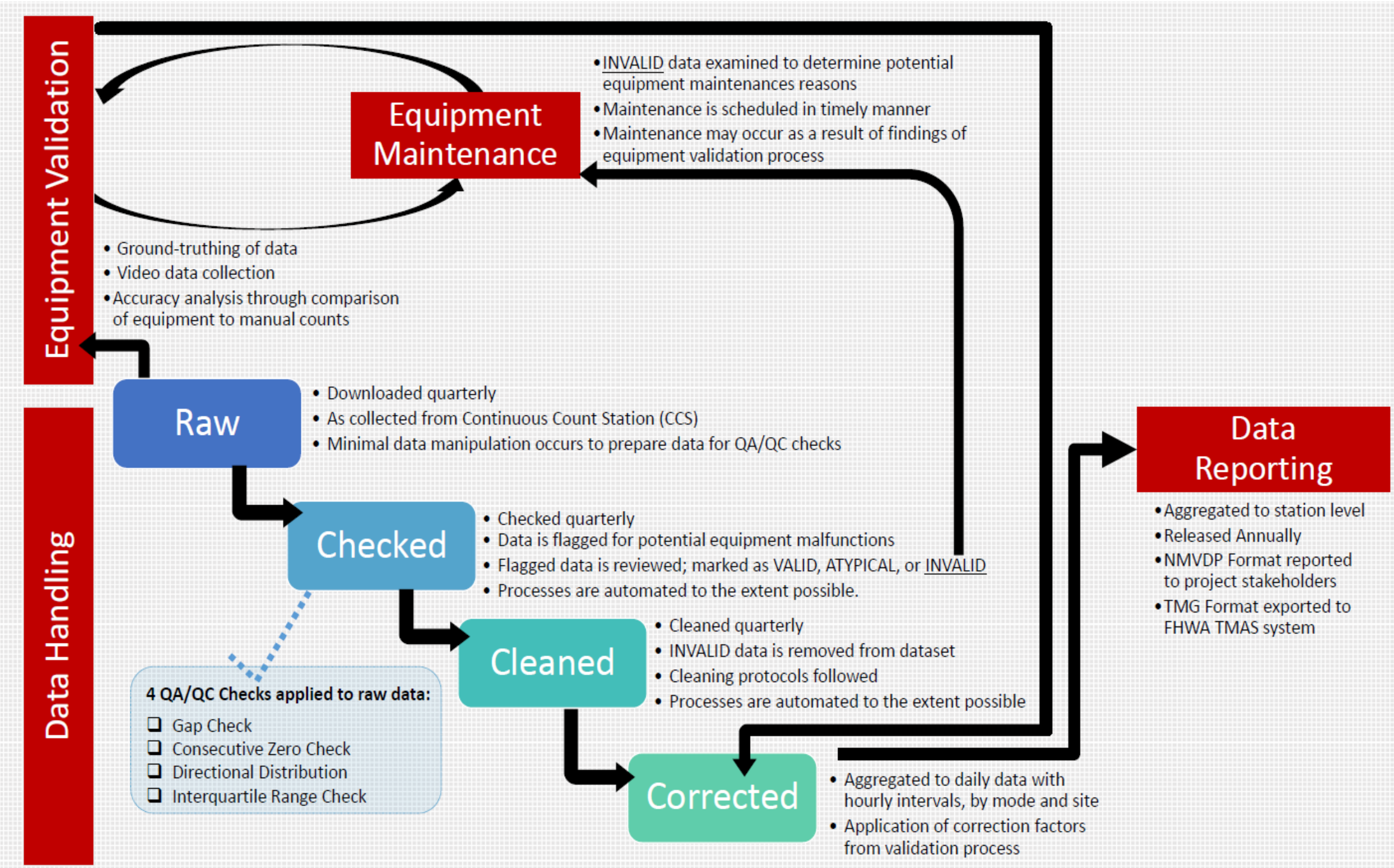

Figure 9. Part B of flowchart of QA/QC Process showing the interrelationship among the NC NMVDP elements (indicated in red) and their internal processes starting with the handling of the raw data (indicated in blue)

Data Handling Procedures

ITRE developed and implemented the following quality control procedures (a) to start a diagnostic process if equipment is malfunctioning or (b) as a mechanism to identify and clean or tag data. In the case of equipment malfunction, data were checked to determine if data was being recorded, if the data transmitted properly, and if the equipment recorded valid information. In cases where equipment malfunctioned and relayed erroneous data, the data were removed prior to reporting.

In some cases, data may be flagged as unusual and investigated, but not removed. Atypical activities like special events are indicated in the data where known. Due to the evolving nature of quality control procedures on non-motorized data, this process was reviewed and updated on a quarterly basis throughout Phase 1 of the NC NMVDP.

ITRE formed three areas of quality control objectives for three major elements of the travel monitoring program –data checking, reporting, and adjustment factor development. These objectives are listed with a description of how the team handled them for each area below.

Quality Control Objectives for Development and Application of Checks

- **QA/QC checks and workbook set up are designed to target the ways in which the equipment can malfunction.** Each check was developed to assist with assessing maintenance issues. The workbook was set up to allow for investigation of multiple pieces of equipment that make up a station simultaneously when data is flagged. These checks are outlined in greater detail on page 8-7.
- **Automate checks to the extent possible.** Review of continuous count data is a large task. Targeted manual visual review was extremely valuable in identifying suspect data prior to the establishment of automated checks. In the NC NMVDP, where counts exceeded deviation from typical conditions, the daily count data was flagged and reviewed by staff. Automated quality review and control processes were implemented where possible in the QA/QC workbook to reduce staff burden and eliminate potential error in data handling. The QA/QC workbook was set up in Excel to receive new data manually downloaded from the vendor’s software and apply workbook checks, updating and refreshing a minimal number of cells to complete this task.
- **Checks are revised as “typical conditions” are established.** When a CCS is first installed, the typical volumes for bicycle and pedestrian usage are not yet known. Checks were created and revised as more data was collected and there was more consistency of “typical conditions.” In the NC NMVDP, four checks were initially developed at with three months of data. Two of the checks were then revised at six, nine, and twelve months of data to reflect a wider range of temperatures, seasons, and potential directional variability.
- **Checks should be conducted on an on-going basis.** To the extent that resources allow, checks should be performed. A regular schedule ensures that maintenance issues can be identified early on. ITRE performed the QA/QC workbook checks on a quarterly basis. A weekly visual inspection was implemented toward the end of Phase 1 reporting as resources became available to identify maintenance issues more quickly.
- **Maintenance should be performed in a timely manner to provide robust data reports and so that accurate adjustment factors can be developed.** The CCSs are the backbone of a non-motorized volume data program as data from the stations are used to extrapolate short duration data from other counting stations to annualized estimates. If large amounts of data are

missing over a twelve-month period, the validity of the factors that can be created from the data could be compromised. ITRE performed maintenance (see page 5-5) as soon as possible after detection with delays occurring due to frequency of QA/QC (quarterly), time needed to troubleshoot (which often required additional coordination with the vendor), scheduling with agencies, and the shipment of parts (due to no stock inventory of spares such as batteries).

Quality Control Objectives for Reporting

- **QA/QC processes should coincide with reporting intentions.** In the NC NMVDP, Phase 1 data was reported to jurisdictions by mode, and by count station (equipment sites are aggregated) at the daily level by hour of day. This means that workbook set-up, data flagging and cleaning maximized validity to those reporting and analysis intentions. For non-motorized travel, creating screenline counts for a particular site involved aggregating data from multiple sites (data loggers). The workbook was therefore set up for determining invalid data at the daily level.
- **QA/QC processes should strive to maintain as much station-level data as possible.** While the direction of travel for each count was detected at some sites (and assigned at others), the analyst ultimately aggregated the data by site and by mode. This allows more data to be kept due to the way infrared sensors in the type of equipment used can skew the data to a particular count bin if a sensor is blocked.
- **Data cleaning protocols are developed to coincide with the reporting intentions of the program.** Errors and malfunctions can happen at a range of data intervals, from one hour to several days of invalid data until the problem clears or maintenance occurs. Since program goals dictate that accurate daily data is the level at which CCS should be reported, when invalid data is discovered, the entire day's data in which invalid counts occurred was removed from the dataset to ensure that all days reported represent 24 valid one-hour count intervals (see **Figure 10**). Hourly data was inspected to determine validity and determine when a problem started and ended. Examples of data cleaning for reporting:
    - Data may not have transmitted for four consecutive one-hour intervals. The entire 24-hour day of data is removed from the dataset.
    - The logger may have undergone maintenance for a 40-hour period which spans over two data collection days and into a third day. Three full days' worth of data is scrubbed from the dataset.

Time	Day of Week	Date	Month	Day Type	B_CHL_MLK_E_NB	B_CHL_MLK_E_SW	B_CHL_MLK_W_SB	B_CHL_MLK_W_SW	B_CRB_OLD_E_NB	B_CRB_OLD_W_SB	B_GSO_ELM_E_NB	B_GSO_ELM_W_SB	B_GSO_SPR_N_WB	B_GSO_SPR_S_EB	B_GSO_WAL_N_WB	B_GSO_WAL_S_EB	B_W-S_4TH_N_WB	B_W-S_4TH_S_EB	B_W-S_ACA_N_EB	B_W-S_ACA_N_WB	B_W-S_END_E_NB	B_W-S_END_W_SB
19	Wed	2015_03_04	Mar	WKDY	2	1	3	0	2	4	0	0	2	5	2	3	7	3	0	0	4	0
20	Wed	2015_03_04	Mar	WKDY	0	1	1	0	3	1	2	1	1	7	0	1	2	0	1	0	0	1
21	Wed	2015_03_04	Mar	WKDY	1	1	0	0	0	1	0	0	0	3	0	1	0	0	1	0	0	0
22	Wed	2015_03_04	Mar	WKDY	1	0	3	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0
23	Wed	2015_03_04	Mar	WKDY	3	0	0	0	0	0	1	0	1	2	0	0	2	0	0	1	0	1
0	Thu	2015_03_05	Mar	WKDY	1	0	0	0	0	0			1	0	2	0	0	0	0	0	0	0
1	Thu	2015_03_05	Mar	WKDY	0	0	0	0	0	0			0	1	0	0	1	0	0	0	0	0
2	Thu	2015_03_05	Mar	WKDY	0	0	0	0	0	0			1	1	0	0	0	1	0	0	1	0
3	Thu	2015_03_05	Mar	WKDY	0	0	0	0	0	0			0	1	0	0	1	0	0	0	0	0
4	Thu	2015_03_05	Mar	WKDY	0	0	0	1	0	0			1	0	0	0	0	0	0	0	0	1
5	Thu	2015_03_05	Mar	WKDY	0	0	0	0	0	0			1	0	0	0	0	1	0	0	0	0
6	Thu	2015_03_05	Mar	WKDY	1	0	2	1	0	1			1	0	0	0	0	0	0	0	1	0
7	Thu	2015_03_05	Mar	WKDY	1	1	3	0	4	6			1	0	1	0	0	2	0	0	1	1
8	Thu	2015_03_05	Mar	WKDY	1	0	4	0	4	0			3	0	1	1	0	0	0	1	0	1
9	Thu	2015_03_05	Mar	WKDY	3	0	1	0	2	1			2	1	0	0	0	4	1	0	0	0
10	Thu	2015_03_05	Mar	WKDY	2	1	1	0	1	2			2	3	2	1	1	1	0	0	0	0
11	Thu	2015_03_05	Mar	WKDY	1	0	1	0	1	1			1	2	0	1	0	1	0	0	0	0
12	Thu	2015_03_05	Mar	WKDY	1	0	4	0	0	2			2	0	0	3	3	4	0	0	0	0
13	Thu	2015_03_05	Mar	WKDY	0	0	3	0	8	2			1	0	1	1	2	8	0	0	0	0
14	Thu	2015_03_05	Mar	WKDY	3	0	1	0	3	4			1	0	2	0	1	5	0	0	0	1
15	Thu	2015_03_05	Mar	WKDY	0	1	1	0	2	3			2	2	2	0	1	6	0	0	0	0
16	Thu	2015_03_05	Mar	WKDY	2	0	0	0	4	1			0	2	0	0	0	1	0	1	0	0
17	Thu	2015_03_05	Mar	WKDY	2	0	2	0	7	2			1	1	0	0	0	0	0	2	1	0
18	Thu	2015_03_05	Mar	WKDY	1	0	1	0	1	2			0	0	0	0	1	1	0	1	0	0
19	Thu	2015_03_05	Mar	WKDY	2	1	0	0	2	0			0	0	0	0	0	0	0	0	1	1
20	Thu	2015_03_05	Mar	WKDY	1	0	1	0	0	0			1	0	0	0	1	0	0	0	0	0
21	Thu	2015_03_05	Mar	WKDY	0	0	0	0	0	0			0	0	0	0	1	0	0	0	1	0
22	Thu	2015_03_05	Mar	WKDY	0	0	0	0	1	0			0	0	0	0	0	0	0	0	0	0
23	Thu	2015_03_05	Mar	WKDY	1	0	0	0	0	0			0	0	0	0	0	0	0	0	1	0
0	Fri	2015_03_06	Mar	WKDY	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
1	Fri	2015_03_06	Mar	WKDY	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Figure 10. Example of data cleaning that aligns with the reporting processes of the NC NMVDP; the bicycle count for the station on Elm Street in Greensboro was removed from the dataset for both sides of the street from midnight through 11:59PM on Thursday, March 05, 2015 due to a logger malfunction

Quality Control Objectives for Development of Correction Factors / Data Substitution

- **Subjective Data Manipulation should be avoided.** Data that is marked as invalid was removed from the dataset. New data was not substituted or "imputed" for removed data; therefore "missing data" is not addressed at this time. As more years' worth of data is collected and confidence in data substitution increases, processes for imputing data may be developed.
- **Corrections to data are made based on sound validation processes.** Raw data was corrected by site based on the correction factors developed through the validation study process (see page 7-1).

All data cleaning protocols and adjustments were documented. Rules and procedures were used in combination with supporting metadata to explain the process that occurred to go from the original raw dataset to the published dataset.

QA/QC Workbook Process and Checks

While the importance of QA/QC checks to the overall strength of a volume program is stressed in prior research, very little research has been published on how to develop checks and whether a minimum amount of data is needed to establish each one in order to validate non-motorized counts once they have been collected *(10, 27)*.

Quality assessment of non-motorized traffic counts can be difficult because:

1. Non-motorized traffic is smaller in magnitude.
2. Temperature and precipitation can play a significant role in the scale and variability of non-motorized traffic.
3. Non-motorized traffic data may have greater percentage changes over seasons.
4. Non-motorized traffic is typically more variable in several time dimensions.

The Colorado Department of Transportation (CDOT) published a strategic plan for non-motorized travel monitoring that outlines processes for identification of outliers and discusses approaches to inspection and validation of suspect daily counts. The CDOT traffic monitoring database software includes twelve validation rules that may be run to check for bad data *(4)*.

The QA/QC workbook contains formulas which review the data in various ways and flag it if it appears suspect according to the checks. The workbook was used to identify suspect data or maintenance concerns and ultimately remove invalid data. The QA/QC workbook consists of tabs with records from each data collection station which details the elements of data collection that ultimately comprise the reported screenline count.

There is a tab in the QA/QC Workbook for each CCS in the NC NMVDP. Where a station is made up of multiple logging devices, this allows for a more robust QA/QC process, as additional directional checks can be performed and reviewed in the same tab. The unique logger ID was applied to the data bin in which the count is stored by the mode collected, the municipality in which the logger is located, the side of the roadway along which the data is counted (where applicable), and the direction of travel. The detailed count data from the raw data tabs are populated into the CCS Station tabs**.**

The reason for looking at data at the station-level within the QA/QC workbook is that when multiple sites make up one station, a malfunctioning machine may affect the assemblage of data for the entire station’s screenline count. A station’s data tab in the workbook tracks both bicycle and pedestrian counts separately, where applicable, due to the logging abilities of the type of equipment used in Phase 1 of the NC NMVDP. For this type of equipment, which logs and stores both modes simultaneously at a given site, comparing each mode’s data from a data logger during inspection in the QA/QC workbook allowed the ability to easily cross-reference the other mode to rule out certain types of malfunctions.

Another set of tabs is associated with individual data checks. These tabs were developed so that they can be updated as QA/QC processes improve, with automation in mind, specifically minimizing the need to modify individual formulas to the extent possible. Cleaned data was manually populated in the last tab. Where data was removed, it was marked with the time period and reason it was removed. This assisted in initiating maintenance (see page 5-5) and also helped to track when issues started and were resolved. A more detailed description of QA/QC workflow operations performed in the Phase 1 workbook are outlined in Detailed QA/QC Workbook Workflow.

QA/QC Checks on Raw Data

The following quality control checks were developed and applied to Phase 1 raw count data with the quality control objectives of the NC NMVDP in mind. Unless noted, the checks applied to all site types (B – Bicycle, P – Pedestrian, and SUP – Shared Use Path). Initial QA/QC checks were reviewed and updated quarterly as more CCS data became available and the outcomes of the checks were reviewed against their purpose.

1. **Data Gap Check**

   This check tests for gaps in the data to determine if the logger is experiencing transmission or retrieval issues.

   - **Context**: Periodically, stations will not transmit daily data due to communications issues which can stem from interruptions in cellular service, inclement weather, or physical obstruction of the signal (due to soil, dirt or water) or inability to find a cellular signal which could be the result of a malfunctioning SIM card. When a CCS does not transmit data, the field remains blank for that data interval. When a SIM card malfunctions or data is not transmitted as long as the battery is good, it is still being stored -- in this instance, while not a normal occurrence and maintenance is required, data is not lost. Some data gaps are normal and do not require maintenance. Occasionally, data will have a lag in transmission of one to two days, which is normal. There can also be a normal gap in data at the time of transmission or when multiple remote commands are sent to the equipment.
   - **Tolerance**: The tolerance for this check is set to look for any blank cell at an hourly interval.
   - **Logic:** A FLAG occurs if any hourly interval contains a blank cell, meaning no data was transmitted for that interval. When all 24 hourly intervals for a given day contain data (including zero counts), no FLAG will occur. This check references a PivotTable from the “GAP” tab which sums cells of available data.

2. **Consecutive Zero Check**
   This check tests for consecutive days of zero count values to determine if the equipment is malfunctioning.

   - **Context:** The purpose of this check is to test for data errors related to equipment, but zero counts may also occur normally as the result of weather events. At some low volume stations, an occasional daily total of zero counts may occur; however, any CCS exhibiting continuous days of zero values could be malfunctioning. Reasons for this could be due to sensor blockage or damage to the loops.
   - **Tolerance:** The tolerance for this check is currently set to three consecutive days of zero counts.
   - **Logic:** A FLAG occurs if the sum of the previous three days of data equals zero.

3. **Range Check**

   This check tests for values outside of a standard range to determine if the equipment is malfunctioning.

- **Context**: The purpose of this check is to find data errors related to equipment malfunction where the equipment is reporting higher or lower values when compared with a predicted volume. Examples of when a logger can produce data that is much greater or much lower than normal values are when equipment is consistently registering invalid events (i.e., overcounting due to sensing motor vehicles), is not registering any events (i.e., a sensor stops working), is not sensitive enough (i.e., undercounting), is registering periodic interference (i.e., overcounting), or is otherwise in need of maintenance (i.e., sensor is blocked or logger needs battery replacement). Seasonal or weather factors such as several weeks of cold days followed by a sunny and warm day may cause a spike in counts. Further examination of flagged data by a technician may inform the degree of calibration or type of maintenance that is required.
- **Tolerance:** Tolerance is set to three standard deviations of the average difference between the predicted value and the measured count for the specific day of the week on which the count was taken. The formula and tolerance can be adjusted in the "RANGE" tab.
- **Logic:** A FLAG occurs if a daily count value falls far outside of a count site's predicted value based on the tolerance given above. The equation used to develop the predicted value comes from a regression of up to six months' worth of available data from each site cleaned of major anomalies. It uses temperature, precipitation, and day of week as predictive variables. The estimate given is a screenline count and is compared by mode at each count site. Adjustments to the formula can be made in the "RANGE" tab. Weather data is referenced from the "NOAA" tab.

4. **Directional Split Check, Same Side**

   This check compares the count for the inbound and outbound direction collected by a single data logger to determine if the equipment at a site is malfunctioning.

   - **Context**: The purpose of this check is to identify maintenance issues that are commonly caused by malfunctioning sensors. This check is currently only applicable to equipment in the NC NMVDP that collects directional data (i.e., NB vs SB) using an infrared sensor. In the NC NMVDP, these are station types indicated by "P" (Pedestrian) and "SUP" (Shared Use Path). When part of the sensor is blocked, pedestrian counts are automatically assigned to the inbound direction causing the data to skew in one direction. This check can help a data technician to identify where data from a blocked infrared sensor starts to skew. Note: In Phase 1 of the NC NMVDP, bicycle counts were preassigned a directional bin, regardless of which direction the user was going. It was assumed that bicyclists would travel in the direction of traffic (i.e., no wrong-way riding.) Therefore, SUP sites with a blocked infrared sensor may show all pedestrian data skewed to the inbound direction, while the bicycle data may still show bi-directional usage. When there are very low daily volumes, there may not enough count activity for data to divide and fall into a normal range of values.
   - **Tolerance**: Tolerance is set to three standard deviations from the average directional split. The directional split can be adjusted in the "DIR"' tab.
   - **Logic:** A FLAG occurs if a daily count value falls far outside the average directional split value for that logger. To develop this check for Phase 1, an average daily directional split and standard deviation was calculated from the station data obtained from previous quarters' checked data.

5. **Directional Split Check, Opposite Sides**

This check compares the volume of the primary direction at a site to the direction of an adjacent site that comprises the station to determine if the equipment at a site is malfunctioning.

- **Context:** The variability of bicycle and pedestrian travel has demonstrated that screenline directional splits are not always 50/50 but are in most cases assumed to be relatively consistent on a day-to-day basis. By comparing counts to the sister logger at a given station, maintenance issues may be identified. This check only occurs where there are two loggers that make up a data collection station, so it does not occur on a SUP facility. This check occurs where there are P (Pedestrian) sensors on sidewalks on both sides of the roadway or B (Bicycle) data being collected on both sides of the roadway on a two-way street. Large spikes in counts on one side of a facility can and often do occur due to special events. A FLAG can also be indicative of a logger malfunction and can help identify where data starts to skew. When there are very low daily volumes, there may not enough count activity for data to divide and fall into a normal range of values.
- **Tolerance:** Tolerance is set to three standard deviations from the average direction split for the station and can be adjusted in the "DIR" tab.
- **Logic:** A FLAG occurs if a daily count value falls far outside the average "opposite side" directional split value. To develop this check for Phase 1, an average daily directional split and standard deviation were calculated from the station data obtained from previous quarters' checked data.

Handling of Flagged Data

In each station tab, data that passes all checks automatically populate as VALID. Data that receives a FLAG for one or more checks remains blank. Once the checks have been performed, it is necessary for a technician to review the "ACTION" column of the workbook for blanks not automatically indicated as VALID. These require further assessment to determine if they are VALID, INVALID, or ATYPICAL. Where data is flagged, the data technician checked when the problem began which did not always occur on the day in which it was flagged. This required inspecting the data in the "RAW_HR" tab.

- Data was marked as VALID if low volumes were noted as the issue and/or it appeared normal compared to days of data that fell around the data in question or if volume ramped up and down normally throughout the day.
- The data was marked as ATYPICAL if it appeared valid but may have been the result of a special event or some explainable phenomenon not related to equipment error. Any reasons for marking data ATYPICAL for that day were noted in the comments.
- The data was marked as INVALID if a flagged day occurred without explanation to lead the technician to believe it was normal bicycle or pedestrian activity given context of the weather or atypical events which may have occurred. Additional days of data were indicated as INVALID based on this inspection when the issue/error covered hours in the previous and/or next day and was indicated with a note.

A data technician entered the results of this assessment in each blank cell and requested maintenance as required. If more than five days of unexplained flags occurred, maintenance was triggered for the CCS.

Data Cleaning

Data marked as INVALID in the "ACTION" column was removed and blank cells for that day's data were reflected in the cleaned data for a site. In other words, if there was data in a station's workbook tab marked as INVALID, an entire day's (24 hours) worth of data was removed regardless of whether the failed check applied to hourly or daily data. In cases where multiple sites make up a station, daily data was removed for both sites. The cleaned data is populated in the "CHK_HR" tab by site. This final tab in the workbook is the cleaned data and was used in the next elements of the data workflow – storing and reporting data (page 9-1) and developing travel statistics (page 10-1).

Table 13 summarizes the number of days of data possible from each logger in Phase 1 of the program, as well as the number of days of data that were removed for reporting and analysis. The table also shows the number of days where a transmission error occurred (i.e., no data) for part or all of a day, days where a blockage or malfunction was indicated for part or all of a day, and the number of days with skewed directional data for part or all of a day. Skewed data were not removed since they did not impact the reporting quality when aggregated to the screenline count.

Table 13. Phase 1 Days of Removed or Missing Data by Site and Mode Identified Through QA/QC Processes

Station	User Type	Total Days of Data (Phase 1)	Total Days with Transmission Error	Total Days with Blockage or Other Malfunction	Total Days with Skewed Data	Total Days with Data Errors	Percentage Days with Data Errors	Total Days of Removed or Missing Data	Percentage Days of Removed or Missing Data
PSU_GSO_LDG	Ped	469	16	23	21	60	12.8%	39	8.3%
B_GSO_SPR_N	Bike	468	1	36	0	37	7.9%	37	7.9%
B_GSO_ELM_W	Bike	469	2	33	0	35	7.5%	35	7.5%
PSU_W-S_STR	Ped	471	29	0	0	29	6.2%	29	6.2%
BSU_W-S_STR	Bike	471	29	0	0	29	6.2%	29	6.2%
BSU_GSO_LDG	Bike	469	16	0	36	52	11.1%	16	3.4%
PSU_DRH_ATT	Ped	470	2	3	89	94	20.0%	5	1.1%
P_GSO_ELM_W	Ped	469	2	3	25	30	6.4%	5	1.1%
B_CHL_MLK_W	Bike	387	4	0	0	4	1.0%	4	1.0%
P_CHL_MLK_W	Ped	387	4	0	0	4	1.0%	4	1.0%
P_GSO_WAL_S	Ped	416	2	2	3	7	1.7%	4	1.0%
P_CRB_OLD	Ped	385	1	2	0	3	0.8%	3	0.8%
B_W-S_4TH_S	Bike	470	2	1	0	3	0.6%	3	0.6%
BSU_DRH_ATT	Bike	470	2	0	91	93	19.8%	2	0.4%
P_GSO_ELM_E	Ped	469	2	0	0	2	0.4%	2	0.4%
B_GSO_ELM_E	Bike	469	2	0	0	2	0.4%	2	0.4%
P_GSO_WAL_N	Ped	416	1	1	0	2	0.5%	2	0.5%
B_GSO_WAL_S	Bike	416	2	0	0	2	0.5%	2	0.5%
P_W-S_4TH_N	Ped	470	2	0	0	2	0.4%	2	0.4%
P_W-S_4TH_S	Ped	470	2	0	0	2	0.4%	2	0.4%
B_W-S_4TH_N	Bike	470	2	0	0	2	0.4%	2	0.4%
P_W-S_END_W	Ped	412	1	1	0	2	0.5%	2	0.5%
P_CHL_MLK_E	Ped	387	1	0	0	1	0.3%	1	0.3%
B_CHL_MLK_E	Bike	387	1	0	0	1	0.3%	1	0.3%
PSU_CRB_LCB	Ped	385	1	0	0	1	0.3%	1	0.3%
BSU_CRB_LCB	Bike	385	1	0	0	1	0.3%	1	0.3%
B_CRB_OLD	Bike	385	1	0	0	1	0.3%	1	0.3%
P_GSO_SPR_N	Ped	468	1	0	0	1	0.2%	1	0.2%
P_GSO_SPR_S	Ped	468	1	0	0	1	0.2%	1	0.2%
B_GSO_SPR_S	Bike	468	1	0	0	1	0.2%	1	0.2%
B_GSO_WAL_N	Bike	416	1	0	0	1	0.2%	1	0.2%
P_W-S_END_E	Ped	412	1	0	0	1	0.2%	1	0.2%
B_W-S_END_E	Bike	412	1	0	0	1	0.2%	1	0.2%
B_W-S_END_W	Bike	412	1	0	0	1	0.2%	1	0.2%
PSU_W-S_SLG	Ped	436	1	0	0	1	0.2%	1	0.2%
BSU_W-S_SLG	Bike	436	1	0	0	1	0.2%	1	0.2%

Chapter 9. Data Storage, Reporting, and Sharing

Data Storage

Several different spreadsheets are used to track and analyze counts data collected and stored in the NC NMVDP. The following briefly describes the how the data is stored provides an overview of how these different warehouses relate to one another. Figure 11 provides a visual representation of the relationships between these different points of storage.

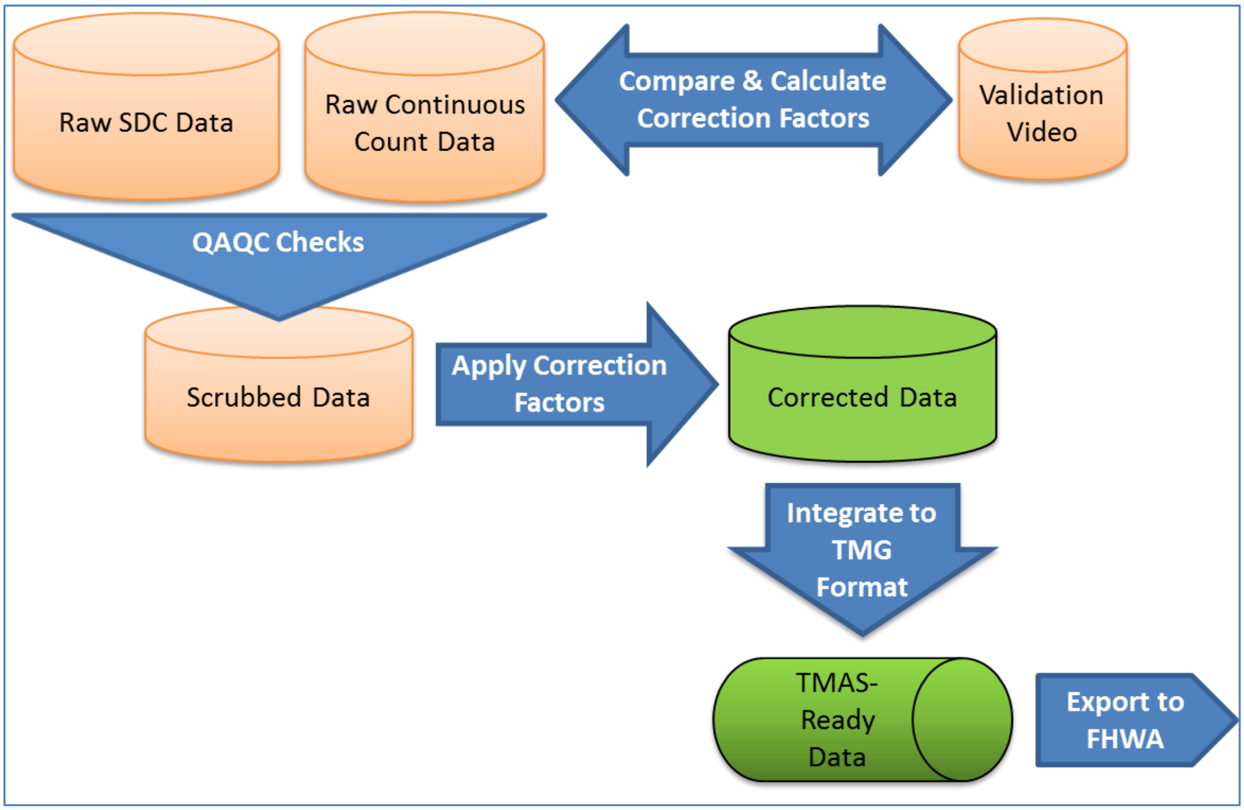

Figure 11. Schematic diagram to show how different data moves through different data warehouses

Raw Data

Continuous Count Data

Continuous count data are stored in the software application provided by the vendor. Quarterly, they are downloaded into the QA/QC workbook and stored in the workbook under two separate tabs: an hourly raw data tab, and a daily raw data tab.

Validation Study Data

Separate Excel workbooks are maintained for each mode: bicyclists or sidewalk users. Within each workbook, the data is stored by station where that mode is counted (one tab for each station). Separate columns within each station tab house the manual counts processed from the video and the equipment counts pulled from the CCS that correspond to the same time period. Once the video has been processed, the video footage is archived on a server, where it will be kept for the length of the project.

Scrubbed Data

Scrubbed Data are kept on a separate "Report" tab in the QA/QC workbook. These data have been processed through the checks (see QA/QC Workbook Process and Checks) and are ready to be used to generate reports.

Reportable Data

For North Carolina's non-motorized traffic volume program, cleaned and corrected count data ready for publishing is stored in two formats:

1. The NC NMVDP format – data is aggregated to the daily level by hour of day, mode, and station for ease of use by project stakeholders
2. The TMG format – data is formatted as specified in the FHWA's Traffic Monitoring Guide to facilitate reporting through the TMAS system

The NC NMVDP format is preferred over the TMD format for data reporting to project stakeholders due to the complexity of the TMG data coding and storage system.

CCS Reporting Process (Interim Reporting)

CCS data was reported on a quarterly and annual basis. Quarterly reporting is defined by the three-month seasonal period in which data was collected, as follows:

- Quarter 1 – Winter (December, January, February)
- Quarter 2 – Spring (March, April, May)
- Quarter 3 – Summer (June, July, August)
- Quarter 4 – Fall (September, October, November)

The decision was made to define the reporting quarters by seasonal periods due to the documented relationship between count volumes and time of year. The quarterly reported data was checked and scrubbed of any major anomalies that result from equipment error based on established QA/QC and data cleaning protocols (see page8-1). Because correction factors and additional QA/QC are applied annually, quarterly data was considered preliminary and do not ultimately match the data published annual data report. This means that the quarterly counts provided increased or decreased depending on the application of additional annual QA/QC processes and correction factors. Quarterly data for all count locations were provided via email to each stakeholder within 30 days of the last day of a reporting period. Stakeholders were informed of the limitations of the preliminary quarterly data during each reporting period.

One year of cleaned and corrected volume data and a summary statistics report were released to stakeholders. It is expected that this reporting will continue on an annual basis. The volume data was provided in the NC NMVDP format for ease of use. Summary statistics were provided in the form of a site narrative for each non-motorized count location. Site narratives contain detailed information about the count locations, including equipment installation date, travel patterns, directional distribution, and summary volume statistics by mode including:

- Highest and Lowest Volume by
  - Season
  - Month
  - Day of Week
  - Date
- Peak Period
- 12 Month Count
- Annual Average Daily Count

Count data plots by mode are also included to aid in visualizing travel activity patterns across different time periods, including day of week, hour of day, and seasonal period for the reporting year. The full summary of site narratives for the Phase 1 stations in the pilot region are provided in Phase 1 .

Creating Annual Reports

Application of Correction Factors

Correction factors are used to account for systemic equipment error. Bicycle and pedestrian counting technology are susceptible to several types of equipment error. For example, the infrared technology used for counting pedestrians is prone to undercounting when there is occlusion caused by pedestrians walking side-by-side in front of the sensor. When this happens, the sensor will detect one person instead of two. For inductance loops, error can occur when the loops detect vehicles other than bicycles, such as mopeds or other motor vehicles. Correction factors were determined based on validation testing (detailed on page 7-1) in conjunction with guidance from NCHRP Report 797 and NCHRP Web-Only Document 205.

The correction factors derived are site-specific and generated for each piece of equipment at a count location, meaning a unique factor is calculated by mode for each facility where counts are captured at a location. For example, for the NC NMVDP count location on MLK Jr. Boulevard in Chapel Hill, individual correction factors were calculated for pedestrian counts on the east sidewalk, pedestrian counts on the west sidewalk, bicycle counts on the east sidewalk, bicycle counts on the east travel lane, bicycle counts on the west sidewalk, and bicycle counts on the west travel lane.

To create the annual report, ITRE applied correction factors to the annual data that had undergone the QA/QC process to remove invalid data from the dataset. This annual data report was released to project stakeholders in the NC NMVDP format and is the TMG formatted version is ready for transmittal to the FHWA through the TMAS system.

Chapter 10. Data Analysis and Generating Traffic Statistics

Factor Group Assignment

Ideally, locations selected for continuous count data collection should include a relatively even distribution of factor groups. **Table 5** of this report provided the proposed mix of factor groups the research team anticipated based on the CCSs selected in the pilot region. The general factor group categories used to guide the pilot program site selection efforts were informed by area type and the travel pattern that was anticipated for a count location. It is understood that factor groups are subject to change over time as more data is obtained from continuous count locations, and that it may take 3-5 years of equipment installations to obtain enough data to establish stable factor groupings for use in calculating daily and seasonal factors to apply to and annualize short duration counts.

ITRE began to refine the factor group categories originally proposed based on an analysis of data trends and preliminary modeling efforts using the first year of data from the pilot region. In general, factor groupings can be established by analyzing day of week peaking characteristics on data plots and by generating counts estimation models from the data to test factors that influence count levels.

Table 14 provides descriptions of the factor groups identified in the pilot region based on an analysis of data from December 1st, 2014 to November 31st, 2015. Most locations were grouped based on day of week peaking characteristics which are summarized for each count location in the site narratives provided starting on page K-1. **Table 15** provides a summary of the updated factor grouping for the pilot region locations by mode.

Table 14. Phase 1 Factor Group Descriptions

Proposed Factor Group	Characterization
Urban Commute	Higher weekday volumes characterized by AM and PM peaks.
Urban Recreation	Higher weekend volumes indicate primarily recreational use. Weekend days have similar hourly travel pattern. AM and PM peaks occur during the weekdays. A lunch peak may also occur.
Urban Mixed	Weekend and weekday have similar average daily volumes. Weekend days have opposite patterns (AM peak Saturday and PM peak Sunday). Weekdays have PM peak but may also have a morning or mid-day peak.
Rural Commute	Higher weekday volumes characterized by AM and PM peaks.
Rural Recreation	Higher weekend volumes indicate primarily recreational use. PM peaking occurs after working hours on weekdays. Pedestrian travel pattern differs from bicycle travel pattern.
Rural Mixed	Higher weekend volumes indicating primary recreational use. On weekdays peaks occur during travel to work/school hours.
University-Related Commute	Higher weekday volumes characterized by AM and PM peaks that vary by weekday based on university class schedules.
University-Related Recreation	Higher weekend volumes indicate primarily recreational use. Weekend days have similar hourly travel pattern. AM and PM peaks occur during the weekdays. A lunch peak may also occur.
University-Related Mixed	Higher weekday volumes with AM and PM peaks. Early morning peaks on weekend days.

Table 15. Recommended Factor Groups for Phase 1 Locations Based on One Year of Data

Site Type: Area Type	Site Type: Travel Pattern Captured	Site Type Example	Pilot Program Continuous Count Locations	Recommended Factor Group	Support for Factor Group Decision
Urban	Commute	Urban sites with weekday volumes highest, primarily journey-to-work trips expected.	B_W-S_4TH	Urban Commute	Peaking Characteristics
			P_CRB_OLD	Urban School-Related Commute	Peaking Characteristics (Future Model Testing Proposed)
	Recreation	Greenway trail or street/sidewalk network within city limits not generally used for commuting or other trip purposes. This pattern may be found around urban parks or bodies of water.	BSU_GSO_LDG	Urban Recreation	Modeling and Peaking Characteristics
	Mixed	Urban site with varied trip purposes and volumes.	B_GSO_ELM	Urban Mixed	Modeling and Peaking Characteristics
			B_GSO_WAL	Urban Mixed	Peaking Characteristics
			B_W-S_ACA	Urban Mixed	Peaking Characteristics
			B_W-S_END	Urban Mixed	Peaking Characteristics
			BSU_W-S_STR	Urban Mixed	Peaking Characteristics
			P_GSO_ELM	Urban Mixed	Modeling and Peaking Characteristics
			P_GSO_WAL	Urban Mixed	Peaking Characteristics
			P_W-S_4TH	Urban Mixed	Peaking Characteristics
			PSU_GSO_LDG	Urban Mixed	Modeling and Peaking Characteristics
			P_W-S_END	Urban Mixed	Peaking Characteristics
			PSU_W-S_STR	Urban Mixed	Peaking Characteristics
Rural	Commute	Large employer generating trips to work in rural area.	No Locations	Rural Commute	No Locations
	Recreation	Greenway trail or rural bicycling/jogging route with primarily recreation-oriented users, weekend users. This pattern may be found around lakes or other natural attractions.	BSU_DRH_ATT	Rural Recreation	Modeling and Peaking Characteristics
			BSU_W-S_SLG	Rural Recreation	Modeling and Peaking Characteristics
			PSU_DRH_ATT	Rural Recreation	Modeling and Peaking Characteristics
			PSU_W-S_SLG	Rural Recreation	Modeling and Peaking Characteristics
	Mixed	Rural facility that receives both recreation and journey to work trips, such as a rail trail in a rural area that connects to employment centers in an urban area.	B_CRB_OLD	Rural Mixed	Modeling and Peaking Characteristics

Site Type		Site Type Example	Pilot Program Continuous Count Locations	Recommended Factor Group	Support for Factor Group Decision
Area Type	Travel Pattern Captured				
University	Commute	Facilities that primarily serve to connect student/staff residences and services to university areas.	B_CHL_MLK	University-Related Commute	Modeling and Peaking Characteristics
			B_GSO_SPR	University-Related Commute	Modeling and Peaking Characteristics
			BSU_CRB_LCB	University-Related Commute	Modeling and Peaking Characteristics
			P_GSO_SPR	University-Related Commute	Modeling and Peaking Characteristics
	Recreation	A location near campus that does not connect to destinations, such as a long distance walking or running loop.	No Locations	University-Related Recreation	No Locations
	Mixed	A location adjacent to a university that captures a variety of trip purposes, such as a mixed use area or connector between university and downtown.	P_CHL_MLK	University-Related Mixed	Modeling and Peaking Characteristics
			PSU_CRB_LCB	University-Related Mixed	Modeling and Peaking Characteristics

Base Model Counts Estimation

Several pilot program locations were assigned a factor group based on additional evidence from counts estimation modeling. Preliminary modeling efforts focused on a base regression model developed by the research team to estimate counts on recreational greenway trails. This model includes day of week, highest recorded daily temperature, and recorded daily precipitation as explanatory variables and daily counts as the response variable. Explanatory variable choice is supported by research included in the literature review that suggests a strong relationship between day of week, temperature, and weather and user activity on recreational greenway trails. The general model form is shown in Equation 1.

Equation 1:

$$\text{EstimatedCount} = B_0 + (B_1{*}\text{Day}_{\text{Sun}}) + (B_2{*}\text{Day}_{\text{Mon}}) + (B_3{*}\text{Day}_{\text{Tues}}) + (B_4{*}\text{Day}_{\text{Wed}}) + (B_5{*}\text{Day}_{\text{Thurs}}) + (B_6{*}\text{Day}_{\text{Fri}}) + (B_7{*}\text{Precip}) + (B_8{*}\text{Precip}^2) + (B_9{*}\text{Temp})$$

A summary of the base model fit for each Phase 1 count location and explanatory variable significance is provided in **Table 16**.

Table 16. Model Fit and Explanatory Variable Significance for Pilot Region Continuous Count Locations

Count Location	# of Days	Adj. R^2	Constant	Explanatory Variables (*p<0.01; **p<0.05; ***p<0.10)								
				Sun	Mon	Tues	Wed	Thurs	Fri	Max Temp (F)	Max Temp (F) squared	Precip
BSU_W-S_SLG	364	0.702		*	*	*	*	*	*		***	*
PSU_W-S_SLG	364	0.692			*	*	*	*	*	*	*	*
B_GSO_ELM	347	0.6677				*	**	*	**	*		*
P_GSO_WAL	360	0.665	*	*	*	*	*	*	*	*	*	*
BSU_DRH_ATT	364	0.6559		*	*	*	*	*	*			*
BSU_GSO_LDG	364	0.6315			*	*	*	*	*	***		*
B_CRB_OLD	353	0.6155			*	*	*	*	*	*	**	
P_W-S_4TH	364	0.5789	**	*	*	*	*	*	*	**	*	**
BSU_CRB_LCB	353	0.5639	*		*	*	*	*	*	*	*	*
PSU_DRH_ATT	362	0.5579	*		*	*	*	*	*	*	*	*
P_GSO_ELM	361	0.5453		*	*	*	*	*	*	*	*	*
BSU_W-S_STR	364	0.4691	***	**		**	***	*	*	*		*
PSU_W-S_STR	364	0.4593	*	*	***		***		*	*	*	*
B_CHL_MLK	351	0.457	*		*	*	*	*	*	*	*	*
B_GSO_WAL	363	0.456	*			*	***	*		*	*	*
B_GSO_SPR	359	0.4539	*		*	*	*	*	*	*	*	*
P_CRB_OLD	351	0.3525	*			**				*	*	*
P_W-S_END	363	0.3349	*	*					*	*	*	*
PSU_GSO_LDG	363	0.3027	*					***	*	*	*	*
B_W-S_4TH	363	0.3016		*					*			*
PSU_CRB_LCB	353	0.2999	*	*	*	*	*	*	**	*	*	*
P_GSO_SPR	364	0.2854	*		*	*	*	*	*	*		*
B_W-S_END	364	0.2272										*
B_W-S_ACA	292	0.2186			*							*
P_CHL_MLK	351	0.0796	**	**	**	***	***	**		*	*	***

Base model fit is described by the R^2 statistic. The R^2 statistic is generally used in regression models to describe how much variability of the data is explained by the model. For our purposes, the variability of the model can be evaluated by the adjusted R^2 statistic, which is an adjustment of the R^2 based on the number of observations and predictors in the model. Higher adjusted R^2 is an indicator of a better fit of the model to the data and the proportion of the data that can be explained by the model. For over half of the locations tested, more than 40% of the variability in daily counts can be explained by day of week, weather, and temperature.

Testing Additional Explanatory Variables

For those locations with lower model fit, additional explanatory variables were explored. For instance, for count locations on facilities used to travel to and from a university or primary school from surrounding residences and services, a binary variable that accounts for class schedules (where class in session=1 and class not in session=0 on the daily level) were included to test their influence on travel patterns. The general model form is shown in Equation 2.

Equation 2:

$$\text{EstimatedCount} = B_0 + (B_1 * \text{Day}_{Sun}) + (B_2 * \text{Day}_{Mon}) + (B_3 * \text{Day}_{Tues}) + (B_4 * \text{Day}_{Wed}) + (B_5 * \text{Day}_{Thurs}) + (B_6 * \text{Day}_{Fri}) + (B_7 * \text{Precip}) + (B_8 * \text{Precip}^2) + (B_9 * \text{Temp}) + (B_{10} * \text{ClassInSession})$$

Table 17 provides a summary of model fit for CCSs near a university. With the addition of a variable that accounts for university class schedules, model fit improved the most for estimating pedestrian and bicycle counts on Spring Garden Street in Greensboro, pedestrian and bicycle counts on MLK Jr. Boulevard in Chapel Hill, and pedestrian and bicycle counts on the Libba Cotten Bikeway in Carrboro. The class in session variable was significant at $p<0.01$ for these locations.

Table 17. Multivariable Model Fit for Pilot Region Continuous Count Locations near Universities

Count Location	# of Days	Base Model	Base Model Adding Class in Session
		Adj. R^2	Adj. R^2
P_GSO_SPR	364	0.2854	0.7593
BSU_CRB_LCB	353	0.5639	0.7169
B_GSO_ELM	347	0.6677	0.6704
P_GSO_WAL	360	0.665	0.664
B_GSO_SPR	359	0.4539	0.6451
BSU_GSO_LDG	364	0.6315	0.6315
B_CRB_OLD	353	0.6155	0.6148
B_CHL_MLK	351	0.457	0.6115
P_GSO_ELM	361	0.5453	0.5442
B_GSO_WAL	363	0.456	0.5365
PSU_CRB_LCB	353	0.2999	0.40004
P_CRB_OLD	351	0.3525	0.3722
PSU_GSO_LDG	363	0.3027	0.3012
P_CHL_MLK	351	0.0796	0.2015

A model that includes only a binary variable for class in session was tested for estimating pedestrian and bicycle counts on Spring Garden Street in Greensboro and pedestrian counts on MLK Jr. Boulevard in Chapel Hill. The general model form is shown in Equation 3

Equation 3:

EstimatedCount = B_0 + (B_1*ClassInSession)

Interestingly, class in session alone accounts for nearly 70% of the variability in daily *pedestrian* counts for the Spring Garden Street location in Greensboro, but less than 20% of the variability in daily *bicycle* counts at the same location (see **Table 18**). Class in session alone accounts for only a small portion (5%) of the variability in daily pedestrian counts for the MLK Jr. Boulevard location in Chapel Hill. The class in session variable is significant at $p<0.01$ for the three models.

Table 18. Single Variable Model Fit for Pilot Program Continuous Count Locations near Universities

Count Location	# of Days	Base Model	Base Model Adding Class in Session	Class in Session Only
		Adj. R^2	Adj. R^2	Adj. R^2
P_GSO_SPR	364	0.2854	0.7593	0.6767
B_GSO_SPR	359	0.4539	0.6451	0.1633
P_CHL_MLK	351	0.0796	0.2015	0.0532

The provided examples show how counts estimation modeling provides an additional tool for determining and supporting the assigning of CCSs to certain factor groups.

Volume Group Considerations

Factor groups may further be characterized by different volume ranges within each type. For example, a station may show a strong pedestrian commute pattern but have a low volume, whereas another pedestrian station with the same shape commute pattern may have a high volume. Within the pilot region dataset, **Figure 12** and **Figure 13** show a suggested breakdown of low, medium, and high volume ranges based on the average daily bicyclist or pedestrian counts respectively at Phase 1 stations.

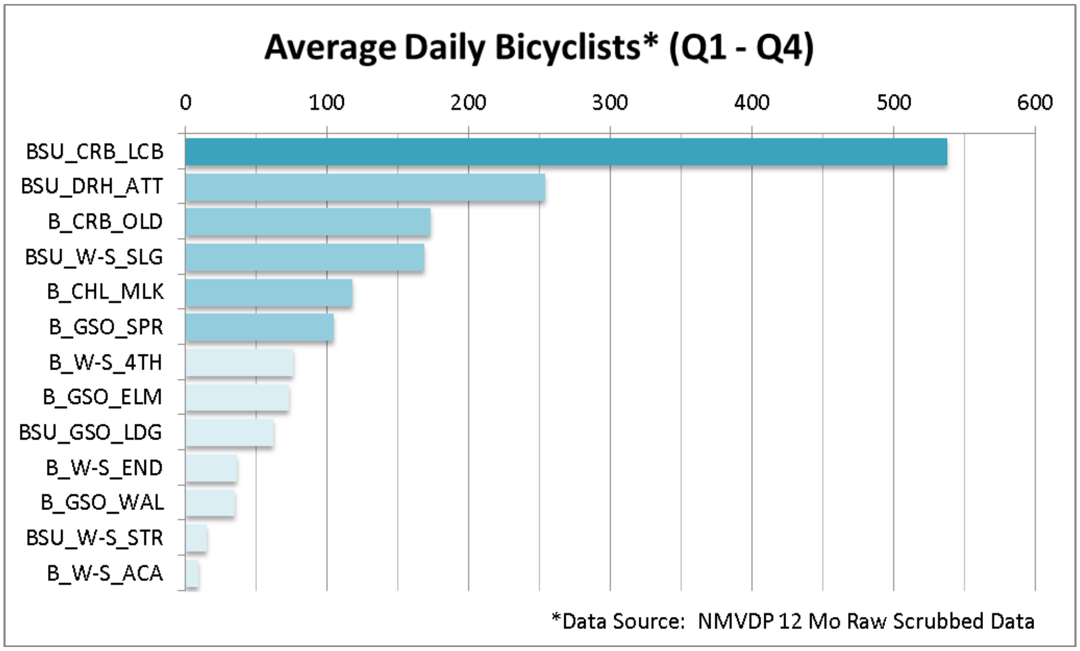

Figure 12. Breakdown of pilot region stations by volume group for bicycle counts: low = less than 100 per day; medium = 100 to 500 per day; high = more than 500 per day

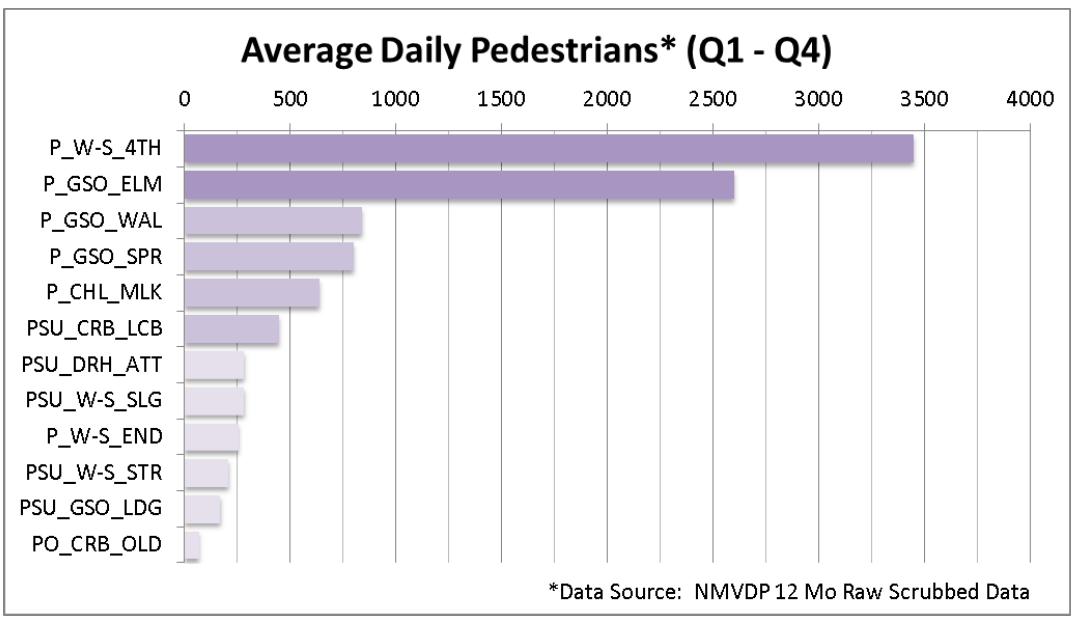

Figure 13. Breakdown of pilot region stations by volume group for pedestrian counts: low = less than 500 per day; medium = 500 to 1500 per day; high = more than 1500 per day

Calculate AADBs and AADPs

Annual Average Daily Bicycle Traffic (AADB) and Annual Average Daily Pedestrian Traffic (AADP) were generated from the year of data for the pilot region CCSs and are included in the site narratives provided in Phase 1 . These traffic statistics were calculated using the AASHTO method, which allows for annual average daily volumes to be estimated without a full 365-day set of data without the need to impute missing data.

CCS Overview and Data Summary Development

A data summary of each CCS from Phase 1 is provided in Phase 1 based on a full year's worth of collected, validated, and corrected count data, with days of missing data and data related to equipment errors removed. The resulting Phase 1 corrected data is represented in the tables and graphs within each site narrative.

Annual Daily Averages for Pedestrian Traffic (AADPT) and Bicycle Traffic (AADBT) calculated using the AASHTO method are, in many cases, very close to the straight average since little data is missing from the 12-month dataset. Due to the limited knowledge for segmentation of non-motorized data, these figures are only representative at the location at which the data were collected, and any generalizations or usage of data should keep this caveat in mind. Information given in the narrative for each station is based on interpretation of the data and cursory research on special events. Local agencies may have more information related to daily data outliers or trends.

ITRE developed the site narratives from summary statistics developed for each station. These results are provided in table and graphical formats by mode and include:

- Volume statistics on the station's peak season, peak month, peak day of week, and peak day
- Volume statistics on the station's lowest season, lowest month, lowest day of week, and lowest day
- Calculated AADBT and AADPT
- Visualization of volumes by mode by month
- Visualization of volumes by time of day and day of week
- Visualization of daily volumes by season

Each narrative also provides station description information along with the aerial site diagrams and street view images of the station.

Chapter 11. Technical Transfer

During the pilot phase of the project, the research team customized and offered training on non-motorized traffic monitoring to local agencies in the pilot region as a way to build capacity within the state and provide an overall understanding of the NC NMVDP. Additionally, ITRE created an installation video to highlight the key steps of installing continuous count equipment such as that used in the pilot region. As statewide interest in the NC NMVDP is growing, the researchers also prepared for and delivered an informational webinar to introduce a broad audience across North Carolina to the program. These three technical transfer activities are further discussed below.

Full-Day Workshop: Maintaining and Contributing to the NC NMVDP

Local agencies contribute to the NC NMVDP in a variety of ways. In Phase 1, after agencies were engaged in the site selection process, those agencies in which count equipment was to be installed were invited to attend a workshop on how to successfully manage a traffic monitoring program while learning how they could contribute to or benefit from the collection and sharing of non-motorized volume data.

The training course is intended to give planners, engineers, and transportation professionals a solid foundation for maintaining and contributing to the non-motorized counting program being undertaken in NC. The project team covered the following topic areas:

- Introduction to the North Carolina Program
- Bicycle/Pedestrian Volume Data Fundamentals
- Non-Motorized Counting Equipment and Installation
- Data Needs and Uses
- Site Selection Methods
- Data Management and Reporting (after field visits)

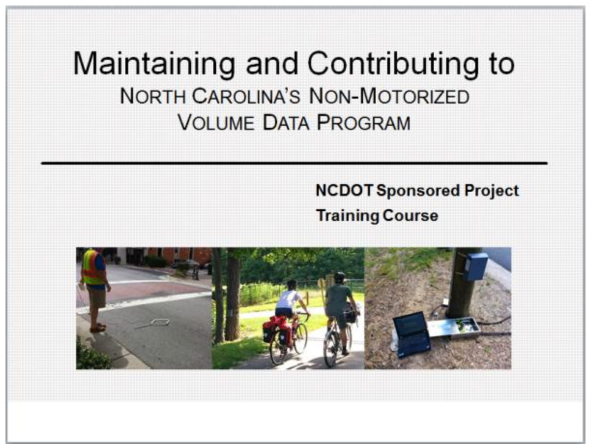

Figure 14. North Carolina's Non-Motorized Volume Data Program course educates agencies on carrying out program responsibilities

The course mixed program specific examples with the best practice guidance outlined in the TMG and is modeled off a National Highway Institute course used to teach about the TMG guidance. The critical importance of quality data collection was emphasized to support project planning, programming, design, and maintenance decisions.

Thirteen attendees from five different agencies (Durham, Winston-Salem, Greensboro, Chapel Hill, and NCDOT Division 9) participated in the workshop, which was held in Greensboro in September 2014.

Installation Video

During the installations of the Phase 1 sites, ITRE collected video and photograph documentation of each installation for recordkeeping purposes as well as to be able to develop a short how-to module.

The resultant video is geared toward technicians and their supervisors to highlight the installation and testing procedures undertaken in the field. The video was posted on both ITRE and NCDOT's YouTube channels and will be offered as another educational tool to Phase 2 agencies. The video has been viewed over a combined 390 times and shared five times from ITRE and NCDOT's posting. Peak viewing occurred in August 2015 on NCDOT's channel and in October 2015 on ITRE's channel.

Informational Webinar

The one-hour informational webinar was held on June 16, 2015 and provided a high-level overview of the Non-motorized Volume Data Program, the objectives of this project, and NCDOT's plans to for continued program expansion and roll-out across the state. ITRE conducted the webinar to explain how agencies could get involved in data collection prior to the NC NMVDP's arrival in a jurisdiction. The content of the webinar sought to address many of the frequently asked questions we heard from the pilot region agencies when they were first engaged in the program.

Over 40 entities joined the webinar, with some participant sites representing more than one individual viewer. The webinar was also recorded, and a link distributed via email to all registered participants as well as posted on ITRE's website. Additionally, the webinar was posted on ITRE's YouTube channel and it has been viewed 20 times since January 2016.

Chapter 12. Recommendations for Phase 2

Site Selection Process Lessons Learned

- Rather than picking sites suitable for counting both bicyclists and pedestrians at a given site, the site selection process should be driven by the selection criteria and specifically that of getting a mix of sites to represent a mix of factor groups. Bicycling sites should be selected independently of pedestrian sites. When conducting field visits, each prospective site can be investigated for the possibility of counting to optimize equipment where it makes sense. However, equipment may be more effectively used by picking ideal sites for each mode independently of the other.
- Other considerations that are good to contemplate when developing site selection criteria include finding sites that provide for unique or interesting travel patterns such as sites near hospitals, transit stations, shopping centers, special recreational districts, etc.
- Consider updating the site selection criteria for future phases to include:
  - **HIA Integration** - Sites selected and recommended for data collection should support the implementation of a Regional Health Impact Assessment (HIA). Example: HIA recommends increasing bicycle and walking within the area. Selecting sites where active transportation engagement projects encourage an increase in bicycling and walking might be appropriate.
  - **Facility Improvements** - Sites selected and recommended for data collection should receive higher priority when sites fall within an area where a known facility improvement (such as adding bike facilities, etc.) will occur. This enables additional research to utilize the data to conduct before/after implementation studies to determine what affect a facility improvement had on non-motorized traffic volumes.
  - **Multiple Agency Support** - Sites can receive higher priority when they fall within an area where multiple agency resources are available, ready, and willing to help in installing and maintaining equipment.
- Update the site selection criterion for **Factor Group Designation**.
  - A site's factor group cannot truly be determined until data has been collected - optimally utilizing one to three years of continuous count data. Now that there is enough data from the Phase 1 sites to better understand what factor groups may be represented by the CCSs in the pilot region, NCDOT can more clearly determine what types of sites are still needed to reach the TMG's rule of thumb of 3-5 sites per factor. However, the NC NMVDP is still in its infancy in North Carolina, and indeed, there is discussion even at the national level about whether there are new, different, or more nuanced factor groups to represent through bicycling and pedestrian volume data. For example, motor vehicle monitoring programs do not factor subsets of commuter travel patterns; however, in bicycling and walking data, one could make a clear distinction between traditional commute, school commute, or university commute patterns.
  - As longer-term data are collected at the Phase 1 sites, NCDOT should consider determining seasonal factors from CCSs. It will take at least three years of continuous

count data from a site to begin to understand seasonal patterns and define season factor groups.
  - Factor groups are subject to change over time due to many variables which include but are not limited to a change in environment, different travel patterns than expected, or even changes in connectivity or community development
- Objects moving behind a fence or off in the distance can cause the infrared sensor to pick up background activity. There could also be an issue with picking up reflections due to windows or water. Interference from power or data transmission could cause inductive loops to miscount, or loops could be placed ineffectively to pick up bicyclists. Placement of a logger too close to a trailhead or rest area may be a target for individuals who want to stretch prior to their run or for a place to hang a jacket. Lingering in front of the equipment may cause a spike in counts. Once installation has occurred, these issues are difficult to correct. Every effort should be taken to address these types of issues at the site selection step or mitigate them at installation, if the option is available.
- Collect SDCs as preliminary data inputs to inform the selection process. When first starting a traffic monitoring program, there is less need to know the exact factor groups that each site falls into as long as a variety of site types have been chosen. It is, however, important to know that there is enough volume at the site to substantiate a CCS. Low volume sites are okay to have, but volumes that are too low make it difficult to determine patterns in the data and therefore are problematic when verifying the quality of the data. Sites with “zeros” for most of the day should be avoided. Sites that likely fit a needed factor group but appear to have low volume during the initial site visit should be further studied for a CCS. It is a best practice to perform a short duration count prior to installation of equipment. This helps determine if the recommended site meets the expectation of the assumed factor group prior to implementation of the CCS and that it has sufficient activity. For example, the lowest volume bicycle site in Phase 1 had an average of 15 bicycles per day. Academy St. in Winston-Salem was ultimately dropped as a site due to a bicycle volume average of 9 per day. A site may be elevated from a SDC to a CCS after performing a short duration count and determining that volumes are high enough to make it a worthwhile investment.
- There are other reasons a manual count and/or gathering more information about the site may be needed. For example, behavioral site observations, sites that may experience patterns that are too unique to assign to a factor group, or other site specific factors that make permanent installation difficult, are all reasons for gathering more information about the site. To answer behavioral questions, interviewing local citizens or business owners during the site visit and setting up longer on-site observation periods or cameras may help to establish confidence in the selected site or assist with placement or configuration of equipment.

Count Technology and Sensor Selection Considerations

- Select sites first; then determine the best automated count equipment to use, given the unique characteristics of each site. Purchasing equipment first constrains the type of sites that can be identified for CCSs and may result in picking less-than-ideal sites to truly represent bicycling and walking in a region.

- Equipment technologies are constantly evolving, and it is important to thoroughly investigate the range of options available. NCHRP 07-19 offers guidance for practitioners on the different methods and technologies based on feasibility, availability, quality, reliability, cost, and compatibility.[1] Accuracy of equipment is a critical component to a count program whose purpose is to develop annualized statistics. As different technologies are used, the NC NMVDP may need to adapt equipment procurement, installation, validation, and maintenance procedures and data management practices to allow for flexibility in using a variety of equipment types.
- In selecting a counting system, consideration should be given to the ability of the system to time-stamp activity. When conducting the Validation Study, there was some challenge in appropriately placing a user in the correct 15-minute bin if the user passed the counting station near the transition from one time bin to the next. Because of clock drift, the video's clock may not always accurately reflect the counting system's clock, even if the two are synched at the beginning of recording. This problem can be reduced, although not avoided entirely, by increasing the bin size.
- Sometimes different types of technology or multiple configurations of a certain type of sensor can be used at the same site, and there could be opportunities for modification in what equipment is ultimately matched to a site (i.e., to save costs or increase battery life). The site diagrams can be modified as decisions are made to best represent the proposed equipment and configuration as well as what is ultimately installed.
- Automated inductive loop-based equipment to detect bicyclists in mixed traffic was found to vary in accuracy depending on the volumes of bicycle traffic in relation to the volumes of vehicle traffic. One station was dropped due to low bicycle volumes and difficulty in validation while another station was dropped due to high motor vehicle volumes which experienced issues with excessive overcounting. These stations' raw data could not be checked through all QA/QC processes or reliably corrected. New configurations of detection (additional inputs and additional loops) will be tested in Phase 2 to determine if accuracy can be increased.

Installation Lessons Learned

- When inventorying equipment is received, if there will be a lag prior to the installation date while waiting on agreements or contractor negotiations, batteries should be unplugged to ensure they are not draining prior to be installed. If any pieces have been damaged or pieces are missing, the vendor is contacted immediately to provide replacements or assess shipping issues. If issues occur, a new installation date may need to be coordinated with the local agency.

[1] Transportation Research Board. 2012. Methodologies and Technologies for Collecting Pedestrian and Bicycle Volume Data (NCHRP 07-19).

- If the proper site preparation requiring significant lead time is not completed prior to the day of installation, it could delay the installation timeline. This is best coordinated in advance if it is a single day installation window.
- It is best practice to sawcut loops in solid concrete or blacktop that has minimal cracking – agencies may be able to prepare a clean and smooth cutting surface in advance by resurfacing a short section of road or trail.
- Ensuring that sealant is smooth and level with the pavement at installation can help to mitigate the risk of sealant becoming pulled out of the pavement though it is challenging to do at the curb face. Having duct seal and backer rod can assist with keeping sealant from pooling at the curb face.
- Care should be taken in places where a run-off-the-road crash may occur or where utility vehicles travel - consider protecting the post with bollards, locating it adjacent to other obstructions such as light poles or trees, or improve its visibility with retro-reflective materials.
- Transmission issues can occur if the valve sprinkler box that houses a logger settles and sinks to a depth where it can no longer transmit through soft soil and grass. This issue should be mitigated at installation by ensuring a good substrate or base of gravel is filled and tamped down prior to placing the sprinkler box in the hole.
- Coordinate with only one agency and their contractors for each installation timeframe - ranging from a single day to multiple days, depending on the number of pieces of equipment. Additional time can be built in for rain delays, depending on the season. This way, if there are installation setbacks, it does not have a domino effect on other agencies that have coordinated their own internal public works staff and/or paid contractors. Using these best practices avoids the complexities of rescheduling multiple agencies and crews.
- A safety vest should not be worn when testing the infrared sensor, as double- or triple-counting may occur with each pass.
- For each pass, the detected direction and detected mode should be recorded in the “On-Site Equipment Validation” portion of the NC NMVDP Installation Onboarding Checklist (page D-1). This differs from the validation study (see page 7-1) in that the equipment is being tested for functionality to determine if it is installed and performing correctly prior to leaving the site, not to compute correction factors which involve collecting numerous hours of field data. Twenty passes are made to test the equipment and determine if the equipment is functioning sufficiently. After performing these tests, the percent error should be calculated for each mode.
- If the error rate is high, the on-site validation sheet can be used to determine if there is any pattern occurring which could indicate what the issue is. If issues cannot be determined and corrected by the installers or experienced technical support staff from ITRE, the vendor should be contacted for troubleshooting support. If equipment is re-configured to adjust sensitivity or any rewiring occurs, there is an area on the on-site validation sheet to indicate the results of the re-test.

Validation Study Lessons Learned

- There were some instances of equipment tampering by civilians. In most cases, the tampering was non-destructive, although some wires were cut. Although the recording device was padlocked to a pole or tree, cutting the wire which ran to the camera did allow for theft of the camera portion. To avoid this, recording systems should be discrete and unobtrusive. Positioning the system such that any bulky objects are out of view of most users (e.g., on the opposite side of a tree from a shared use path) reduces the visibility of the system. Additionally, placing the camera as high as possible not only givens a better field of view but removes the camera from reach for most citizens.
- Manually counting pedestrians and bicycles requires attention to proper positioning of validation equipment. Using a monitor to check the field of view is recommended. Also, the recording may require a higher resolution than typically used to process the same footage for motor vehicles due to the relative scale of non-motorized modes.
- After analyzing the data collected through the validation study process in Phase 1, it became clear that collecting one weekday and one weekend day of video data was not the correct priority. As the counting system is ignorant of the day of the week, the more important factor to consider when validating continuous count equipment is observing a variety of volumes, which can generally be accomplished on any given day, due to the variation in volume by time of day.
- Having a definition of users is also important. To define how an unusual situation should be processed (tandem bicycle, for instance), it is important to have a larger definition of what is being counted. In this project, it was determined bicycle loops were counting vehicles; therefore, a bicycle was counted as one unit regardless of the number of passengers, mirroring an AADT's ignorance of the number of passengers in a motor vehicle. However, as most walkway traffic is composed of individuals and not vehicles, the walkway counts enumerated the people using the system regardless of the mode of transport. It is trivial, then, to apply this definition to any unusual scenario and consistently define how it should be recorded.

Local Agency Coordination and Technical Transfer Lessons Learned:

- Prior to implementing the site selection process, it is advantageous for agencies to be familiar with the NC NMVDP and its purpose and objectives. Therefore, the full day workshop should be offered as the first level of engagement with agencies within the Phase 2 region to improve the likelihood that good sites will be submitted for review.
- The portion of the course that covers the basics of site selection is intended to assist stakeholder agencies in contributing sites that are beneficial to program objectives. Although other objectives such as demonstrating high volume corridors, selecting areas with crashes, or before and after study opportunities are clearly beneficial and taken into consideration in the site selection process, holding the course prior to gathering sites gives the best opportunity for the NC NMVDP objectives to be addressed.
- MOAs should be initiated at the municipal level for Phase 2. While the establishment of regional programmatic coordination may be an efficient partnering strategy to build capacity within

MPOs and RPOs to potentially develop their own volume monitoring programs, the reality observed in Phase 1 was that installation responsibilities fell to the individual municipalities.

Maintenance Lessons Learned and Best Practices:

The maintenance task for this pilot project was underestimated, in large part due to a naïve understanding of the ways in which equipment may need adjusting or how it can fail, and due to unclear definitions of what would be considered “routine” versus “non-routine” maintenance. As per the MOA, the local agency is only responsible for routine maintenance within the first two years of installation. Many of the “bugs” get worked out during this initial interval, and the research team acting as NCDOT’s agent did not fully grasp the ramifications of what that meant.

Due to ITRE’s experience in Phase 1, the team compiled some techniques to implement in a more consistent manner in future phases:

- Maintenance should not occur until further troubleshooting has been conducted prior to going into the field. This usually starts with inspecting the data, either as collected on the NC NMVDP Installation Onboarding Checklist (see page D-1) or by looking at the raw data feeding into the QA/QC check or validation process through which the error was discovered. For this reason, the QA/QC Checks on Raw Data in (see page 8-7) highlight the types of issue that could occur in the context section of each check – noting the relationship between the issue and what the check is designed to do. Reviewing these issues will assist in troubleshooting.
- Notify the vendor when an equipment malfunction is identified and prior to going into the field to perform maintenance. This will open a ticket so that the vendor knows there is an issue and, if under warranty, parts can be sent as deemed necessary. They may have helpful insight as to what will be needed in the field to perform a diagnosis or repair. This will also prepare them with the information about the logger ID of the equipment so they can find it quickly and easily in the software should a call be required. If more than one site within a station has an issue, a separate maintenance ticket should be generated for each logger ID. Problems with internal wiring or internal hardware should be covered to a certain extent by warranty within the first two years but may also be due to not following proper installation techniques. Warrantied parts are typically labeled, shored, and shipped back to the vendor using pre-paid shipping labels so that they can further troubleshoot the cause of the issue.
- Troubleshooting to identify the correct part for replacement may require in-field diagnostics. Having parts shipped directly to the local agency may expedite completing the maintenance need.
- Ensure equipment and tools are on hand to perform diagnostics. These usually include a Bluetooth enabled device with the full version of the software. A username and password with permission to access the software account is typically necessary. ITRE has a maintenance account for this purpose which allows a proxy to perform diagnostics but not to access or manipulate the logger information or data.

- A headset is best to have so that both hands are free to manipulate equipment because calls to customer support are often necessary while diagnosing malfunctions. A camera and cellular phone that can e-mail photos on site may also be useful.
- Be prepared to do some excavation on equipment that has been installed inside an irrigation valve box in the ground. This may require a hand trowel and also a pick to remove dirt so the security bits fit into the bolt head. It is also best to have gloves as some equipment will be wet/dirty or it may be necessary to pull apart silicone gel enclosures to ensure wiring connections are correct.
- Visiting sites for maintenance is time consuming in a large count program and should be balanced with timely maintenance to the loggers. Some equipment issues are more time-sensitive than others. It is prudent to schedule maintenance so that multiple sites are visited in tandem to maximize the efficiency of travel.
- If batteries are not changed in a timely manner, the equipment will malfunction, and data can be lost for a period that lasts until the battery is replaced. Due to the scale of the NC NMVDP, it is recommended that NCDOT have an inventory of extra batteries in stock so that if a battery problem is identified, completing the maintenance of a logger is not delayed by shipment. Label each battery with the date that it was installed. Used batteries should be labeled as such and can be recycled by placing them in one of the yellow electronics recycling bins on NCSU's campus.

Short Duration Count Lessons Learned:

- If a contractor is new to collecting non-motorized counts, it is recommended that they submit a sample of their required counts to NCDOT/ITRE prior to collecting all assigned weeks'/locations' worth of data to guarantee compliance with the data collection specification.
- If a major error is apparent upon inspecting the data received, contractors should be requested to recollect the counts in accordance with NCDOT's IFB.

QA/QC Lessons Learned:

- Due to the evolving nature of quality control procedures on non-motorized data, the QA/QC process should continue to be reviewed on a quarterly basis to investigate ways to improve data quality. For example, the program currently implements no hourly data checks. ITRE recommends that the development of an hourly data check be explored as more data is received to attempt to identify outliers not obvious at the daily level.
- Checks should be conducted on an on-going basis. To the extent that resources allow, checks should be performed. A regular schedule ensures that maintenance issues can be identified in a timely fashion. A weekly manual visual inspection was implemented toward the end of Phase 1 to identify maintenance issues more quickly. This is important to minimize the number of days of data that may need to be scrubbed due to a poorly maintained station.
- The range check will be updated in Phase 2 to a simpler interquartile range check requiring less outside data and less staff time. An interquartile range check will increase workbook automation

and will be tested to accurately flag outliers. The original range check is still being used in other program process and is a useful estimation tool. This tool can be referenced in Appendix J.

- ITRE has requested that the equipment vendor skew the direction of travel detected for bicycle data in the same way as the pedestrian data where there may be a blocked sensor so that issues can more easily be identified. It should be expected that vendors do not manipulate the raw data.
- ITRE has also requested that the vendor provide an API to access the raw data so that there may be the potential to increase automation of the data workflow in a future phase.
- Although not currently present in the NC NMVDP, the directional split check for stations where there is a separate equipment site on each side of the road may also be appropriate as a bicycle-only check where there are paired one-way streets.
- The process of cleaning data and populating the “CHK_HR” tab was not automated in Phase 1 but has been identified of improvement for future iterations of the QA/QC Workbook in future phases of the project.

Data Analyses to Explore:

- The research team will continue exploratory testing of explanatory variables to build counts estimation models as more data becomes available from the pilot region count locations and new CCSs are established in Phase 2 of the research project.
- In order to calculate average annual daily bicyclists (AADBs) and average annual daily pedestrians (AADPs) volumes from short duration count data, monthly, day of week, and hour-of-day (if applicable) adjustment factors (commonly called expansion factors) must be derived from the continuous count data and applied based on the factor grouping of the count locations. The current literature offers multiple methods for generating adjustment factors for pedestrian and bicycle counts, including methods adapted from those used to annualized motorized counts and methods that incorporate temperature and weather into the calculation. In practice, few agencies have applied monthly, day of week, or hour-of-day adjustment factors to non-motorized short duration counts. It is more common for agencies to collect short duration counts during the dates and times that are expected to be average in order to reduce the need for adjustment. The development of adjustment factors by the research team is currently in progress as exploratory testing for factor grouping continues into Phase 2 of the research project.
- There is promise in identifying additional factor groups that may be unique to non-motorized travel patterns that cannot be detected for motor vehicle volumes. Patterns to continue to explore in Phase 2 include:
    - Central business district (CBD) or entertainment district patterns, which may have a peak late at night when restaurants and other businesses close. A few pilot region stations showed this pattern visually, but when preliminarily tested as a binary explanatory variable for estimating counts at these sites with daily level data (where Thursday/Friday/Saturday=1 and all other days=0), a statistically significant relationship

between the days assumed to account for CBD activity (Thursday/Friday/Saturday) and the non-motorized counts was not found.
  - School-related travel patterns, which were captured at the daily level, can be estimated using binary variables similarly to the class in session variable tested for locations near universities. Bicycle and pedestrian activity near elementary, middle, and high school sites should be further tested to determine whether school-related travel may be a unique type of commute travel pattern that can be factored.

New Resources, Tools or Checklists to be Deployed and Tested in Future Phases

- The informational webinar has some higher level information on site installation for agencies considering being stakeholders in the NC NMVDP. This webinar should continue to be a go-to resource to encourage newcomers to the program to watch to become familiar with it.
- The installation video should be sent to prospective Phase 2 agencies to ensure an efficient installation process. After Phase 2 installations, ITRE should poll agency staff to determine how useful the video was to those who watched it prior to conducting the installs.
- An improved Onboarding Checklist will be implemented in Phase 2: There is now a place to indicate that equipment-specific security tools have been given to the local agency, the installation date has been written on the battery, and that basic maintenance procedures have been explained to party responsible for the routine maintenance. On-site testing/validation results are also recorded on this checklist.
- The SDC data entry template provided to NCDOT contractors was improved and will be implemented in Phase 2. While data will ultimately need to be formatted for reporting the data to FHWA's TMAS, the TMG format is not very user-friendly. Additionally, only receiving data from the contractors in the TMG format makes it difficult to inspect the station record description information fields to ensure the correct coding was used. Therefore, ITRE developed a new template with fields for capturing the count data as well as the descriptive information specific to the data collection location. While formatted differently, it captures the information required in a way that allows ITRE to review it for quality assurance before transforming it into the TMG format and exporting it to the Annual Report. **Figure 15** provides an example of how the data entry template can be formatted.

Road Name:	US 74
Location Detail:	Between Graham / Silkes Ave
City/Town:	Wadesboro
County:	Anson
State:	NC
Site Code:	
Start Date:	01/21/16
Start Time:	16:00
End Date:	02/02/16
End Time:	12:00
Data Collection Agency:	ITRE
Data Collection Method:	Infrared PYROBOX Sensors

			Equipment ID:	COMB 5830	COMB 5830	COMB 5828	COMB 5828
			Equipment Location:	North Side	North Side	South Side	South Side
			Equipment Coordinates:	34.969475, -80.078839	34.969475, -80.078839	34.969475, -80.078839	34.969475, -80.078839
				Count Side of Street/Direction of Travel	Count Side of Street/Direction of Travel	Count Side of Street/Direction of Travel	Count Side of Street/Direction of Travel
Date	Day of Week	Time	Type	North / SEB To Downtown	North / NWB	South / SEB To Downtown	South / NWB
[e.g., MM/DD/YYYY, 02/22/2015]	[e.g., DDD, Fri]	[HH:MM]	[B, Bike; P, Ped; M, Mixed]	[# of Pedestrians in 1 hr interval]	[# of Pedestrians in 1 hr interval]	[# of Pedestrians in 1 hr interval]	[# of Pedestrians in 1 hr interval]
01/21/2016	Thu	16:00	P	0	5	4	3
01/21/2016	Thu	17:00	P	3	1	11	8
01/21/2016	Thu	18:00	P	6	5	1	3
01/21/2016	Thu	19:00	P	14	0	1	1
01/21/2016	Thu	20:00	P	3	0	0	0
01/21/2016	Thu	21:00	P	5	8	2	1
01/21/2016	Thu	22:00	P	1	2	0	0
01/21/2016	Thu	23:00	P	0	0	0	0
01/22/2016	Fri	0:00	P	0	0	0	0
01/22/2016	Fri	1:00	P	0	0	0	0
01/22/2016	Fri	2:00	P	0	0	0	0
01/22/2016	Fri	3:00	P	0	0	0	0
01/22/2016	Fri	4:00	P	1	0	0	0
01/22/2016	Fri	5:00	P	0	0	0	0
01/22/2016	Fri	6:00	P	0	0	1	1
01/22/2016	Fri	7:00	P	1	1	0	0
01/22/2016	Fri	8:00	P	2	1	1	1
01/22/2016	Fri	9:00	P	1	0	0	2
01/22/2016	Fri	10:00	P	1	0	0	5
01/22/2016	Fri	11:00	P	0	0	0	1
01/22/2016	Fri	12:00	P	1	1	4	3
01/22/2016	Fri	13:00	P	1	1	0	0

Figure 15. Screenshot of Phase 2 SDC data collection template

Program Expansion Considerations

- Any agency interested in collecting bicycle and/or pedestrian volume count data should do so by working closely with the data wrangler (a role currently filled by ITRE) to ensure program protocols are followed.
- Local agency data from automated equipment installed outside of the NC NMVDP's process would be advantageous to potentially integrate into a statewide data warehouse as the state's non-motorized traffic monitoring program is developed. Accurate short-duration counts utilizing a consistent format and methodology would also be beneficial.
- NCDOT needs to develop a short duration count coverage program. At a minimum, data at SDC stations established for traffic monitoring purposes should be collected on a rotating basis. However, research is still needed to determine best practice methodologies for collecting short duration counts – to determine how many times a year counts should be collected to account for seasonality, the frequency of collecting SDCs at a given station on a cyclical basis (i.e., every year, every three years, or some other schedule), and how long SDC counts should be collected to be valid for extrapolating to AADBs and AADPs. This is particularly true for pedestrian volumes; however, the current protocol of collecting a minimum of seven continuous days for 24 hours each day is based on one study that used bicycle data from Colorado. ITRE recommends that this study be replicated using the Phase 1 data from North Carolina for bicycles and expanded to consider variability in pedestrian counts, too.

- Due to the time involved, as more data is collected and new stations are added to the program for management, consideration should be given to automating a weekly QA/QC process. This may also entail the development of a web-based application to seamlessly integrate data from vendor software into the NC NMVDP QA/QC process, and ultimately offer functions to visualize the data geospatially.

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Appendices

Appendix A. Summary of Local Agency Non-Motorized Count Activities in North Carolina (2014)

Agency	Department	Extent of Counts Conducted	Bicycle/Pedestrian Count Effort(s)	Start Date of Effort (year)	Mode(s)	Number of Counts (all types)	Count Method	Facilities (I)ntersection, (S)creenline	Count Duration	Data Plan or Collection Protocol	Data Usage	Data Sharing	Other Information
Southwestern RPO	RPO Staff	1 count taken in Downtown Sylva circa 2011	No program	NA	Bicyclists	1	Manual	Roadway(I)	2-hour	No	Project specific	Yes	
Wilmington MPO	MPO Staff (Transportation Review Committee)	Several counts taken on Market Street corridor and at 3 locations on the Cross City Trail	Project specific, regular shared-use path counts	2011	Bicyclists and Pedestrians	10-15 per year	Video, manual via handheld counters	Sidewalks(I)(S), Paved shared-use paths(I)(S), Roadway(S)	2-3 hour	Unknown	Planning, evaluation, safety analysis, funding	Yes	
Durham-Chapel Hill-Carrboro MPO	City of Durham Department of Transportation	Counts conducted in Chatham, Orange, and Durham counties and Town of Chapel Hill, Carrboro, and Hillsborough	Dedicated bicycle and pedestrian count program, peak hour intersection counts	2012 video, manual counts for 10+ years	Bicyclists and Pedestrians	Over 200 annually	Video (Miovision), manual via handheld counters (JMAR)	Sidewalks(I), Paved shared-use paths(S)(I), Unpaved shared-use paths, Roadway(I)	7-day,* 12-hour	Yes	Planning, modeling, funding, operational analysis	Yes	7-day counts were conducted at 10 sites but only 40% of data yielded usable results, working to develop count database
Capital Area MPO	MPO Staff	Counts conducted on shared use paths throughout the MPO region	Shared-use path count effort	2013	Bicyclists and Pedestrians (not counted separately)	10-15 per year	Infrared (Eco-Counter Pyrobox)	Paved shared-use paths(S)	7 days to 2 weeks	No	Local area project program call	Yes	In the process of developing a count program and data collection plan
Greensboro MPO	GDOT Engineering	Regular counts conducted using video at intersections and manually on an as-needed basis, manual counts conducted in downtown Greensboro and on UNCG Campus	Peak hour intersection counts, before and after counts on Spring Garden Street (bicycle lane)	2011 video, manual counts for 5+ years	Bicyclists and Pedestrians	150-200 per year	Video (Miovision)	Sidewalks(I), Paved shared-use paths(I), Roadway(I)	12-hour (15-minute increment)	No	Planning, safety analysis, before and after study	Yes	
City of Greensboro	Parks and Recreation	Counts conducted on trail system for over 5 years	Shared-use path count effort	2008	Bicyclists and Pedestrians (not counted separately)	Continuous	(7) TRAFx infrared counters*	Shared-use paths(S)	Continuous	Unknown	Unknown	Unknown	Counts were conducted using a less reliable infrared counter prior to 2013, accuracy of counts before 2013 is unknown

Agency	Department	Extent of Counts Conducted	Bicycle/Pedestrian Count Effort(s)	Start Date of Effort (year)	Mode(s)	Number of Counts (all types)	Count Method	Facilities (I)ntersection, (S)creenline	Count Duration	Data Plan or Collection Protocol	Data Usage	Data Sharing	Other Information
Town of Carrboro	Transportation Planning	Counts conducted for Mobility Report Card, regular peak hour counts at intersection of Main and Greensboro, and for traffic impact analyses	Peak hour intersection counts, 2005 Mobility Report Card, 2013 Mobility Report Card	2011	Bicyclists and Pedestrians	4 per year (goal not always met)	Manual	Sidewalks(I)(S), Paved shared-use paths(S), Roadway(I)(S), Locations lacking sidewalks	2-hour to 12-hour (15-minute increment)	No	Project specific (traffic impact), information	Yes	Shapefile of count locations processed manually, intention of purchasing counter in 2014
Land of Sky Regional Council	MPO Staff with support from RPO Staff	Regular rotation of automated counts conducted throughout MPO and RPO region (Waynesville, Asheville, Brevard, Black Mountain, Hendersonville)	Dedicated bicycle and pedestrian count program	2012	Bicyclists and Pedestrians	15-20 per year	Eco-Counter (Pyro) and pneumatic tube counter	Sidewalks(S), Paved shared-use paths(S), Unpaved shared-use paths(S), Roadway(S)	7-day	No	Local assistance, inform Regional Bicycle Plan	Yes	Plans to count in Marshall and Fletcher in spring of 2014, staff has an informal collection protocol and is formalizing a data collection plan and has identified a need for training
City of Winston-Salem	Transportation	Project/situation specific counts	Wake Forest University Plan	2014	Bicyclists	NA	5 DIY pneumatic tube counters	Paved shared-use paths(S), Roadway(S)	12-hour (planned)	No	Baseline data, educational project, justification of bicycle and pedestrian expenditures	Yes	Arduino boards programmed and calibrated equipment in partnership with UNC Center for Design Innovation, directional data not available, working on mapping and visualization project with CDI
City of Charlotte	Transportation	Regular pedestrian counts conducted using video at intersections and manually for bicyclists on an as-needed basis	Peak hour intersection counts	2011	Pedestrians	Unknown	Video (Miovision)	Sidewalks(I), Bridge(S)	12-hour (15-minute increment)	No	Baseline data, operations (signal timing)	Yes	Map of count locations is processed manually
City of Raleigh	Transportation Operations	Project/situation specific counts	Peak hour intersection counts, 2011 Downtown Pedestrian Study, 2013 Hillsborough Street Bicycle and Pedestrian Count Project	2011	Bicyclists and Pedestrians	Unknown	Video, manual	Sidewalks(I)(S), Roadway(I)(S)	11-hour, 7-day	No	Cost estimates, safety analysis, economic development and marketing, before and after study	Yes	Counts conduced in partnership with Downtown Raleigh Alliance, GIS shapefile of data is available, currently in process of developing a more formal counting program

Agency	Department	Extent of Counts Conducted	Bicycle/Pedestrian Count Effort(s)	Start Date of Effort (year)	Mode(s)	Number of Counts (all types)	Count Method	Facilities (I)ntersection, (S)creenline	Count Duration	Data Plan or Collection Protocol	Data Usage	Data Sharing	Other Information
Town of Chapel Hill	Planning	Counts conducted for traffic impact analyses, no additional counting program	2001, 2003, and 2005 Mobility Report Card	2001	Bicyclists and Pedestrians	NA	NA, work is contracted	--	12-hour	NA	Traffic impacts	Yes	Independent bicycle and pedestrian counting efforts are no longer conducted as the MPO now serves this function, mobility report card has GIS shapefile
City of Asheville	Transportation, UNC Center for Health and Wellness*	Counts conducted by large-scale volunteer effort at locations of interest	Volunteer count program	2009	Bicyclists and Pedestrians	15-20 per year	Manual	Sidewalks(I), Paved shared-use paths(S), Roadway(S)	2-hour	No	Planning, project design, baseline data to show need	Yes	In the process of developing a program and partnership with the UNC Center for Health and Wellness, over 50 volunteer counts conducted in some years
NCDOT	Division of Mobility and Safety	Agency is a data supplier, counts are conducted per request from Divisions and Departments internal to NCDOT, 15 contractors are on call to carry out requests, contracts provide flexibility for a range of requests	Types of requests received to date include intersection counts, pedestrian crossing corridor studies, and evaluation counts after an intersection improvement	1999	Bicyclists and Pedestrians (as requested)	300-500 per year	Determined by contractor	Determined by department requesting count	13-hour (15-minute interval) for typical intersection, duration is as requested	Yes, supplied by requester	Varies	Yes	New contracts (established December 2014) can be adjusted to meet project needs, agency has plans to create a more dynamic system for viewing data, data has 3-year retention schedule
Town of Cary	Facility Design and Transportation	Ongoing volunteer count program on randomly selected segments of shared-use path	Volunteer count program	2007	Bicyclists and Pedestrians	50-75 per year	Manual	Counts are conducted "in motion" as volunteers walk the shared-use path	1-hour	Yes	Funding, research	Yes	Weekends only, segments are geolocated, data is processed manually, protocol is statistically informed

Appendix B. Research Methods to Determine Baseline Data Needs

The research team developed a methodology to estimate the number of count locations where pedestrian/bicycle counts within NCDOT Division 7 and 9 could take place. This is an idealized analysis in the sense that it represents the best possible approach to identifying possible counting locations. Practical considerations such as budget constraints, local priorities, technological considerations, and expertise also play an important role in determining how many locations will be sampled first and how. Akin to the procedure identified in FHWA's *Traffic Monitoring Guide*, the aim was to use the regression analysis to identify groups of census tracts that were similar to each other in terms of their volume and seasonality patterns. Separate analyses were conducted for pedestrians and bicyclists. Our approach had several steps. First, the number of pedestrian and bicyclist trips was estimated based on four types of travelers (journey-to-work commuters, school travelers, college travelers, and other travelers) using data from American Community Survey and NHTS. Second, multivariate regression models were then employed to investigate the effects of population characteristics (e.g., population density, job density, percentage of college students, percentage of population in poverty, etc.), location characteristics, and pedestrian/bicyclist infrastructure on the trips estimated above. The Akaike Information Criterion was used to identify appropriate factor groups (which we call strata). As a result, five walking site classifications and four bicycling site classifications were created. Important factors are the percentage of population enrolled in colleges or universities, the coverage of sidewalk, bicycle lanes, and trail infrastructure, and whether the tracts were located in special interest areas (in our case, these are the Carrboro-Chapel Hill area). The estimated sample sizes for tracts to be considered should be used as a guide that can assist with practical considerations. Over time, as the count program expands, more tracts will be included, and the count program will more closely match the sampling suggested in the ideal scenario presented here.

The objectives of this task are to:

- Implement a methodology to estimate pedestrian and bicycle travel demand based on location characteristics and population characteristics, and
- Use the estimation to inform the count site sampling frame.

More specifically, this section describes the research activities conducted in the development of the bicycle and pedestrian demand forecasting methodology and documents the approach to identifying site selection criteria.

Forecasting Total Pedestrian and Bicycle Trips by Tract

The methodology for estimating the number of walking and bicycle trips was developed by Alta Planning and improved by Kerr et al*.* (2013). It has been applied in the Durham Comprehensive Bicycle Transportation Plan (2006) as well as the Raleigh Bicycle Transportation Plan (2009). The methodology estimates daily walking or bicycle trips based on four categories of travelers: journey-to-work commuters, school travelers, college travelers, and other travelers.

Data regarding journey-to-work commuters were obtained from the American Community Survey (ACS) 2007-2011 (statistics: means of transportation to work for workers 16 years or over). In addition to employers commuting to the workplace by walking or biking, the model also incorporated a portion of employed adults working at home. Specifically, it was assumed that about half of them made at least 1 pedestrian/bicyclist trip during the workday.

The ACS 2007-2011 data was also used to estimate the number of school children (aged 5-14 years). This figure was then multiplied by the percentage of children walking or biking to/from school estimated by National Safe Routes to School surveys to obtain the number of school pedestrian/bicyclist commuters. Because currently the NC Safe Routes to School program doesn't report a state-specific percentage for school pedestrian and bicyclist commute share, we used the estimated average school trips mode share nationwide instead, which were 13% for walking and 2% for biking.

For college travelers, the number of enrolled college students was derived from the ACS 2007-2011 using the statistics "sex by college or graduate school enrollment by types of school by age for the population 15 years and over." We assumed that the college pedestrian and bicyclist commute share was equivalent to that of employed adults.

Finally, the 2009 National Household Transportation Survey (NHTS) provided sources to estimate the proportion of commute trips to overall all-purpose trips for pedestrians and bicyclists. The original dataset was extracted and processed in order to obtain the ratio of pedestrians/bicyclists commute trips to all-purpose pedestrians/bicyclists trips for NC only. This ratio can be used to infer the number of all-purpose trips as well as non-commute trips. Proper adjustments were made to get the final average daily trips estimation. **Table 19** summarizes the detailed calculations and data sources.

Table 19. Calculation Process for Estimating Pedestrian and Bicyclist Trips

Category	Calculation	Data Origin and notes
Employed adults, 16 years and older		
a. total employed persons		ACS 2007-2011 estimates [a]
b. pedestrian/bicyclist commuters		ACS 2007-2011 estimates
c. pedestrian/bicyclist commute percentage	(b/a)	
d. work-at-home		ACS 2007-2011 estimates
e. work-at-home pedestrian/bicyclist commuters	(d/2)	Assumes 50% of population working at home makes at least 1 daily pedestrian/bicyclist trip.
School children		
f. population, ages 5-14		ACS 2007-2011 estimates
g. estimated school pedestrian/bicyclist commute share	13% (walking) 2%(biking)	Safe Routes to School report [b]
h. school pedestrian/bicyclist commuters	(f*g)	
College students		
i. full-time college students		ACS 2007-2011 estimates
j. college pedestrian/bicyclist commuters	(i*c)	Assumes same pedestrian/bicyclist commute share as employed adults, 16 years and older
Work and school commute trips sub-total		
k. daily commuters sub-total	(b+e+h+j)	
l. daily commute trips sub-total	(k*2)	Assumes 2 trips per commuters per day
m. yearly commute trips sub-total	(l*260)	Assumes 260 workdays per year
n. percentage of commute trips in all trips	4.15% (walking) 11.71% (biking)	Commute trips make up 4.15% and 11.71% of all pedestrian and bicyclist trips, respectively (NHTS 2009)
o. total yearly pedestrian/bicyclist trips	(m/n)	
p. average daily pedestrian/bicyclist trips	(o/365)	Assumes 365 days per year

a. http://www.socialexplorer.com/tables/ACS2011_5yr
b. http://saferoutesinfo.org/sites/default/files/resources/NHTS_school_travel_report_2011_0.pdf

Variables Potentially Explaining Total Pedestrian and Bicycle Trips

Variables that would influence pedestrian or bicycle demand and activity patterns can fall within three categories: socio-economic and demographic characteristics, built environments, and types of pedestrian and bicycle facilities. Based on preliminary discussions during interim meetings, seven socio-economic and demographic variables, three major trip generator variables, and four types of facilities variables were identified as the independent variables that may help explain heterogeneity in demand (**Table 20**). All data were obtained and summarized at the census tract level.

Table 20. Definitions and Data Sources

Variable	Definition	Data Origin
Socio-economics and Demographics		
pop_dens	Persons per sq. mile	ACS 2007-2011 estimates a
per_coll	Percentage of population enrolled in colleges or universities	ACS 2007-2011 estimates
university	Census tracts with universities/colleges or over 50% population are enrolled college students	ACS 2007-2011 estimates "Colleges and University" from NCOneMap b
urban	Census tracts with population density over 1,280 persons per sq. mile	ACS 2007-2011 estimates
job_dens	Job counts per sq. mile	LEHD 2011 c
perc_pov	Percentage of population living in poverty d	ACS 2007-2011 estimates
transit_capita	Transit use per capita	ACS 2007-2011 estimates
Major Trip Generators		
library	Number of libraries per tract	Institute of Museum and Library Services: Public Library 2011 e
schoolcount	Number of schools per tract	"Public Schools" & "Non-Public Schools" from NCOneMap f
cch	Special interest area: Area with substantial pedestrian or bicycle activity not explained by other independent variables. In this case, it corresponds to census tracts fully or partially located within the Chapel Hill-Carrboro municipal boundaries.	
Pedestrian and Bicycle Facilities		
sidewalk	Miles of sidewalk per tract	NC PBIN
bikelanes	Miles of bike lanes per tract	NC PBIN
trails	Miles of trail per tract	NC PBIN
roaddensity	Road length in miles divided by area in sq. mile (highway excluded)	NC PBIN

a. http://www.socialexplorer.com/tables/ACS2011_5yr
b. http://data.nconemap.com/geoportal/catalog/main/home.page;jsessionid=B0BF3E1DCB60F110A85A9E4272A37606
c. http://onthemap.ces.census.gov/
d. Individuals were determined as living in poverty if the ratio of their family or personal income in 2011 to their appropriate poverty threshold was below 1.00.
e. http://www.imls.gov/research/pls_data_files.aspx
f. http://data.nconemap.com/geoportal/catalog/main/home.page;jsessionid=B0BF3E1DCB60F110A85A9E4272A37606

Regression Analysis

To understand which independent variables help explain variation in estimated pedestrian and bicycle activity, we utilized regression analysis. We examined the use of count regression models, but spatial heterogeneity led us to examine various ways of explicitly accounting for space in the models. We included explicit latitude, longitude, their squares, and their cross-products as independent variables. We also estimated a spatial error model, but this required the use of ordinary least squares regression. For comparability, and to strengthen our ability to test different ways of accounting for spatial effects, we report results of the linear regression models here. Two separate sets of models were estimated, with outcome variables being the natural log of pedestrian trips per capita and the natural log of bicyclist trips per capita, respectively. We also examined the use of total pedestrian or bicycle trips in the census tract, but this unnecessarily skewed results in favor of tracts with more population (larger tracts) regardless of the concentration of destinations. Thus, the choice of trips per capita was deemed more appropriate.

In addition to the independent variables described above, we created a set of interaction variables to test with the models (**Table 21**). We used backwards stepwise regression to identify a subset of least correlated independent variables that can explain dependent variables. Specifically, the final model only includes independent variables with p-value < 0.20.

Table 21. Interaction Variables Considered in Model-Building

Variable	Definition
pov_side	interaction %poverty sidewalk
pov_trails	interaction %poverty trails
pov_bikeln	interaction %poverty bikelanes
coll_side	interaction %college sidewalk
coll_bikeln	interaction %college bikelanes
coll_trails	interaction %college trails
uni_side	interaction %university sidewalk
uni_bikeln	interaction %university bikelane
uni_trails	interaction %university trails
dens_side	interaction density sidewalk
dens_trails	interaction density trails
dens_bikeln	interaction density bikelane
jdens_side	interaction jobdensity sidewalk
jdens_trails	interaction jobdensity trails
jdens_bikeln	interaction jobdensity bikelane

Regression Results and Strata

Descriptive Statistics

A broad brush, initial classification of the pilot region into three site types helped us become familiar with the area. Of 383 census tracts in NCDOT's Divisions 7 and 9, 23 were classified as "university" site type, 158 "urban", and 202 "rural". Descriptive statistics are in Appendix A. Socioeconomics and demographics are different, with higher poverty population, lower car ownership, and higher mode share other than driving in university tracts compared to urban or rural tracts. Unsurprisingly, the estimated average number of pedestrian and bicyclist trips in university and urban tracts are greater than the number in rural tracts.

Regression Results

One census tract with no population (and hence no trips per capita) was excluded from all regression models. This tract was added back later to the sample when determining the strata based on the characteristics of the built environment and other relevant independent variables. The significant variables for the walking model are: percentage of population in colleges or universities, sidewalk in mileage, dummy variables of Carrboro-Chapel Hill tracts, job density, interaction job density with sidewalk, interaction percentage of poverty population with sidewalk, and interaction university tracts with sidewalk (not shown). The significant variables for the biking model are: percentage of population in colleges or universities, miles of bike lanes, miles of trails, road density, transit use per capita, percentage of population in poverty, interaction bike lanes mileage with trails, interaction between job density and trails, interaction percentage of college students and bike lane mileage, and the dummy variables for the Carrboro-Chapel Hill tracts (not shown).

The selected independent variables were then transformed into categorical variables (initially dummy variables, and if they remained significant, then into two dummy variables denoting three categories). Although we lose information by transforming the variables into dummy variables, it was the most transparent way of identifying relevant strata. **Table 22** and **Table 23** show the estimated coefficients for the independent variables for the walking and cycling model results. We utilized the Akaike Information Criterion (AIC) to measure the relative quality of the models for variable selection and to determine a subset of variables that could help identify the strata for sampling. Variables that made the largest contribution to decreasing the AIC were maintained in the mode.

The walking model has significantly better fit than the bicycling model. Almost 56% of the variation in the natural log of per capita walking, but only 18% of the variation in the natural log of per capita bicycling, is explained by the independent variables. Models that account for space explicitly (not shown) yielded better fit, but the results were largely consistent with those shown here. Residual plots maps for walking and biking regression models are presented in Appendix B.

Table 22. Regression Model of the Natural Logarithm of Per Capita Walking Trips (n=420)

Independent Variables	Definition	Coef.	Std.Err.
d_percol1	d_percol1=1 when % population in college are between 0.2 and 0.5	0.73	0.10***
d_percol2	d_percol2=1 when % population in college >=0.5	2.14	0.14***
d_side	d_side=1 when sidewalk >= 10 mile	0.27	0.06***
cch	cch=1 when tract is in Carrboro-Chapel Hill area	0.51	0.10***
d_jobd	d_jobd=1 when job density >= 6000 person per sq. mile	0.38	0.15***
dpercpov_dside	interaction d_percpov d_side; d_percpov=1 when % population in poverty>0.4, d_side=1 when sidewalk >= 10 miles	-0.30	0.11***
constant		-0.02	0.02

Adj R^2= 0.56

p<0.01 ***, p<0.05 **, p<0.1*

Table 23. Regression Model of the Natural Logarithm of Per Capita Bicycling Trips (n=420)

Independent Variables	Definition	Coef.	Std.Err.
cch	cch=1 when tract is in Carrboro-Chapel Hill area	0.98	0.20***
d_percol	d_percol=1 when % population in college > 0.4	0.62	0.21***
d_bikeln	d_bikeln=1 when bike lanes > 2 miles	0.30	0.18*
d_trails	d_trails=1 when trails > 1 mile	0.22	0.09**
constant		-2.21	0.04***

Adj R^2 = 0.18

p<0.01 ***, p<0.05 **, p<0.1*

Because the dependent variable in the models is log-transformed, coefficients can be interpreted as the percent change in the outcome (walking and bicycling rates) given a unit increase in the explanatory variable. For walking, it means that when the percentage of the population is greater than 50, per capita walking rates are 214% higher, holding everything else constant. Similarly, in tracts with greater than 10 miles of sidewalk or where job density exceeds 6,000 persons per square mile, per capita walking rates increase 27 % and 38%, respectively. For bicycling, when the percentage of the population is greater than 40, per capita bicycling rates are 62% higher, holding everything else constant. Having more than two miles of bicycle lanes and one mile of trails is associated with 30% and 22% higher bicycling per capita, respectively.

Strata Criteria

Based on the results from regression models above, all potential combinations from the independent variables were examined. In all, 48 possible combinations for the walking model and 16 combinations for the biking model were examined. These represent all the combinations of the dummy variables selected (3×2^4 combinations for walking and 2^4 combinations for bicycling) and constitute the strata from which to sample. Some combinations of dummy variables had no observations. If the number of tracts in a certain stratum was greater than 5, then the stratum was retained; otherwise it was merged. Strata were merged based on the value of bivariate and multivariate AIC estimates. **Table 24** and **Table 25** contain the walking and biking models' bivariate AIC, multivariate AIC, and their corresponding percentages of change relative to the constant-only model, respectively. Strata with variables that had a higher percentage of change in AIC relative to the constant-only model were left intact, while strata with variables that had a lower percentage of change in AIC were prioritized to be merged, for simplicity.

Table 24. Walking Model AIC Estimates

Variable	Bivariate AIC	% change	Multivariate AIC	% change
Constant only	624.55			
d_percol2	432.03	-30.8%		
cch	551.71	-11.7%	384.28	-11.05%
d_percol1	592.93	-5.1%	337.49	-12.18%
d_jobd	597.4	-4.3%	327.69	-2.90%
d_side	609.64	-2.4%	318.12	-2.92%
dpercpov_dside	626.38	0.3%	313.05	-1.59%

Table 25. Biking Model AIC Estimates

Variable	Bivariate AIC	% change	Multivariate	% change
Constant only	821.02			
cch	761.18	-7.3%		
d_percol	796.48	-3.0%	756.03	-0.68%
d_bikeln	802.65	-2.2%	754.12	-0.25%
d_trails	805.68	-1.9%	749.72	-0.58%

For the walking model, strata were merged based on the order of d_percol2, Carrboro-Chapel Hill, d_percol1, d_jobd, and d_side. For the biking model, strata were first merged based on Carrboro-Chapel Hill and followed by d_percol, d_bikeln, and d_trails. Strata were further aggregated to ensure a large enough number of tracts as well as for parsimony. The final strata with number of tracts and criteria for walking and biking models are presented in **Table 26** and **Table 27**.

Table 26. Resulting Walking Strata

Strata	# tracts	Criteria
1	8	% college population > 50%
2	12	Special zone (CCH) and not above
3	12	% college population > 20% but < 50% and not above
4	42	Sidewalk length > 10 miles and not above
5	309	Else (all 0s except for 2 obs with job density > 6000)

Table 27. Resulting Bicycling Strata

Strata	# tracts	Criteria
1	15	Special zone (CCH)
2	6	% population is students in college > 40%* and not in above
3	62	Miles of trails > 1 or Miles of bikelanes > 2 and not in above
4	300	Else (all 0s)

Ideal Sampling Plan

There are two inputs that go into the calculation of the sampling plan: the margin of error and the confidence level. The margin of error is the amount of error one is willing to tolerate. Lower margin of error requires a larger sample size. The confidence level is the amount of uncertainty one can tolerate. Suppose that you have 20 yes-no questions in your survey. With a confidence level of 95%, you would expect that for one of the questions (1 in 20), the percentage of people who answer *yes* would be more than the margin of error away from the true answer. The true answer is the percentage you would get if you exhaustively interviewed everyone. Higher confidence level requires a larger sample size. We show resulting samples for 95% and 90% levels of confidence, assuming a normal distribution.

The sample size is calculated as:

$$sample\ size = \frac{Z^2 \times p \times (1-p)}{c^2}$$

Where:

Z = Z value-from normal table (e.g., 1.96 for 95% confidence level)
p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)
c = margin of error, expressed as decimal (e.g., 0.05)

Finally, we correct for finiteness of the population:

$$corrected\ sample\ size = \frac{sample\ size}{1 + \frac{sample\ size - 1}{n}}$$

Where n is the population size (421 census tracts in our case). The resulting sampling plan suggests observing tracts (and within them a count location) for between 7 and 172 tracts for walking and 6 and 169 for bicycling, depending on the confidence level and tolerated margin of error. The least conservative approach, and closer to what is recommended here, suggests a sample between 7 and 28 tracts for walking and 6 and 28 tracts for cycling as shown in **Table 28** and **Table 29**.

Table 28. Walking Tract Sample Sizes for Different Confidence Levels and Margins of Error

			95% Confidence level			***90% Confidence level***		
Strata label	**# tracts**	**Mean road segments per tract**	**MoE 10%**	**MoE 15%**	**MoE 20%**	**MoE 10%**	**MoE 15%**	**MoE 20%**
High college	8	144.9	8	7	7	8	7	6
Special interest	12	230.6	11	10	9	11	9	8
Medium college	12	254.8	11	10	9	11	9	8
Sidewalk facilities	42	272.6	30	22	16	27	18	13
Other	309	324.5	74	38	23	56	28	17

Table 29. Bicycling Sample Sizes for Different Confidence Levels and Margins of Error

			95% Confidence level			***90% Confidence level***		
Strata label	**# tracts**	**Mean road segments per tract**	**MoE 10%**	**MoE 15%**	**MoE 20%**	**MoE 5%**	**MoE 10%**	**MoE 10%**
Special interest	15	205.4	14	12	10	13	11	9
Medium-high college	6	169.5	6	6	5	6	6	5
Bicycle facilities	62	268.3	38	26	18	33	21	14
Other	300	326.43	73	38	23	56	28	17

Conclusion

The regression models' results suggest that college population, whether in Carrboro-Chapel Hill tracts, and pedestrian and bicyclist infrastructure's coverage are important indicators for understanding the site classification and forecasting the non-motorized travel demand. The site classification and selection criteria served as a framework for guiding further efforts in determining the sample size and identifying candidate site locations. One could assume that segments within these tracts have equal volumes, and proceed to select a single location within a tract.

Overlaying the different strata for bicycling and walking suggests areas of coincidence and areas of difference (**Figure 16**). Although most tracts overlap in how we classify them into strata for walking and bicycling, this is driven largely by the fact that the "other" category is quite large. Tracts shown in green are the high walkability and high bikeability tracts that coincide among the two stratification processes. Vertical or horizontal shading indicates differences in how a given tract was stratified in both approaches.

One possible next step of this research would be to develop a methodology to assign the estimated trips to the street network's major segments. An increasing number of studies have focused on analyzing non-motorized travel behavior and forecasting non-motorized travel demand using the theory of space syntax, and they widely acknowledge that there is clear correlation between the presence and magnitude of non-motorized activities and several measures of a spatial network (i.e., axial maps). Further study will examine the relationships between syntactical measures and non-motorized activities using existing observed counts in the Carrboro and Greensboro areas. The expected outcomes are intended to help determine the major street segment selection at the micro-level within the site locations.

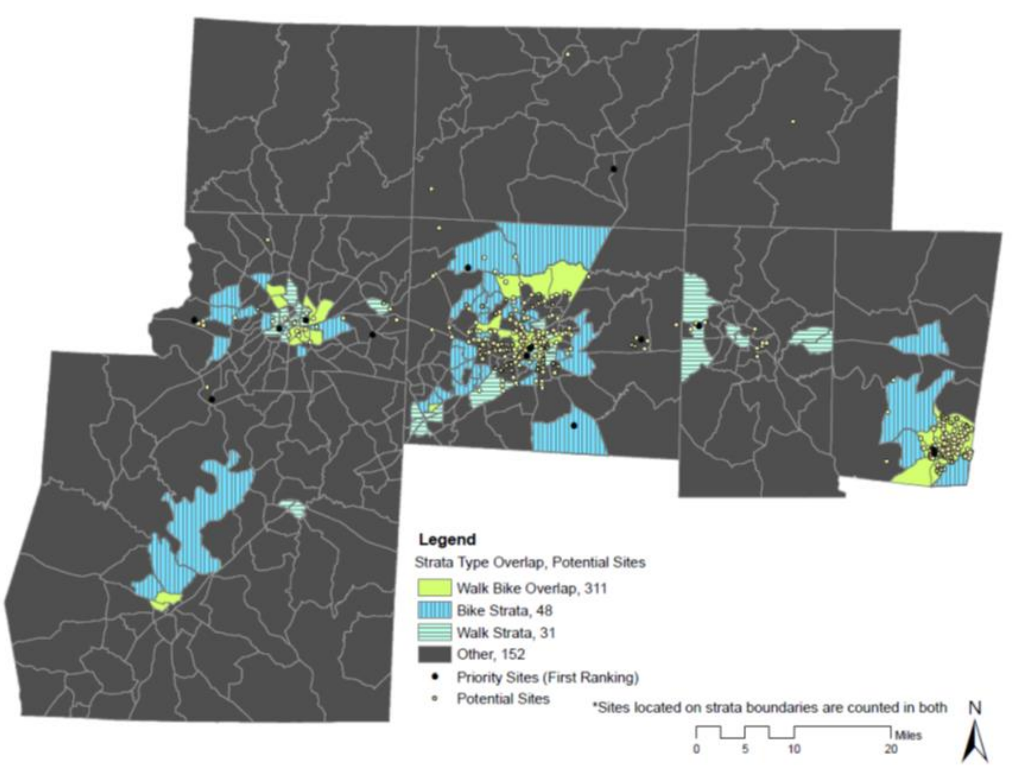

Figure 16. Overlapping walking and bicycling strata in pilot region

Appendix C. Example Memorandum of Agreement used in Phase 1

NCDOT Non-Motorized Counts Hardware
Memorandum of Agreement

This Memorandum of Agreement, hereinafter referred to as the "Agreement", is made and entered into on the last date executed below, by and between the North Carolina Department of Transportation, an agency of the State of North Carolina, hereinafter referred to as the "Department", and the Winston-Salem Urban Area MPO hereinafter referred to as the "MPO".

WITNESSETH:

WHEREAS, the North Carolina Department of Transportation seeks to establish a statewide Non-Motorized Traffic Monitoring Program; and,

WHEREAS, the Winston-Salem Urban Area MPO has agreed to participate in data collection needs and to assume certain responsibilities in the manner and to the extent as hereinafter set out; and,

NOW, THEREFORE, the parties hereto shall approve this Agreement within sixty (60) days of receipt of this Agreement. In the event the MPO fails to approve said Agreement within sixty (60) days of receipt, the MPO forfeits its access to the equipment and training offered by the Department as hereinafter stated.

This Agreement states the promises and undertakings of each party as herein provided, and the parties do hereby covenant and agree, each with the other, as follows:

1. GENERAL PROVISIONS

The MPO shall be responsible for administering all work performed and for certifying to the Department that all terms set forth in this Agreement are met and adhered to by the MPO and/or its agents. The MPO may select any agent with which it has established agreements or contracts equal to the terms of this Agreement. Such agents may include a local government member of the MPO or a contractor qualified and approved to perform the work described in this Agreement.

The Department and/or its agents will provide technical oversight to guide the MPO and/or its agent. The MPO and/or its agent must provide a primary contact for the program to the Department upon approving this Agreement.

The MPO and/or its agent shall complete installation activities described in project exhibits by September 30, 2014 unless provided an agreed-to alternative installation deadline by the Department and/or its agent. The MPO and/or its agent will complete these installation activities at no cost to the Department.

Failure on the part of the MPO to comply with any of the provisions of this Agreement will be grounds for the Department to terminate its participation, take the counter equipment back from the MPO and, if applicable, seek repayment for any damage done to the equipment beyond standard wear and tear.

Any administrative modifications to this Agreement or its terms will be agreed upon in writing by all parties prior to being implemented. The Department may delegate the approval of these administrative modifications to the Director of the Department's Bicycle and Pedestrian Division.

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2. SCOPE OF PROJECT

The MPO and/or its agent is responsible for installing, monitoring and maintaining counter equipment at permanent continuous count station locations as specified in project exhibits and descriptions of work. All station locations must be identified and selected in accordance to the Department's Non-motorized Traffic Monitoring program. The MPO will submit candidate sites to the Department for approval prior to the installation of any counter equipment. Both parties will provide access to data collected through the provided equipment.

The Department will provide the MPO and/or its agents with the bicycle and pedestrian counter equipment and other hardware which adhere to the following specifications:

- differentiate between pedestrians and cyclists, using bicycle detector loops and passive infrared sensors
- measure the direction of travel of both pedestrians and cyclists
- transmit data wirelessly
- do not have any speed restrictions on capturing data
- detect pedestrians or cyclists at minimum distance of 10'
- record count data at 15 minute intervals for minimum of 300 days per year
- may be removed using readily available tools and street maintenance equipment
- include necessary supporting installation equipment such as any enclosure box, post, screws, bands, cables, wires, etc
- include posts and loops are designed to reasonably blend in with surroundings
- enclosed in a secure box or structure with key entry or other unlocking device included
- include any necessary cords to connect a field computer to the count device
- include a minimum 2 year warranty for all equipment and software
- include a manual describing installation procedures, specifications, and maintenance instructions
- contained by waterproof design
- having a battery life of 2 years for loop detectors, and 10 years for passive sensor equipment
- having data compatibility with Microsoft Office Excel (v 2010 or later)

The Department and/or its agent will also offer an initial training to the MPO and/or its agents and provide ongoing technical support to the MPO and/or its agents regarding installation, monitoring and maintenance needs of the equipment as further set forth in this Agreement. As the equipment is received, a unique identifier code will be assigned to each set of equipment. This inventory of code information will be conveyed to the MPO and/or its agent at such time the equipment is delivered.

3. USEFUL LIFE

The Useful Life of this equipment is determined to be ten (10) years. Any agreements entered into shall be for the length of the Useful Life.

4. ENCROACHMENT AGREEMENT

If any part of the equipment is to be located on State Highway System right of way or property, the MPO shall secure an Encroachment Agreement with the Department prior to performing any work or improvements on that right of way or property.

5. RIGHT TO INSPECT

The Department and/or its agent shall have the right to inspect, test, approve or reject, any portion of the work being performed by the MPO or its agent(s) to ensure compliance with the provisions of this

Agreement. Any deficiencies inconsistent with the Department's data collection protocols or Non-Motorized Travel Monitoring Guidebook and specifications found during an inspection must be corrected. The Department will cede this right to inspect once ownership of the equipment is conveyed to the MPO.

6. CONTRACTOR COMPLIANCE

The MPO will be responsible for ensuring that its agent(s) and contractor(s) comply with all of the terms of the contract and any instructions issued by the Department as a result of any review or inspection made by said representatives.

7. MAINTENANCE

The MPO and/or its agent, at no expense or liability to the Department, shall assume all routine maintenance responsibilities for the counter equipment provided, or as required by an executed encroachment agreement. Expected routine maintenance responsibilities may include battery replacement, removing obstructions or equipment hazards on or near the equipment, and monitoring the security of the equipment. The MPO and/or its agent(s) should ensure that it does not perform any activities which may interfere with the equipment's condition or functionality.

8. OWNERSHIP

The MPO and/or its agent will assume ownership of the hardware as early as twenty-four (24) months after installation, per authorization by the Department. The MPO will be held to the terms of this agreement through the Useful Life of the equipment.

The Department and/or its agent will be responsible for replacing malfunctioning equipment, data transmittal charges, and for any other non-routine hardware or software maintenance during its period of ownership. The MPO and/or its agent will be responsible for all equipment maintenance and improvements when it assumes ownership. The MPO will be responsible for data transmittal charges and parts replacement when it assumes ownership.

After the MPO has assumed ownership of the equipment, the Department (or its contractor) will require written approval from the MPO to inspect or otherwise access the equipment. The MPO and the Department will continue to provide access to data collected by the equipment during the Useful Life of the equipment. This data will continue to be subject to the Department's formats and standards as defined by its Non-Motorized Traffic Monitoring Program.

MPO REPRESENTATIVE

Signed by: ______________________________

Title: __________________________________

Date: ____________________

DEPARTMENT OF TRANSPORTATION

Signed by: ______________________________ (Deputy Secretary for Transit)

Date: ____________________

APPROVED BY BOARD OF TRANSPORTATION - ITEM O: ____________________ (Date)

3

Appendix D. CCS Installation: Agency Roles and Responsibilities

Non-Motorized Volume Data Program – Continuous Count Station Installation
North Carolina Department of Transportation

This document explains the general process of continuous counter installations conducted through the Non-Motorized Volume Data Program. It clarifies roles and responsibilities between ITRE, acting as NCDOT's agent, and the local municipality and/or its contractor.

For a general overview of the equipment installation, please review this video: https://www.youtube.com/watch?v=y4nVwjnESzw.

ITRE, in coordination with the local agency, will select the installation site based on interference testing, feasibility, and the factor group(s) it is expected to represent. Count equipment is purchased by NCDOT with ownership reverting to the local agency per the memorandum of agreement.

Local Agency Responsibility

1. Locate utilities
2. Set up and manage traffic control
3. If applicable, set concrete with anchors and run conduit (note – for curing time, this may be done prior to equipment installation day)
4. Mark loop template with paint
5. Saw cut loops and any extensions to curb/edge of pavement
6. Clean channels
7. If curb present, drill hole and run conduit
8. Excavate earth for rainbird and/or post
9. Wire loops (with ITRE assistance)
10. Twist and feed wires through cuts/conduit
11. Set post and/or rainbird and tighten bolts/fill holes
12. Seal loops
13. Clean up site

ITRE Responsibility

1. Bring counter equipment to be installed
2. Test for interference
3. Determine loop placement
4. Determine post placement
5. Calculate and draw loop template
6. Check channel depths
7. Check wire installation
8. Check twist frequency
9. Connect wires to count equipment
10. Check post alignment and sensor height
11. Test equipment (with assistance from municipality)
12. Conduct diagnostics/compile logger information

Last updated 7/31/15

NC Non-Motorized Volume Data Program

Bicycle and Pedestrian Counting Equipment
Installation Materials List
October 21, 2015

Vendor / Agency Responsible

- Paint and line for marking loops
- Saw cutter (s) (preferably one self-propelled and one hand-driven wet saw cutter) – loops will be cut in the concrete/asphalt in a specific diamond shape for bicycle counting
- Saw blades – One for asphalt, one for concrete
- Water and Hose – to make wet saw cuts
- Gasoline to power the saw cutting equipment
- Chisel for popping out small sections of the cut
- Electric drill (used to spin the wires together)
- Backer Board (Rod) to help in sealing the epoxy and used to keep loop wires in saw cut channel and to hold sealant from leaking out of curb while curing (not always required, but should have on hand)
- Loop sealant (cannot exceed 140 degrees when curing, excludes most epoxy type sealants. 3M 5000 Loop Detector Sealant and Chemique QSeal 2905 meet specifications. If intending to use another type of sealant, please contact ITRE in advance with sealant specs.)
- Squeegee for loop sealant
- Conduit to protect the wires leading from the sawcut back to logger housing
- Shovel
- Auger for digging hole (optional)
- Rake / Broom for site clean up
- Hammer
- Screw drivers in various sizes in both formats (flat and Phillips)
- Duct tape
- Wet/dry vacuum for environmental control
- Cones
- Level
- Safety vests for ALL staff
- Traffic control at site (motor vehicles, bicyclists and pedestrians)

URBAN POST INSTALLATIONS*

- 3/4" anchors, bolts, and washers for leveling
- Concrete drill bit for anchors

*Set mounting cage in advance

RAINBIRD INSTALLATIONS (also called a Sprinkler Box)

- Gravel Fill - In order to provide acceptable drainage for logging equipment, some locations require deeper excavation and gravel fill under the rainbird.

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NC Non-Motorized Volume Data Program

ITRE Responsible

- Interference tester
- Wires for making loops
- Square for checking sawcut depth
- 4-foot straight edge for drawing loops
- Tape Measure
- Chalk for drawing loops
- Logging equipment and housing (mounting cage*, urban post, wooden post or rainbird)
- Wire connectors
- Wire cutters
- Electrical tape
- Specialty screwdrivers/bits
- Bicycle for testing equipment
- Laptop for finalizing and testing equipment
- Magnetic Key for waking equipment
- On-site validation equipment
- Safety vests for ITRE staff
- Tool kit to pass over to Agency upon completion of installation (specialty screwdriver, magnetic key, etc.) for maintenance of equipment.

*May be shipped in advance for agency to set in concrete prior to installation of URBAN POST only

Appendix E. CCS Installation: ITRE Onboarding Checklist

NC NON-MOTORIZED VOLUME DATA PROGRAM

NMVDP INSTALLATION PROCEDURES CHECKLIST

Pre-Installation

Site Name:	Interference reading at Site Visit:
_	

Serial Number:	NCDOT ID:

Agency/Contractor Contact(s):	Cell Number(s):

Loop Diagram: (Number of Loops, Loop Size, Spacing)

Installation Diagram: (Street/Path, Cross Streets on Either Side, Indicate Location of Equipment)

N

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ITRE

NC Non-Motorized Volume Data Program

Installation Notes

Installation Date: Start Time: End Time:

Verify Serial Number: Interference Reading at Installation:

Installer:

GPS Coordinates:

N ° . ′ W ° . ′

Eco Visio:

- ❑ Install and Pair the Counter
- ❑ Modem Test, Results:

PED Inbound Direction: PED Outbound Direction:

BIKE Inbound Direction: BIKE Outbound Direction:

- ❑ Give key/tools to local agency
- ❑ Write installation date on battery
- ❑ Explain basic maintenance procedures

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NC Non-Motorized Volume Data Program

On-Site Equipment Validation

On-Site Equipment Validation (Prior to Sealing Loops)

Pedestrian Test

Actual Dir	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
	Near Side --- Far Side																			
PASS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Detected Dir																				
Detected Mode																				
% Error																				
Notes:																				

Bicycle Test

Actual Dir	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
	Near Side ------- A1 ------- Far Side								Middle				Near Side ------- A2 ------- Far Side							
PASS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Detected Dir																				
Detected Mode																				
% Error																				
Notes:																				

Re-Test:

Actual Dir	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT	IN	OUT
PASS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Detected Dir																				
Detected Mode																				
% Error																				
Notes:																				

Eco-Counter Customer Support: 1-866-849-9779 / 1-866-518-4404

NC Non-Motorized Volume Data Program

Post Install Validation

- ☐ Mark edge of bicycle zone with spray chalk
- ☐ Mark edge of pedestrian zone with flag if no natural/man made barrier
- ☐ Take photos of site with surrounding context, ensuring any posts, poles, or trees are visible
- ☐ Set up Validation Camera

Appendix F. Equipment Specifications for NCDOT's Request for Bids

SPECIFICATIONS:
Bicycle and pedestrian count equipment must be able to do or include the following:

- differentiate between pedestrians and cyclists, using bicycle detector loops and passive infrared sensors
- measure the direction of travel of both pedestrians and cyclists
- transmit data wirelessly
- not have any speed restrictions on capturing data
- detect pedestrians or cyclists at minimum distance of 10'
- record count data at 15-minute intervals for minimum of 300 days per year
- be removable using readily available tools and street maintenance equipment
- include necessary supporting installation equipment such as any enclosure box, post, screws, bands, cables, wires, etc.
- be enclosed in a secure box or structure with key entry or other unlocking device included
- include any necessary cords to connect a field computer to the count device
- include a minimum 2-year warranty for all equipment and software
- include a manual describing installation procedures, specifications, and maintenance instructions
- waterproof design
- temperature tolerance of -10°F to 105°F

In addition to those features included above, the passive infrared sensor component of the counter systems shall have the following features:

- battery life for unit 10 year minimum
- detection height of 24"-36" within a vertical post or structure

In addition to those features included above, the loop detector component of the counters shall have the following features:

- battery life minimum of 2 years
- total loop length: 3' to 5'
- total loop width: 15"-24"

Software used for transmittal and storage of data shall allow for the following:

- collection of weather information
- wireless data transmittal
- database or data compatibility with Microsoft Office Excel (v 2010)

Appendix G. Equipment Inventory

Screenshot of tracking spreadsheet used to track equipment inventory by station.

Site #	Division	Phase	Location	LoggerName	Install Date	Item #	Logger Side	Bike Dir	Serial Number	GPS Coordinates (DD)	Eco-Counter Description	Spec Sheet	GSM Number	NCDOT ID	COUNTY CODE	NMVDP STATION ID	Check In Date	Battery life	Battery Type	Loops Installed
Site 1	9	I	Winston-Salem	W-S_4TH_S_EB	9/17/2014	Item 1	S	EB	YUG14086212	N36.098167 W080.247567	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.86.07	267714	33	C3300003	9/12/2014	2	744	2
				W-S_4TH_N_WB	9/17/2014		N	WB	YUG14086213	N36.098017 W080.24748	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.85.66	267711	33		9/12/2014	2	744	2
Site 2	9	I	Winston-Salem	W-S_SLG	10/16/2014	Item 5			Y2H14086242	N36.09288 W080.19205	Eco-MULTI with 3 preformed ZELT Loops	MULTI COUNTER	06.31.15.12.54	267721	33	C3300004	9/12/2014	1	744	2
Site 3	7	I	Greensboro	GSO_WAL_S_EB	11/10/2014	Item 1	S	EB	YUG14086214	N36.06649 W079.80411	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.83.63	267716	40	C4000004	9/12/2014	2	744	2
				GSO_WAL_N_WB	11/10/2014		N	WB	YUG14086215	N36.06657 W079.80379	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.83.15	267720	40		9/12/2014	2	744	2
Site 4	7	I	Carrboro	CRB_LCB	12/11/2014	Item 2			Y2H14096279	N35.90842 W079.06612	Urban-MULTI with 4 loops Greenway set	Urban MULTI COUNTER	06.43.87.04.56	267727	67	C6700002	10/16/2014	1	898	3
Site 5	9	I	Winston-Salem	W-S_END_W_SB	11/14/2014	Item 1	W	SB	YUG14086216	N36.10050 W080.26083	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.83.14	267715	33	C3300005	9/12/2014	2	744	2
				W-S_END_E_NB	11/10/2014		E	NB	YUG14086217	N36.10020 W080.26087	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.81.74	267718	33		9/12/2014	2	744	2
Site 6	7	I	Greensboro	GSO_SPR_N_WB	9/19/2014	Item 1	N	WB	YUG14086218	N36.06657 W079.80379	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.79.93	267712	40	C4000003	9/12/2014	2	744	2
				GSO_SPR_S_EB	9/19/2014		S	EB	YUG14086219	N36.06649 W079.80411	Urban-MULTI with 2 loops selective & in	MULTI COUNTER	06.31.15.78.21	267713	40		9/12/2014	2	744	2
Site 7	9	I	Winston-Salem	W-S_STR	9/16/2014	Item 6			Y2H14086243	N36.08705 W080.24386	Eco-MULTI with 2 loops	MULTI COUNTER	06.31.15.11.89	267726	33	C3300002	9/12/2014	2	898	2
Site 13	9	I	Winston-Salem	W_S_ACA	9/16/2014		S	Both Direction	Y2H14086244	N36.08727 W080.24402	Stretch ZELT with 4 selective loops	ZELT COUNTER	06.31.15.11.40	267725	33	C3300001	9/12/2014	1	898	4
Site 8	7	I	Greensboro	GSO_LDG	9/18/2014	Item 4			Y2H14086235	N36.07977 W079.81432	Eco-MULTI with 2 loops	MULTI COUNTER	06.31.15.28.51	267724	40	C4000002	9/12/2014	2	898	2
Site 9	7	I	Greensboro	GSO_ELM_E_NB	9/18/2014	Item 1	E	NB	YUG14086221	N36.06926 W079.79048	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.76.75	267719	40	C4000001	9/12/2014	2	744	2
				GSO_ELM_W_SB	9/18/2014		W	SB	YUG14086220	N36.06926 W079.79048	Urban-MULTI with 2 loops selective & in	Urban MULTI COUNTER	06.31.15.73.87	267717	40		10/16/2014	2	744	2
Site 10	7	I	Carrboro	CRB_OLD_E_NB	12/11/2014	Item 3	E	NB	Y2H14096282	N35.93412 W079.10204	Urban-MULTI with 4 loops Selective (2+2	Urban MULTI COUNTER	06.31.15.08.07	267728	67	C6700001	10/16/2014	1	744	2
				CRB_OLD_W_SB	12/11/2014	NA-See Note	W	SB	Y2H14106620	N35.93487 W079.10250	2 Loop ZELT Selective (converted Urban M	ZELT COUNTER	06.71.68.82.62	267738	67		12/4/2014	2	898	2
Site 11	7	I	Chapel Hill	CHL_MLK_W_SB	12/10/2014	Item 1	W	SB	Y2H74096280	N35.91611 W079.05715	Urban-MULTI with 3 loops (2 SE + 1 GW) &	Urban MULTI COUNTER	06.31.18.91.45	267729	67	C6700003	10/16/2014	1	898	2
				CHL_MLK_E_NB	12/10/2014		E	NB	Y2H14096281	N35.91618 W079.05672	Urban-MULTI with 3 loops (2 SE + 1 GW) &	Urban MULTI COUNTER	06.31.18.67.20	267730	67		10/16/2014	1	898	2
Site 12	5	I	Durham	DRH_ATT	9/17/2014	Item 4			Y2H14086236	N35.90903 W078.94175	Eco-MULTI with 2 loops	MULTI COUNTER	06.31.15.26.91	267723	31	C3100001	9/12/2014	2	898	2

Appendix H. CCS Installation: ITRE Materials Checklist

NC Non-Motorized Volume Data Program

NMVDP CCS Installation Materials Checklist - ITRE

- ☐ Installation Procedures checklist
- ☐ Installation Binder with Site Selection Notes
- ☐ Sunscreen
- ☐ Safety Vests for ITRE Staff
- ☐ Work Gloves
- ☐ Camera
- ☐ Water Bottle
- ☐ Eye Protection / Sunglasses
- ☐ Interference tester
- ☐ Wires for making loops
- ☐ Square for checking sawcut depth
- ☐ 4-foot straight edge for drawing loops
- ☐ Tape Measure
- ☐ Chalk for drawing loops
- ☐ Logging equipment and housing (mounting cage*, urban post, wooden post or rainbird)
- ☐ Wire connectors
- ☐ Wire cutters
- ☐ Electrical tape
- ☐ Specialty screwdrivers/bits
- ☐ Bicycle for testing equipment
- ☐ Laptop/Tablet for finalizing and testing equipment
- ☐ Magnetic Key for waking equipment
- ☐ On-site validation equipment
- ☐ Safety vests for ITRE staff
- ☐ Tool kit to pass over to Agency upon completion of installation (specialty screwdriver, magnetic key, etc.) for maintenance of equipment.

*Mailed in advance of install

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NC Non-Motorized Volume Data Program

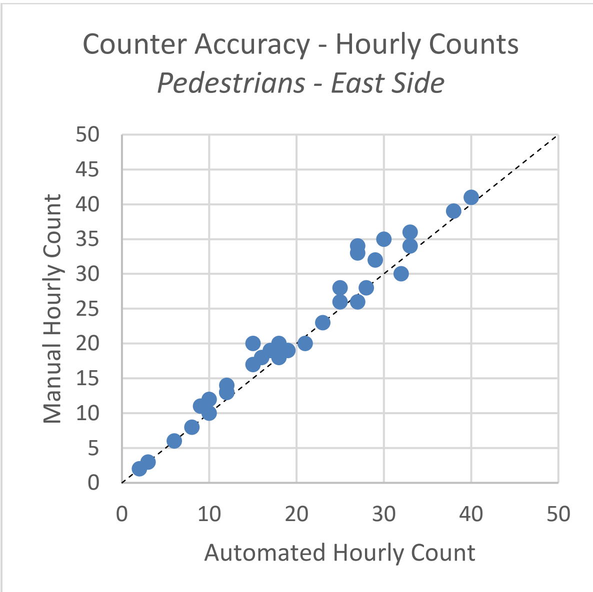
NMVDP Validation Materials Checklist - ITRE

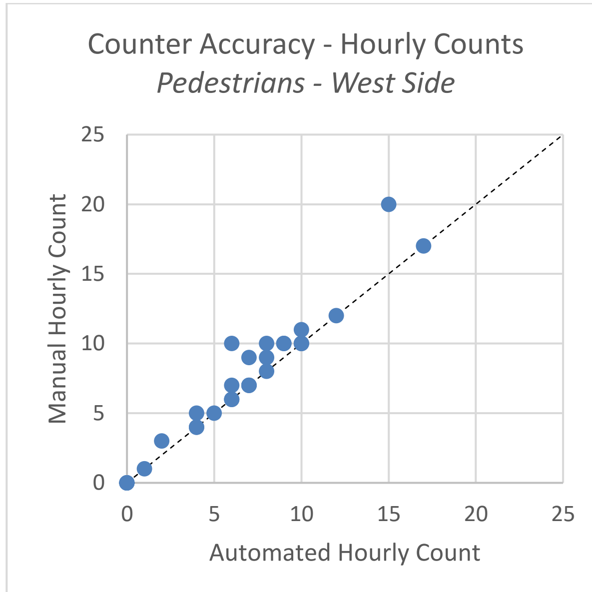
- ☐ Spray Chalk for demarcating edge of bicycle zone
- ☐ Lawn Flags for demarcating edge of pedestrian zone
- ☐ Ladder
- ☐ Ammo Box (Battery – check with volt meter, ~12V)
- ☐ Wire Splitters
- ☐ Monitor for camera
- ☐ DVR Remote
- ☐ Double-Male and Double-Female Splitter
- ☐ Sun Shield
- ☐ Electrical Tape
- ☐ DVR Recorder
- ☐ SD Cards
- ☐ Zip Ties
- ☐ Paint Poles and Hose Clamps
- ☐ Drill and Bit (for hose clamps)
- ☐ Camera
- ☐ Cable with Lock
- ☐ Ratcheting Straps
- ☐ Electronics Screwdriver

Appendix I. Validation, Accuracy Analyses, and Correction Factors Results

MLK Junior Boulevard // Chapel Hill, NC

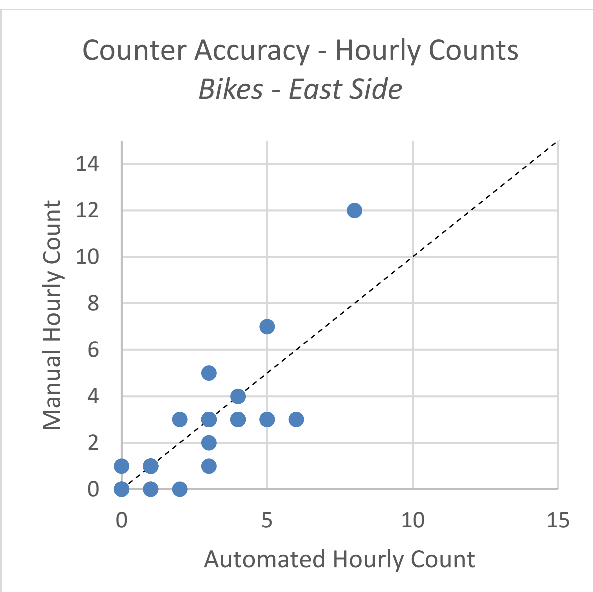
1. Manual vs. Automated Scatter Plots

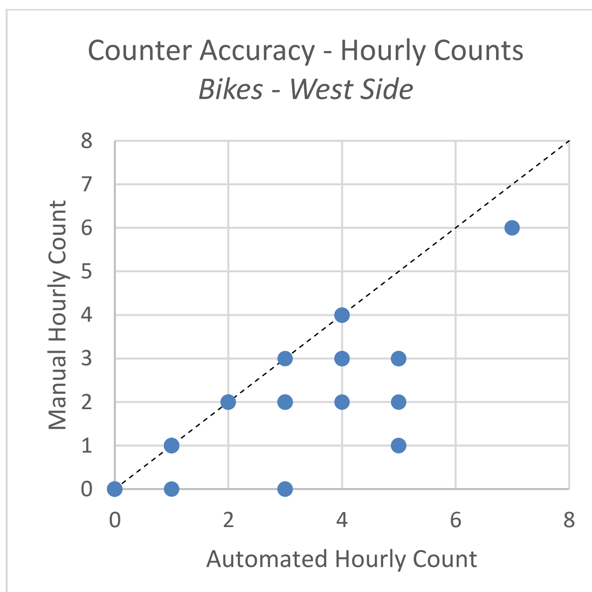




Pedestrian East Side Validation Dates:
12/09/14 06:00-22:00, 05/30/15 06:00-22:00

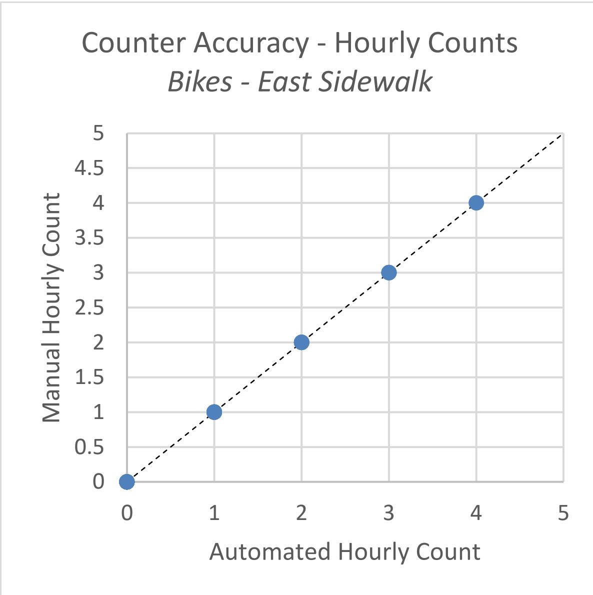
Pedestrian West Side Validation Dates:
12/03/15 06:00-20:00, 12/05/15 06:00-22:00

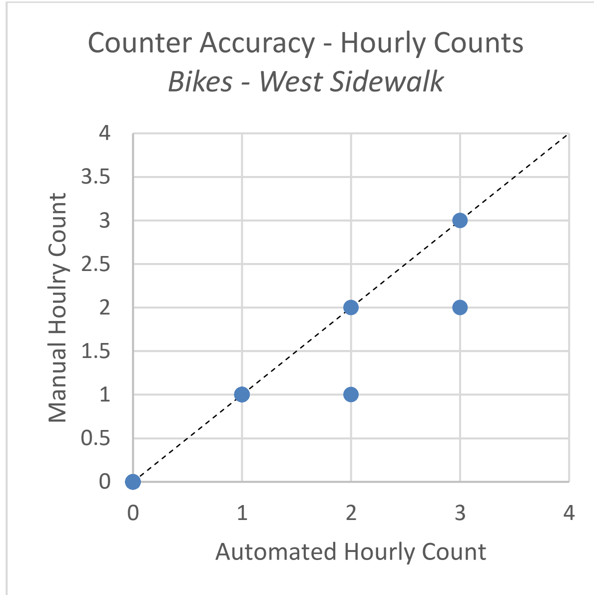




Bike East Side Validation Dates:
05/14/15 06:00-22:00, 05/30/15 06:00-22:00

Bike West Side Validation Dates:
12/03/15 06:00-20:00, 12/05/15 06:00-22:00





Bike East Sidewalk Validation Dates: 05/14/15 06:00-22:00, 05/30/15 06:00-22:00

Bike West Sidewalk Validation Dates: 12/03/15 06:00-22:00, 12/05/15 06:00-22:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian – East Side[1]	1.48%	1.29%	8.14%	0.982	32	21.5
Pedestrian – West Side[2]	1.55%	1.55%	9.17%	0.970	30	7.267
Bike – East Side[3]	-0.42%	0.26%	30.67%	0.831	32	2.34375
Bike – West Side[4]	-0.16%	0.16%	45.10%	0.736	30	1.7
Bike – East Sidewalk[5]	0.00%	0.00%	0.00%	1.000	32	0.96875
Bike – West Sidewalk[6]	0.00%	2.08%	10.53%	0.963	32	0.59375

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/09/14 06:00-22:00, 05/30/15 06:00-22:00
[2] Validation dates: 12/03/15 06:00-20:00, 12/05/15 06:00-22:00
[3] Validation dates: 05/14/15 06:00-22:00, 05/30/15 06:00-22:00
[4] Validation dates: 12/03/15 06:00-20:00, 12/05/15 06:00-22:00
[5] Validation dates: 05/14/15 06:00-22:00, 05/30/15 06:00-22:00
[6] Validation dates: 12/03/15 06:00-22:00, 12/05/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.067	66.13
R^2	0.9930	4373.75
AIC	137.490	--

Validation Dates: 12/09/14 06:00-22:00, 05/30/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.067 * (Automated\ Hourly\ Count)$$

Pedestrian Hourly Count Regression – West Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.097	40.52
R^2	0.9826	1641.77
AIC	94.915	--

Validation Dates: 12/03/15 06:00-20:00, 12/05/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.097 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.954	12.82
R^2	0.8414	164.42
AIC	110.899	--

Validation Dates: 05/14/15 06:00-22:00, 05/30/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 0.954 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – West Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.610	10.99
R^2	0.8064	120.78
AIC	85.96192	--

Validation Dates: 12/03/15 06:00-20:00, 12/05/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 0.610 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – East Sidewalk

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.0	--
R^2	1.0	--
AIC	--	--

Validation Dates: 05/14/15 06:00-22:00, 05/30/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.0 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression – West Sidewalk

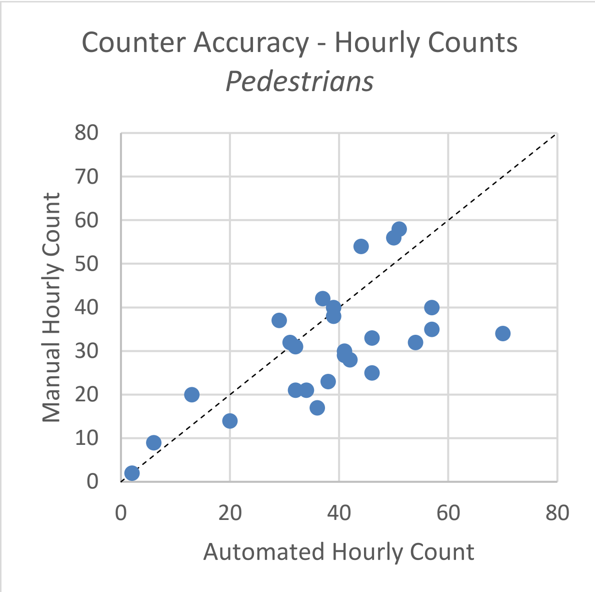
	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.865	25.45
R^2	0.9543	647.84
AIC	-9.102	--

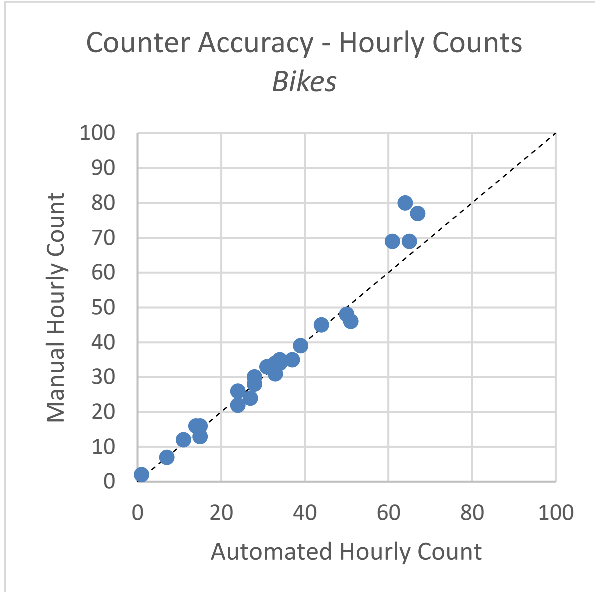
Validation Dates: 12/03/15 06:00-22:00, 12/05/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 0.865 * (Automated\ Hourly\ Count)$

Libba Cotten Bikeway // Carrboro, NC

1. Manual vs. Automated Scatter Plots





Pedestrian Validation Dates:
12/03/15 06:00-20:00, 12/05/15 06:00-18:00

Bike Validation Dates:
12/03/15 06:00-20:00, 12/05/15 06:00-18:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian[1]	-0.53%	0.38%	35.21%	0.670	26	30.808
Bike[2]	3.91%	1.70%	7.99%	0.983	26	34.654

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/03/15 06:00-20:00, 12/05/15 06:00-18:00
[2] Validation dates: 12/03/15 06:00-20:00, 12/05/15 06:00-18:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.789	15.46
R^2	0.9053	239.09
AIC	197.1144	--

Validation Dates: 12/03/15 06:00-20:00, 12/05/15 06:00-18:00

Regression Equation:
$Corrected\ Hourly\ Count = 0.789 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression

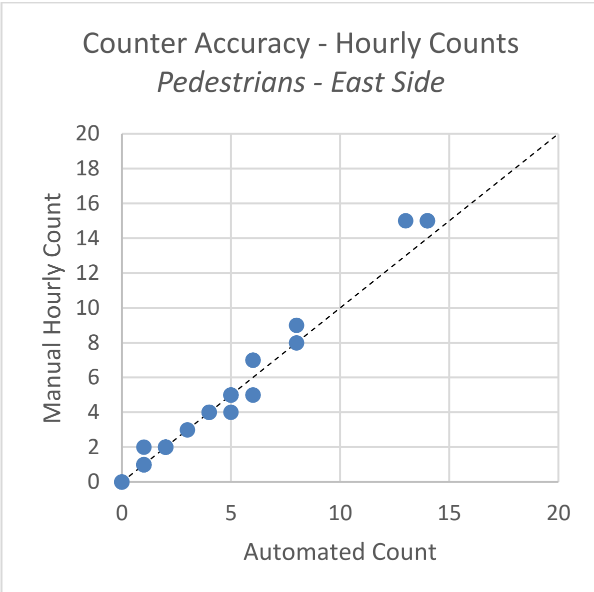
	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.059	51.68
R^2	0.9907	2670.83
AIC	146.053	--

Validation Dates: 12/03/15 06:00-20:00, 12/05/15 06:00-18:00

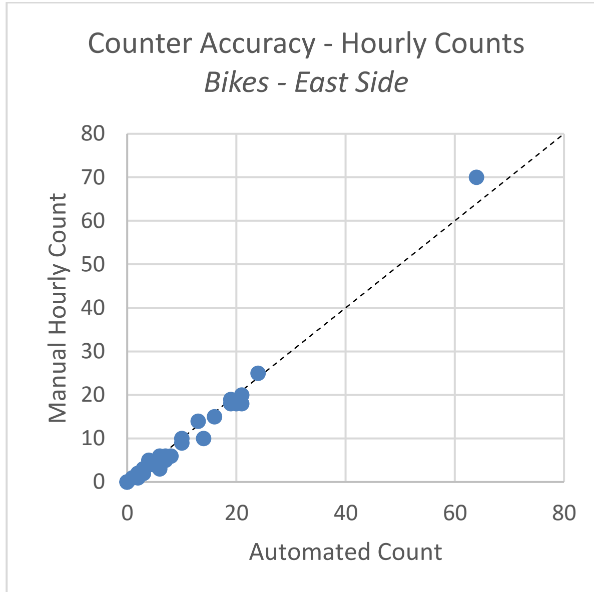
Regression Equation:
$Corrected\ Hourly\ Count = 1.059 * (Automated\ Hourly\ Count)$

Old NC 86 // Carrboro, NC

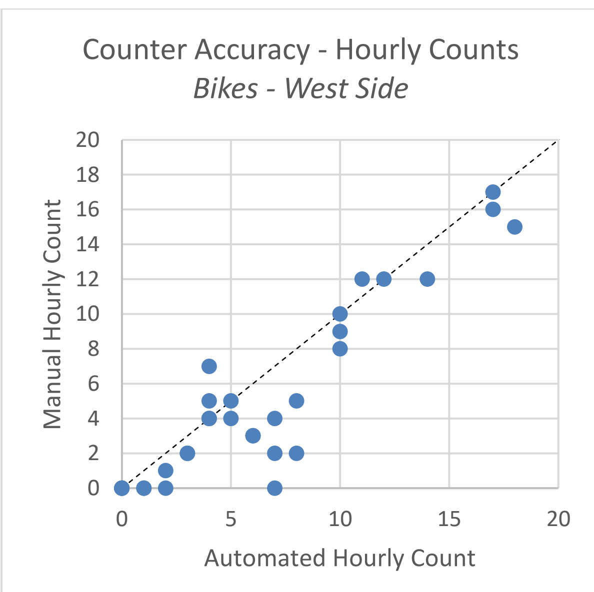
1. Manual vs. Automated Scatter Plots



Pedestrian East Side Validation Dates:
05/14/2015 06:00-22:00, 05/16/15 06:00-22:00



Bikes East Side Validation Dates:
05/14/15 06:00-22:00, 05/16/15 06:00-22:00



Bikes West Side Validation Dates:
05/14/15 06:00-22:00, 05/17/15 06:00-22:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian – East Side[1]	6.09%	1.72%	7.91%	0.992	32	4.34
Bike – East Side[2]	-0.66%	0.57%	11.15%	0.994	32	9.53
Bike – West Side[3]	-0.14%	0.13%	25.00%	0.921	32	5.125

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 05/14/2015 06:00-22:00, 05/16/15 06:00-22:00
[2] Validation dates: 05/14/15 06:00-22:00, 05/16/15 06:00-22:00
[3] Validation dates: 05/14/15 06:00-22:00, 05/17/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.057	60.34
R^2	0.9916	3640.32
AIC	54.623	--

Validation Dates: 05/14/15 06:00-22:00, 05/16/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.057 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.017	52.37
R^2	0.9888	2742.34
AIC	126.530	--

Validation Dates: 05/14/15 06:00-22:00, 05/16/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.017 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – West Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.845	18.84
R^2	0.9197	354.88
AIC	138.678	--

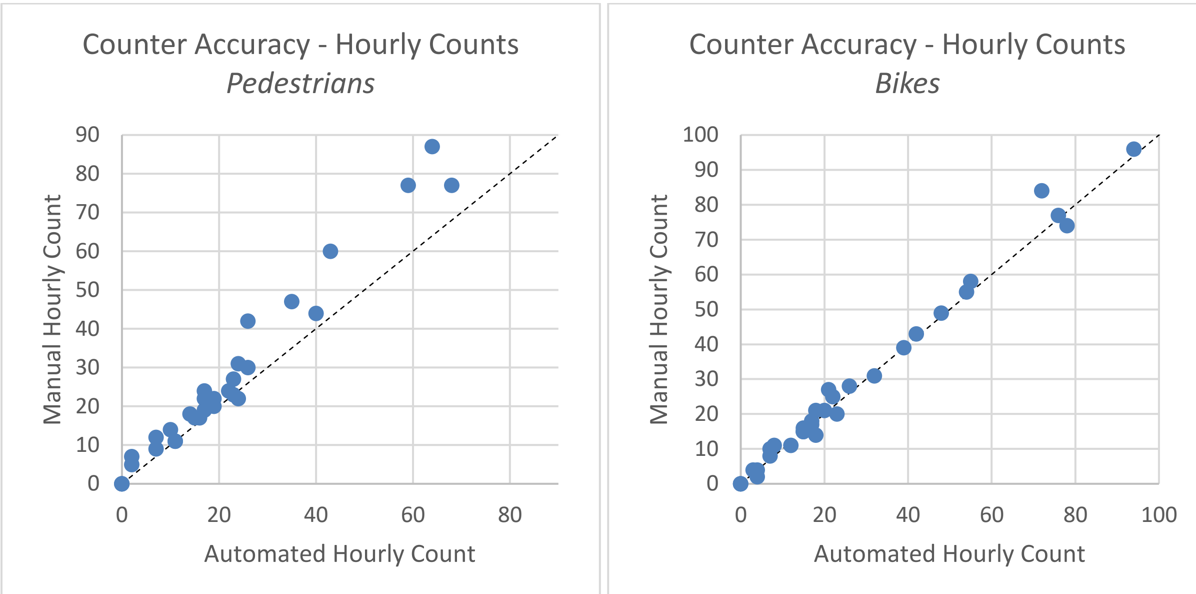
Validation Dates: 05/14/15 06:00-22:00, 05/17/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 0.845 * (Automated\ Hourly\ Count)$$

American Tobacco Trail // Durham, NC

1. Manual vs. Automated Scatter Plots



Pedestrian Validation Dates:
09/05/15 06:00-22:00, 09/03/15 06:00-22:00

Bike Validation Dates:
09/05/15 06:00-22:00, 09/03/15 06:00-22:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian[1]	0.54%	0.53%	19.74%	0.983	32	26.281
Bike[2]	9.00%	0.87%	6.83%	0.994	32	27.906

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00
[2] Validation dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.243	47.20
R^2	0.9863	2227.47
AIC	181.742	--

Validation Dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.243 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.031	75.83
R^2	0.9946	5749.44
AIC	158.291	--

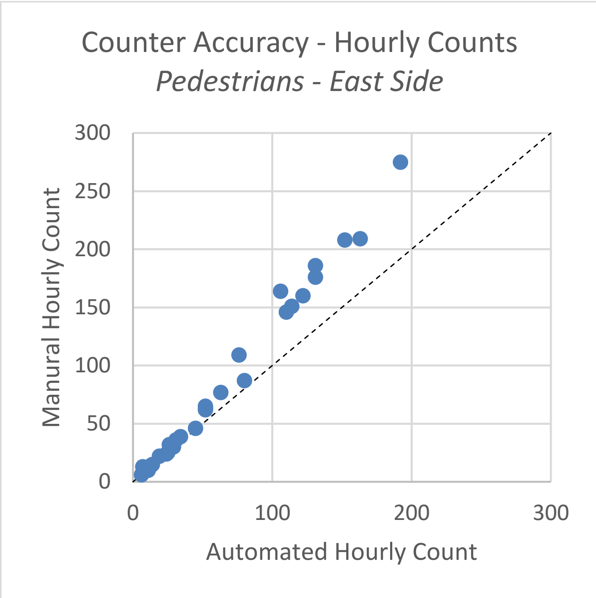
Validation Dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00

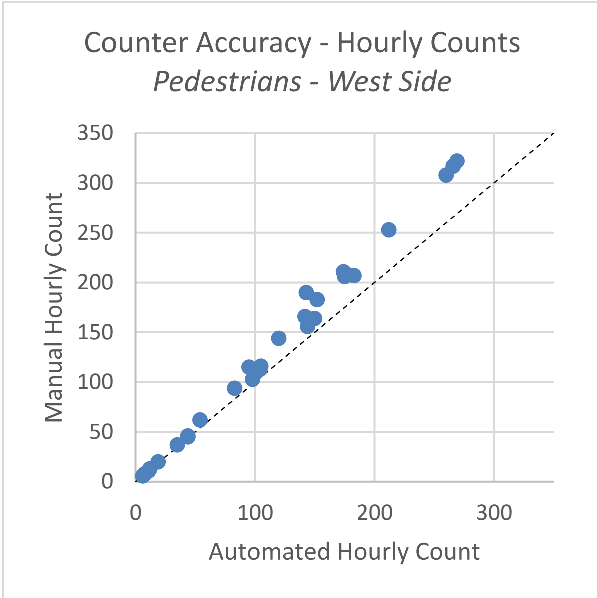
Regression Equation:

$$Corrected\ Hourly\ Count = 1.031 * (Automated\ Hourly\ Count)$$

South Elm Street // Greensboro, NC

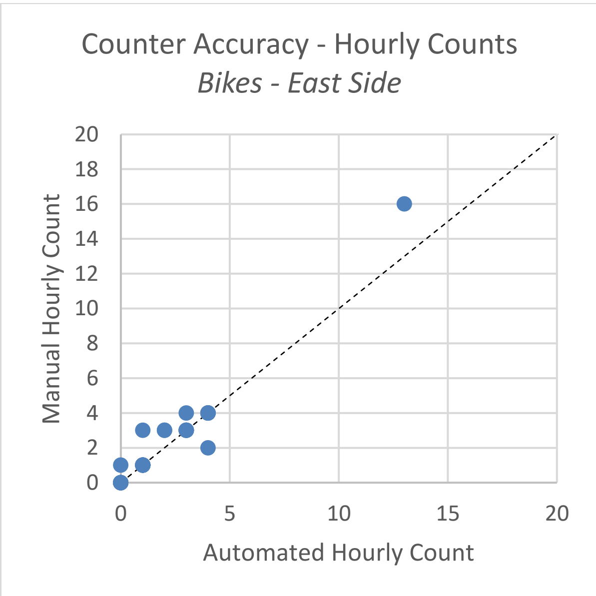
1. Manual vs. Automated Scatter Plots

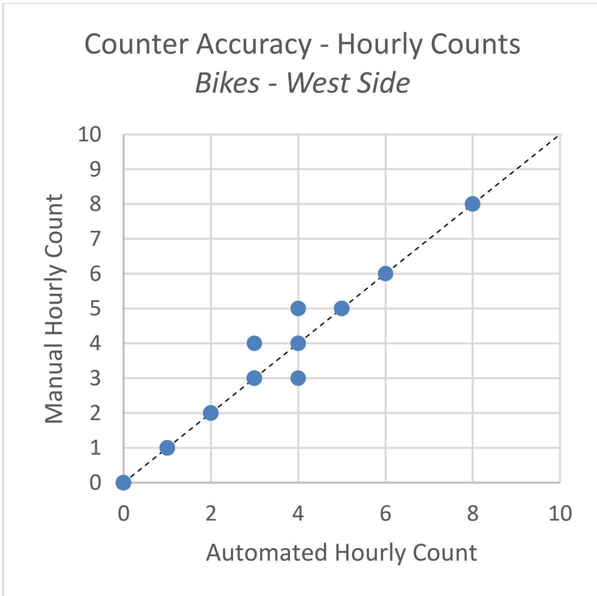




Pedestrian East Side Validation Dates:
12/02/14 06:00-18:00, 05/23/15 06:00-22:00

Pedestrian West Side Validation Dates:
4/21/15 06:00-20:00, 5/23/15 06:00-22:00





Bikes East Side Validation Dates:
12/02/14 06:00-18:00, 05/23/15 06:00-22:00

Bikes West Side Validation Dates:
4/21/15 060:00-20:00, 5/23/15 06:00-22:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian – East Side[1]	0.76%	0.73%	23.35%	0.995	28	87.5
Pedestrian – West Side[2]	1.07%	1.07%	13.99%	0.998	30	131.567
Bike – East Side[3]	2.02%	0.95%	16.42%	0.968	28	2.393
Bike – West Side[4]	10.53%	3.39%	4.65%	0.987	30	2.867

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/02/14 06:00-18:00, 05/23/15 06:00-22:00
[2] Validation dates: 4/21/15 06:00-20:00, 5/23/15 06:00-22:00
[3] Validation dates: 12/02/14 06:00-18:00, 05/23/15 06:00-22:00
[4] Validation dates: 4/21/15 060:00-20:00, 5/23/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.345	66.61
R^2	0.9940	4436.99
AIC	204.240	--

Validation Dates: 12/02/14 06:00-18:00, 05/23/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.345 * (Automated\ Hourly\ Count)$

Pedestrian Hourly Count Regression – West Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.176	121.71
R^2	0.9980	14814.12
AIC	205.252	--

Validation Dates: 04/21/15 06:00-20:00, 05/23/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.176 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.129	25.95
R^2	0.9615	673.63
AIC	65.507	--

Validation Dates: 12/02/14 06:00-18:00, 05/23/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.129 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression – West Side

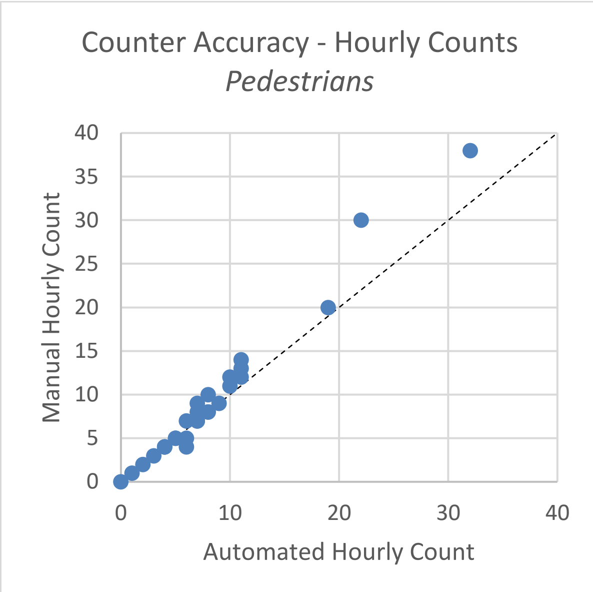
	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.018	54.34
R^2	0.9903	2952.62
AIC	25.706	--

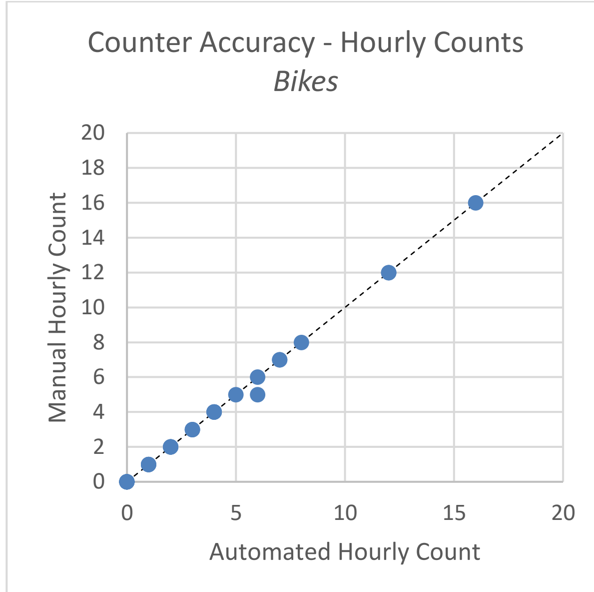
Validation Dates: 04/21/15 06:00-20:00, 05/23/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.018 * (Automated\ Hourly\ Count)$

Lake Daniel Greenway // Greensboro, NC

1. Manual vs. Automated Scatter Plots





Pedestrian Validation Dates:
12/04/14 06:00-18:00, 06/20/15 06:00-22:00

Bike Validation Dates:
12/04/14 06:00-18:00, 06/20/15 06:00-22:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian[1]	3.04%	1.39%	12.69%	0.989	28	9.286
Bike[2]	-17.86%	17.86%	0.90%	0.999	28	3.964

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/04/14 06:00-18:00, 06/20/15 06:00-22:00
[2] Validation dates: 12/04/14 06:00-18:00, 06/20/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.163	46.67
R^2	0.9878	2177.85
AIC	98.962	--

Validation Dates: 12/04/14 06:00-18:00, 06/20/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.163 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.993	158.38
R^2	0.9989	25084.00
AIC	-12.979	--

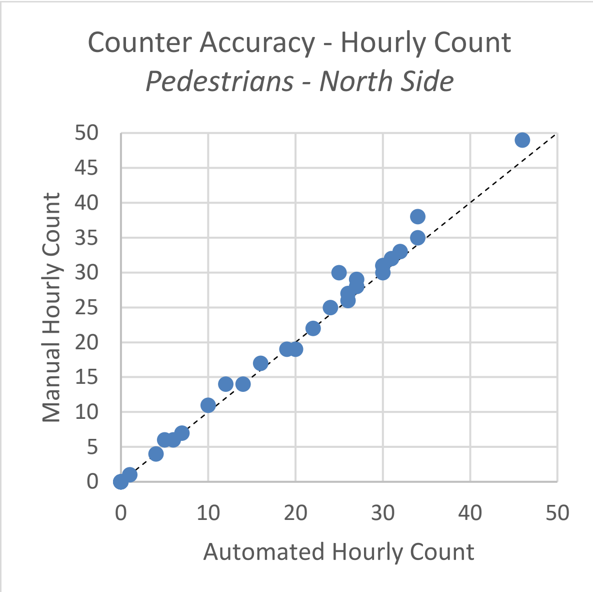
Validation Dates: 12/04/14 06:00-18:00, 06/20/15 06:00-22:00

Regression Equation:

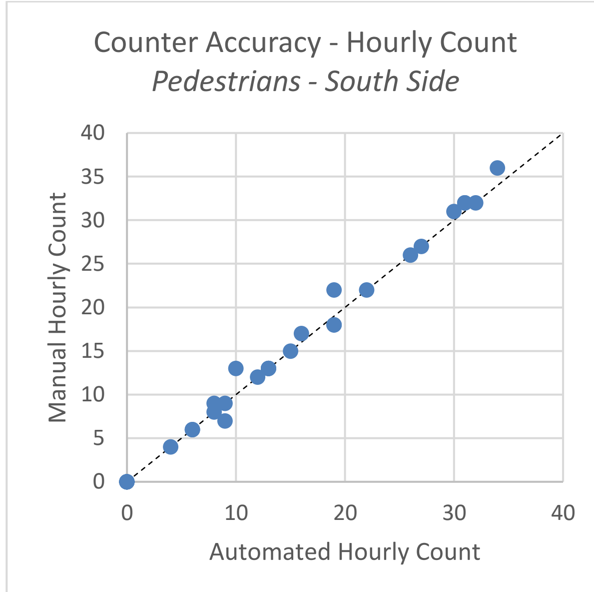
$$Corrected\ Hourly\ Count = 0.993 * (Automated\ Hourly\ Count)$$

Spring Garden Street // Greensboro, NC

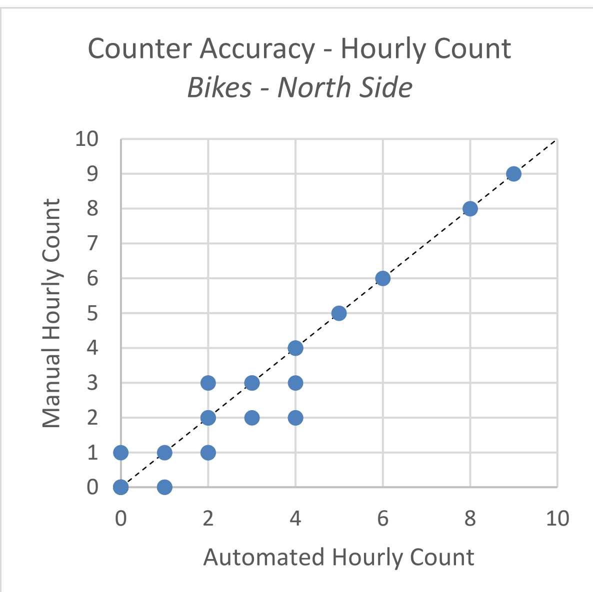
1. Manual vs. Automated Scatter Plots



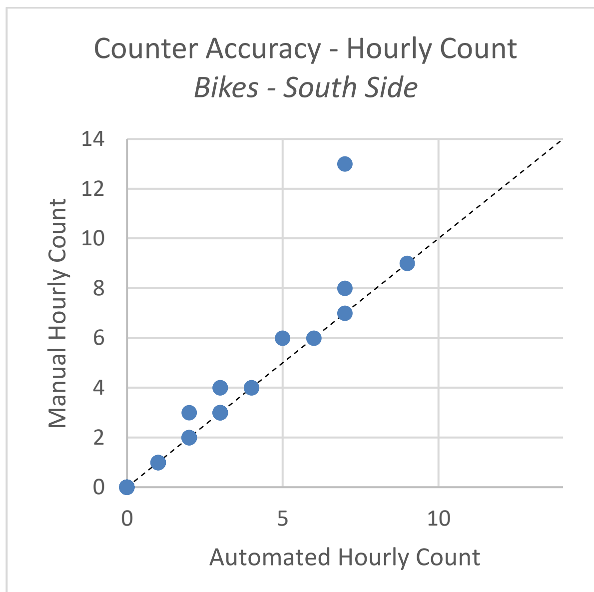
Pedestrian North Side Validation Dates:
12/02/14 06:00-21:00, 04/18/15 06:00-22:00
22:00



Pedestrian South Side Validation Dates:
12/02/14 06:00-21:00, 04/18/15 06:00-
22:00



Bike North Side Validation Dates:
12/02/14 06:00-21:00, 04/18/15 06:00-22:00
22:00



Bike South Side Validation Dates:
12/02/14 06:00-21:00, 04/18/15 06:00-

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian – North Side[1]	3.00%	2.73%	4.79%	0.997	31	18.839
Pedestrian – South Side[2]	11.10%	2.98%	3.85%	0.996	31	14.226
Bike – North Side[3]	-0.59%	0.39%	14.71%	0.959	31	2.194
Bike – South Side[4]	2.03%	2.03%	11.96%	0.945	31	2.968

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00
[2] Validation dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00
[3] Validation dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00
[4] Validation dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression – North Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.048	118.38
R^2	0.9979	14013.79
AIC	94.339	--

Validation Dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.048 * (Automated\ Hourly\ Count)$

Pedestrian Hourly Count Regression – South Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.022	103.28
R^2	0.9972	10667.08
AIC	87.014	--

Validation Dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.022 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression – North Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.924	25.57
R^2	0.9561	653.76
AIC	65.225	--

Validation Dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 0.924 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression –South Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.155	22.57
R^2	0.9444	509.44
AIC	90.338	--

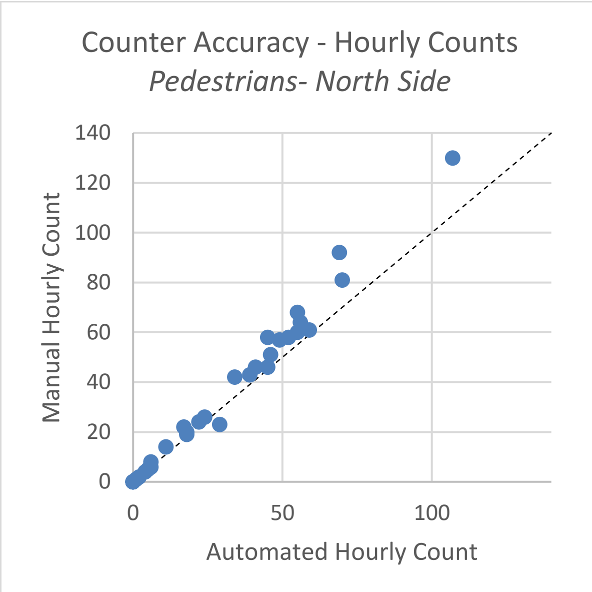
Validation Dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00

Regression Equation:

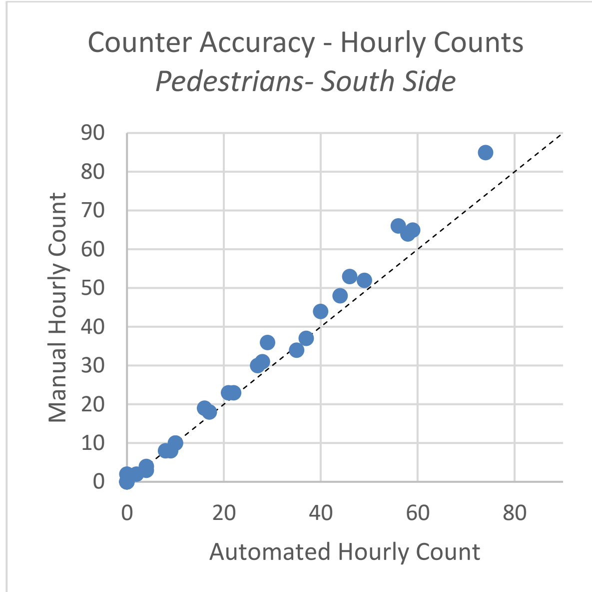
$$Corrected\ Hourly\ Count = 1.155 * (Automated\ Hourly\ Count)$$

Walker Avenue // Greensboro, NC

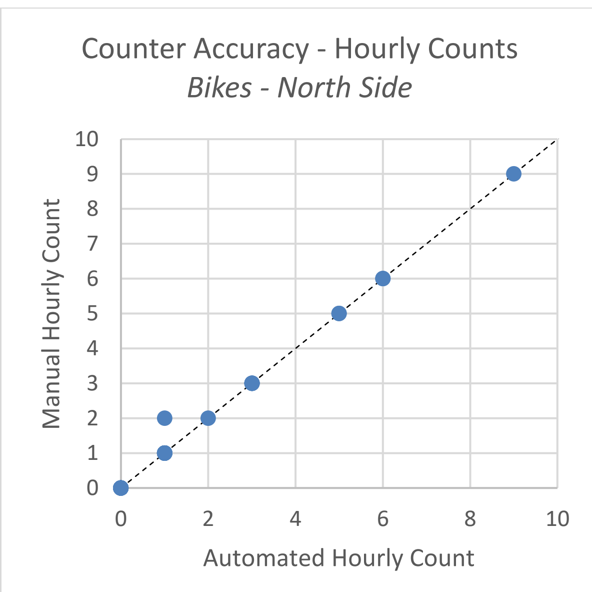
1. Manual vs. Automated Scatter Plots



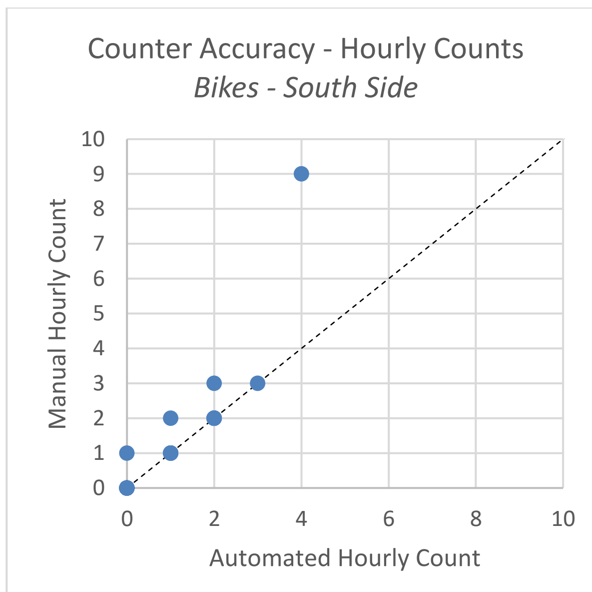
Pedestrian North Side Validation Dates:
04/22/2015 06:00-22:00, 04/18/15 06:00-22:00



Pedestrian South Side Validation Dates:
12/03/15 05:00-20:00, 12/05/15 05:00-20:00



Bikes North Side Validation Dates:
04/22/2015 06:00-22:00, 04/18/15 06:00-22:00



Bikes South Side Validation Dates:
12/03/15 05:00-19:00, 12/05/15 05:00-21:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian – North Side[1]	1.15%	0.96%	13.97%	0.993	32	35.344
Pedestrian – South Side[2]	1.60%	1.09%	9.81%	0.997	30	25.833
Bike – North Side[3]	6.25%	6.25%	1.82%	0.997	32	1.719
Bike South Side[4]	1.40%	1.40%	23.53%	0.895	30	1.133

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 04/22/2015 06:00-22:00, 04/18/15 06:00-22:00
[2] Validation dates: 12/03/15 05:00-20:00, 12/05/15 05:00-20:00
[3] Validation dates: 04/22/2015 06:00-22:00, 04/18/15 06:00-22:00
[4] Validation dates: 12/03/15 05:00-19:00, 12/05/15 05:00-21:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression – North Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.165	66.82
R^2	0.9931	4465.09
AIC	180.439	--

Validation Dates: 04/22/2015 06:00-22:00, 04/18/15 06:00-22:00

Regression Equation:
$$Corrected\ Hourly\ Count = 1.165 * (Automated\ Hourly\ Count)$$

Pedestrian Hourly Count Regression – South Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.110	101.00
R^2	0.9972	10200.94
AIC	125.043	--

Validation Dates: 12/03/15 05:00-20:00, 12/05/15 05:00-20:00

Regression Equation:
$$Corrected\ Hourly\ Count = 1.110 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – North Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.004	88.91
R^2	0.9960	7905.49
AIC	-18.219	--

Validation Dates: 04/22/2015 06:00-22:00, 04/18/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.004 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – South Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.397	13.18
R^2	0.8570	173.76
AIC	73.242	--

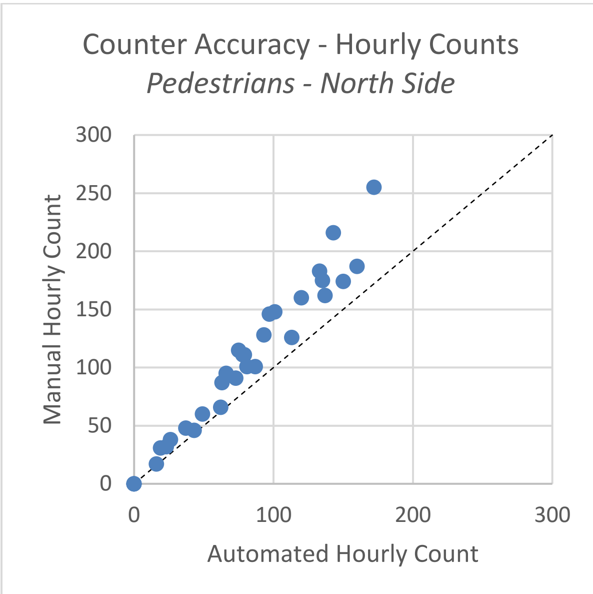
Validation Dates: 12/03/15 05:00-19:00, 12/05/15 05:00-21:00

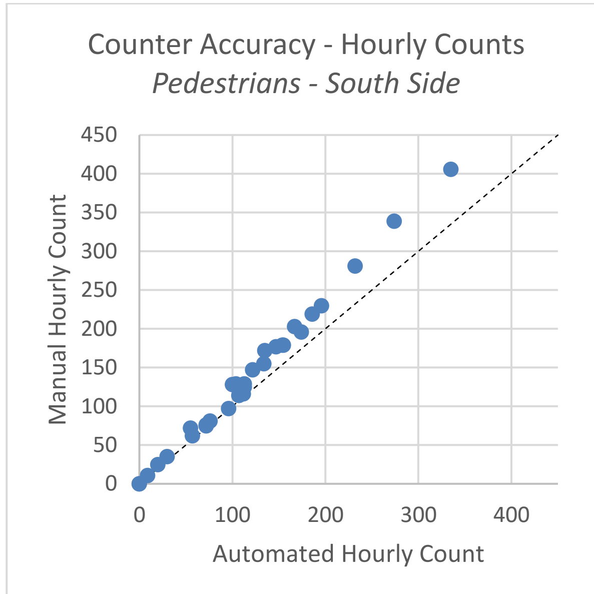
Regression Equation:

$$Corrected\ Hourly\ Count = 1.397 * (Automated\ Hourly\ Count)$$

West 4th Street // Winston Salem, NC

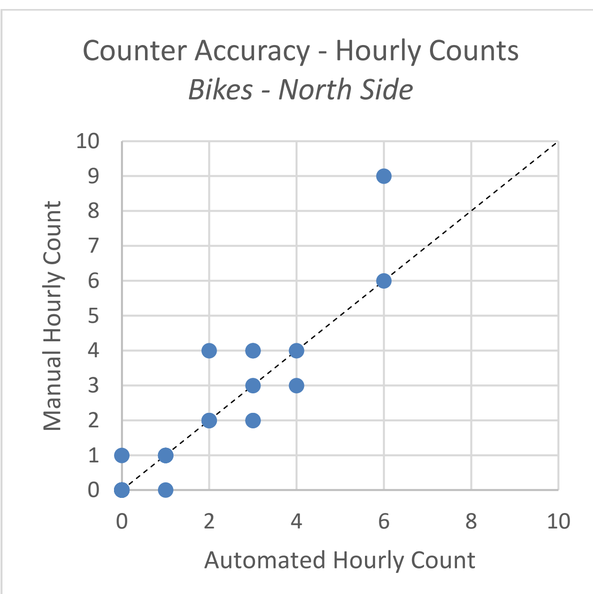
1. Manual vs. Automated Scatter Plots

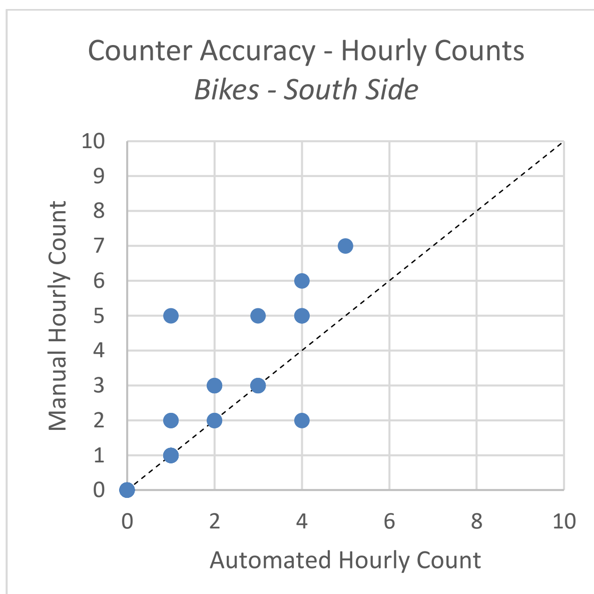




Pedestrian North Side Validation Dates: 06/27/15 06:00-22:00, 11/12/14 06:00-21:00 22:00

Pedestrian South Side Validation Dates: 08/26/15 06:00-20:00, 08/30/15 06:00-





Bike North Side Validation Dates: 11/12/14 06:00-18:00, 06/27/15 06:00-22:00 22:00

Bike South Side Validation Dates: 08/26/15 06:00-20:00, 08/30/15 06:00-

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian – North Side[1]	0.50%	0.50%	24.27%	0.980	31	103.548
Pedestrian – South Side[2]	0.87%	0.87%	14.69%	0.997	30	138.6
Bike – North Side[3]	0%	0.77%	21.15%	0.926	28	1.857
Bike – South Side[4]	1.04%	0.64%	27.54%	0.858	30	2.3

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 06/27/15 06:00-22:00, 11/12/14 06:00-21:00
[2] Validation dates: 08/26/15 06:00-20:00, 08/30/15 06:00-22:00
[3] Validation dates: 11/12/14 06:00-18:00, 06/27/15 06:00-22:00
[4] Validation dates: 08/26/15 06:00-20:00, 08/30/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression – North Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.320	50.84
R^2	0.9885	2584.28
AIC	249.743	--

Validation Dates: 11/12/14 06:00-21:00, 06/27/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.320 * (Automated\ Hourly\ Count)$$

Pedestrian Hourly Count Regression – South Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.186	110.99
R^2	0.9977	12319.84
AIC	212.7125	--

Validation Dates: 08/26/115 06:00-20:00, 08/30/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.186 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – North Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.1	17.42
R^2	0.9183	303.49
AIC	69.552	--

Validation Dates: 11/12/14 06:00-18:00, 06/27/15 06:00-22:00

Regression Equation:

$$Corrected\ Hourly\ Count = 1.1 * (Automated\ Hourly\ Count)$$

Bike Hourly Count Regression – South Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.222	15.05
R^2	0.8864	226.39
AIC	88.120	--

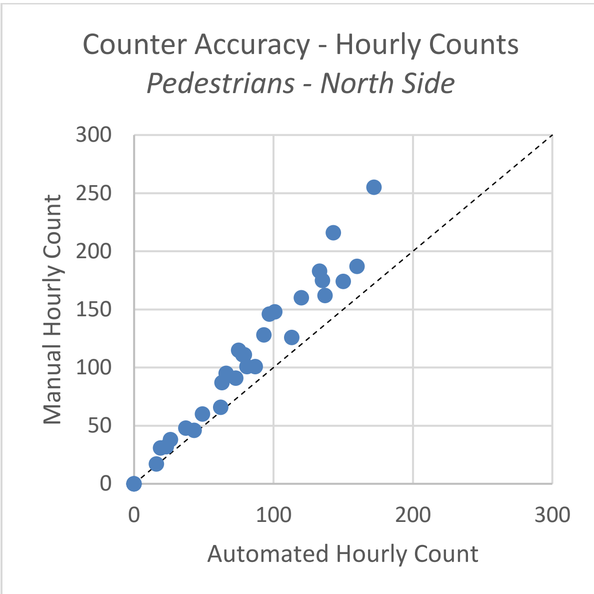
Validation Dates: 08/26/115 06:00-20:00, 08/30/15 06:00-22:00

Regression Equation:

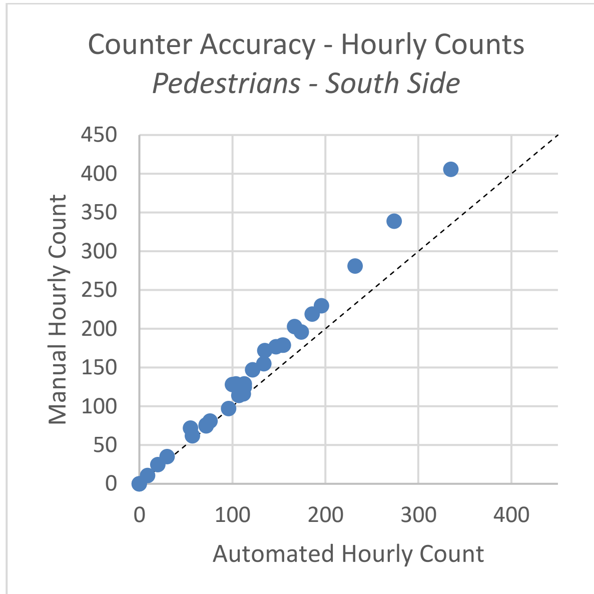
$$Corrected\ Hourly\ Count = 1.222 * (Automated\ Hourly\ Count)$$

Academy Street // Winston Salem, NC

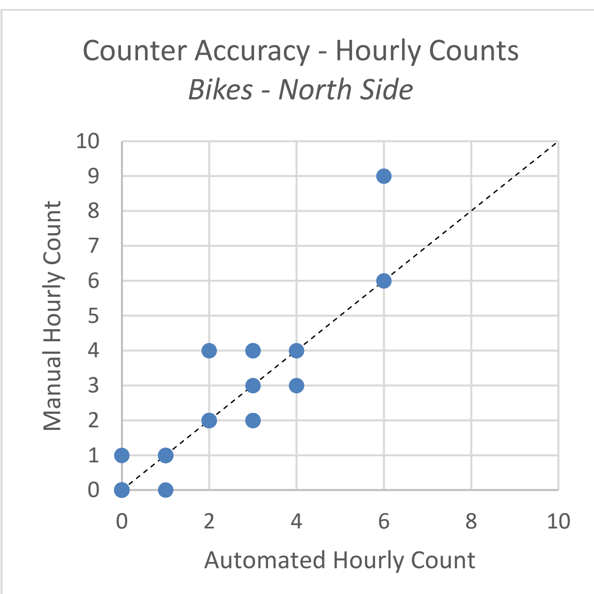
1. Manual vs. Automated Scatter Plots



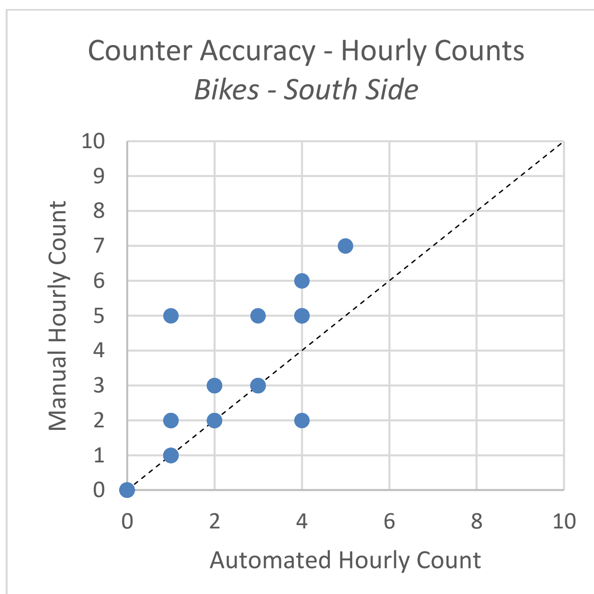
Pedestrian North Side Validation Dates:
06/27/15 06:00-22:00, 11/12/14 06:00-21:00
22:00



Pedestrian South Side Validation Dates:
08/26/15 06:00-20:00, 08/30/15 06:00-



Bike North Side Validation Dates:
11/12/14 06:00-18:00, 06/27/15 06:00-22:00
22:00



Bike South Side Validation Dates:
08/26/15 06:00-20:00, 08/30/15 06:00-

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Bike – Eastbound[1]	-0.78%	0.78%	0.00%	0.771	32	0.156
Bike – Westbound[2]	1.56%	1.56%	100.00%	#DIV/0!	32	0.094

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00
[2] Validation dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Bike Hourly Count Regression – Eastbound

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.636	7.37
R^2	0.636	54.25
AIC	11.806	--

Validation Dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 0.636 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression – Westbound – All Variables Omitted Due to Collinearity

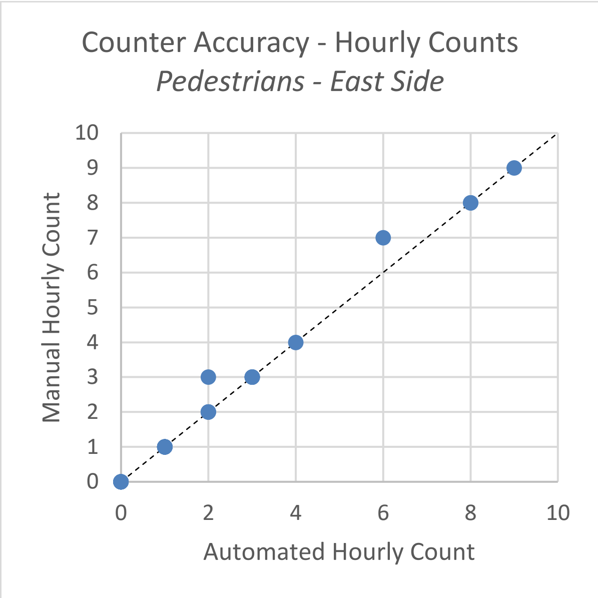
	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0	--
R^2	0.0	0.0
AIC	31.411	--

Validation Dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00

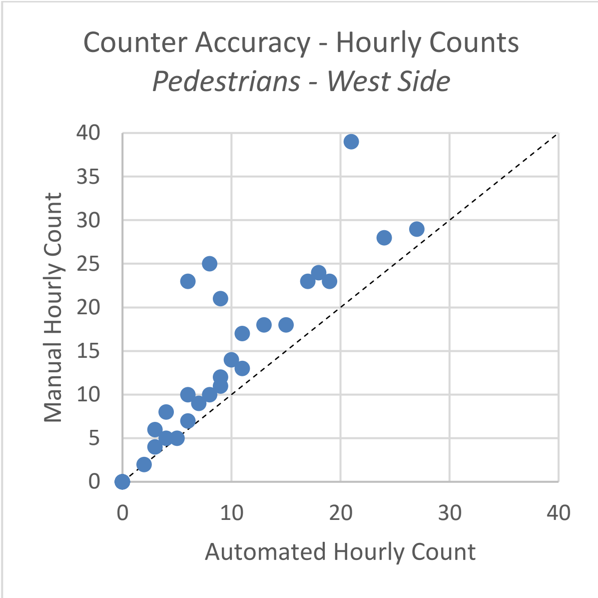
Regression Equation:
$Corrected\ Hourly\ Count = 0 * (Automated\ Hourly\ Count)$

West End Boulevard // Winston Salem, NC

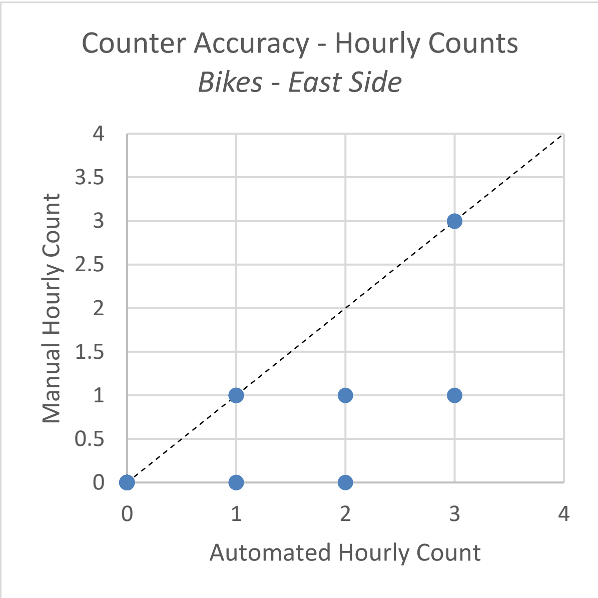
1. Manual vs. Automated Scatter Plots



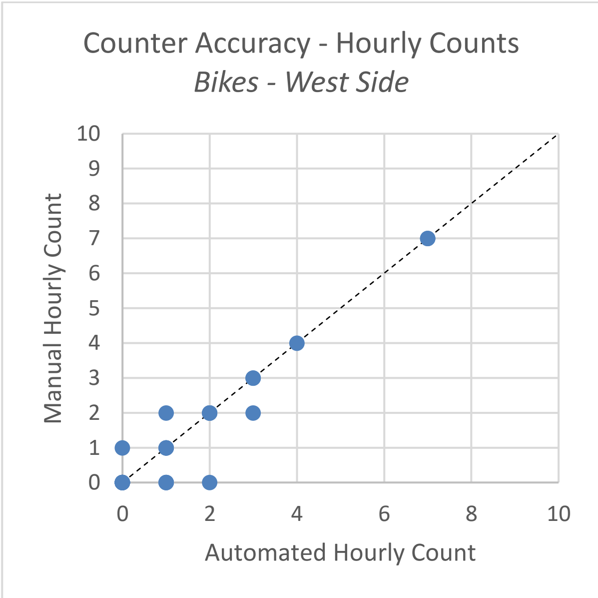
Pedestrian East Side Validation Dates:
12/03/15 06:00-20:00, 12/05/15 05:00-19:00
22:00



Pedestrian West Side Validation Dates:
12/02/14 06:00-21:00, 04/18/15 06:00-



Bike East Side Validation Dates:
12/03/15 06:00-19:00, 12/05/15 06:00-22:00
22:00



Bike West Side Validation Dates:
12/02/14 06:00-18:00, 04/18/15 06:00-

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian – East Side[1]	7.50%	7.50%	3.13%	0.995	28	2.286
Pedestrian – West Side[2]	0.43%	0.43%	31.93%	0.887	31	13.032
Bike – East Side[3]	-0.49%	0.49%	27.27%	0.823	29	0.379
Bike – West Side[4]	-0.96%	0.55%	7.89%	0.952	26	1.462

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/03/15 06:00-20:00, 12/05/15 05:00-19:00
[2] Validation dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00
[3] Validation dates: 12/03/15 06:00-19:00, 12/05/15 06:00-22:00
[4] Validation dates: 12/02/14 06:00-18:00, 04/18/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.025	70.45
R^2	0.9946	4963.6
AIC	4.557	--

Validation Dates: 12/03/15 06:00-20:00, 12/05/15 05:00-19:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.025 * (Automated\ Hourly\ Count)$

Pedestrian Hourly Count Regression – West Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.378	17.81
R^2	0.914	317.37
AIC	187.866	--

Validation Dates: 12/02/14 06:00-21:00, 04/18/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.378 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression – East Side

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.65	8.81
R^2	0.7348	77.57
AIC	39.087	--

Validation Dates: 12/03/15 06:00-19:00, 12/05/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 0.65 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression – West Side

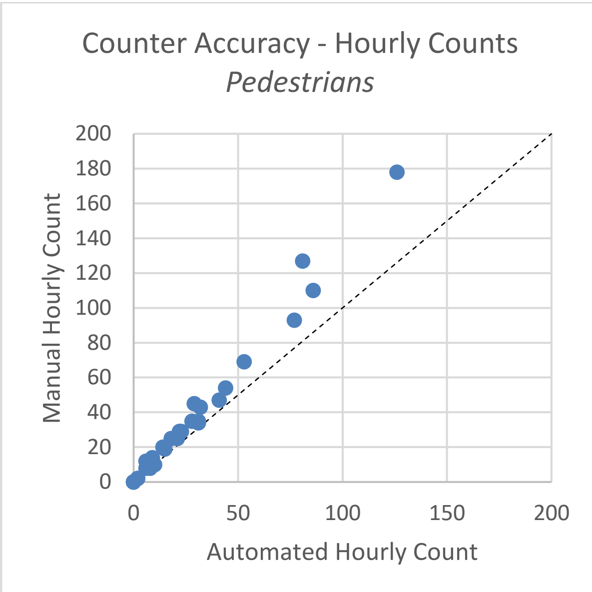
	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.945	19.63
R^2	0.9391	385.26
AIC	49.625	--

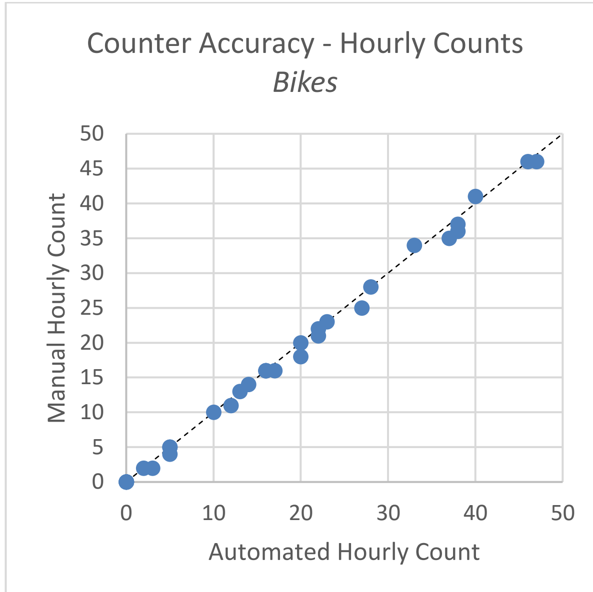
Validation Dates: 12/02/14 06:00-18:00, 04/18/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 0.945 * (Automated\ Hourly\ Count)$

Salem Lake Greenway // Winston Salem, NC

1. Manual vs. Automated Scatter Plots





Pedestrian Validation Dates:
09/05/15 06:00-22:00, 09/03/15 06:00-22:00

Bike Validation Dates:
09/05/15 06:00-22:00, 09/03/15 06:00-22:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian[1]	0.54%	0.54%	24.02%	0.992	32	35.125
Bike[2]	-2.50%	2.30%	3.02%	0.999	32	17.5625

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00
[2] Validation dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression

	Model Parameters	**t-statistic or F-statistic**
Automated Hourly Count Coefficient	1.346	57.53
R^2	0.9907	3309.67
AIC	197.645	--

Validation Dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.346 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression

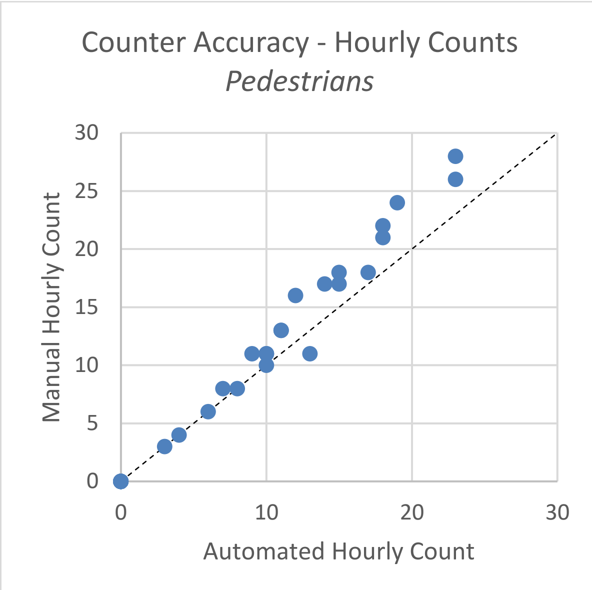
	Model Parameters	**t-statistic or F-statistic**
Automated Hourly Count Coefficient	0.981	162.18
R^2	0.9988	26302.57
AIC	76.308	--

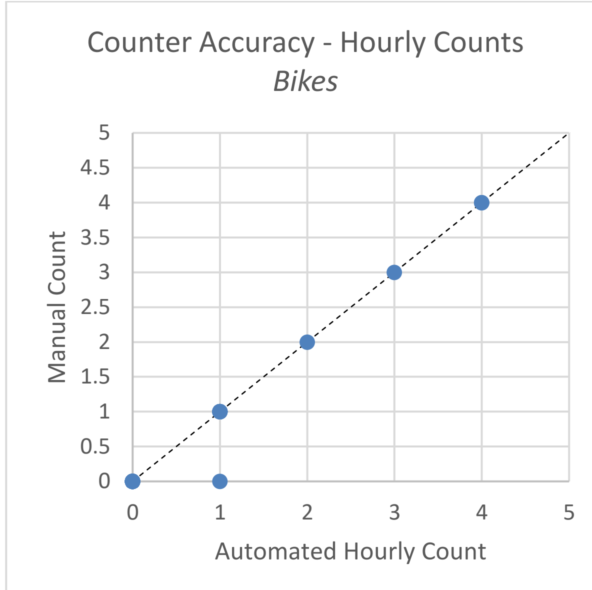
Validation Dates: 09/05/15 06:00-22:00, 09/03/15 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 0.981 * (Automated\ Hourly\ Count)$

Strollway at Academy // Winston Salem, NC

1. Manual vs. Automated Scatter Plots





Pedestrian Validation Dates:
12/09/14 06:00-22:00, 12/07/14 06:00-22:00

Bike Validation Dates:
12/09/14 06:00-22:00, 12/07/14 06:00-22:00

2. ERROR CALCULATION – HOURLY COUNTS

Counter	APD	AAPD	WAPD	*r*	N	Average Hourly Volume
Pedestrian [1]	1.42%	1.22%	13.92%	0.992	32	9.875
Bike[2]	-3.13%	3.13%	0.00%	0.988	32	0.625

APD: Average Percent Difference // **AAPD**: Average Absolute Percent Difference // **WAPD**: Weighted Average Percent Difference // ***r***: Pearson's Correlation Coefficient // **N**: number of hourly time points

[1] Validation dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00
[2] Validation dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00

3. REGRESSION MODELS FOR HOURLY COUNTS

Pedestrian Hourly Count Regression

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	1.158	66.00
R^2	0.9929	4355.38
AIC	99.349	--

Validation Dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 1.158 * (Automated\ Hourly\ Count)$

Bike Hourly Count Regression

	Model Parameters	t-statistic or F-statistic
Automated Hourly Count Coefficient	0.981	40.15
R^2	0.9811	1612.00
AIC	-18.701	--

Validation Dates: 12/09/14 06:00-22:00, 12/07/14 06:00-22:00

Regression Equation:
$Corrected\ Hourly\ Count = 0.981 * (Automated\ Hourly\ Count)$

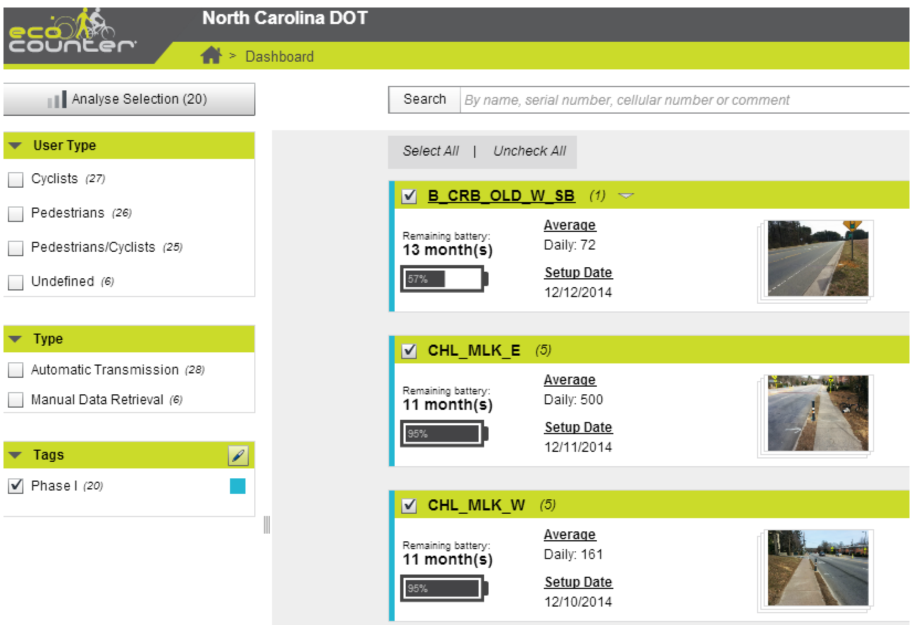
Appendix J. Detailed QA/QC Workbook Workflow

In Phase 1 of the NC NMVDP, protocols were set up to inspect and clean data on a quarterly basis. The following information details the workflow of the QA/QC workbook to go from a raw dataset to cleaned dataset.

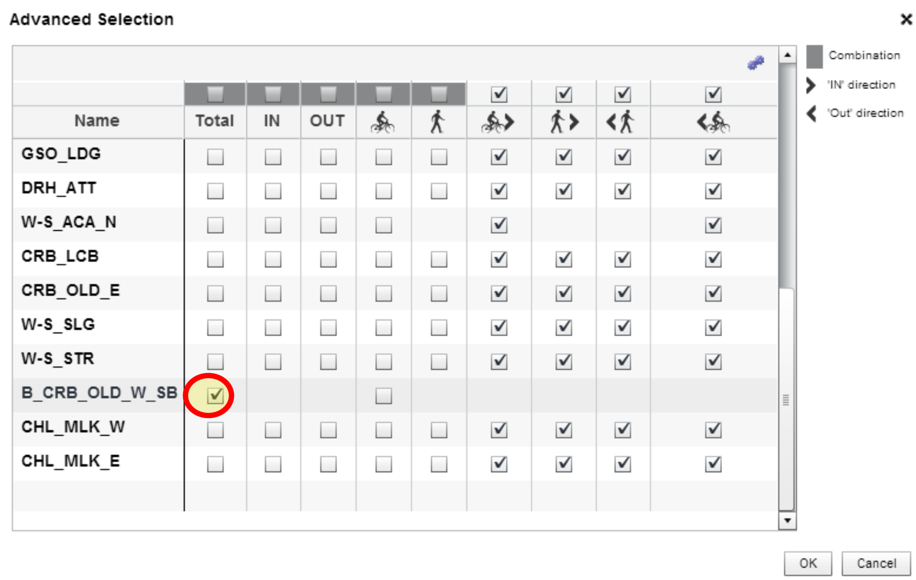
Downloading Raw Data

Raw data for the time period is downloaded in a batch from Eco-Visio to be transferred into the workbook. The raw data is temporarily stored in a spreadsheet where modifications are made to match the template set up in the QA/QC workbook.

Download raw data from Eco-Visio by selecting all the CCS Counters. It is easiest to do this by selecting loggers by their tag (i.e., “Phase 1”) and then choosing “Select All.” Then click the “Analyze Selection” button in the upper left-hand corner. If setting up QA/QC for the first time, batch the loggers by giving them a relevant tag so they can be found quickly.



Next indicate the attributes. Choose “Advanced.” Use the following guidance to select data by direction for all sites, except for bicycle only sites. No directional attribute is given for bicycle only sites (e.g., B_CRB_OLD_W_SB), it is inferred from logger placement so data is downloaded from the total category. An example of how to download data is shown in the figure below.



Next indicate the date range under the "Period" section. Choose the start date and end date for the quarter's data download.

Select a "Classic Spreadsheet." Export as .xlsx and save the file in the "Raw Data" folder.

Preparing Data for the Workbook

Prior to adding data to the workbook, it needs to be prepared to match the format in the QA/QC workbook. First, the sites must be alphabetized from left to right. Second, the columns need to be formatted to match those in the workbook. Remove "NULL" placeholder columns and ensure all columns are in the raw data by checking them against those in the QA/QC Workbook. Add a blank column for Column. The blank column will later be used to populate date information.

Adding Raw Data to the Workbook

Save previous version of QA/QC workbook as a new file for the incoming data using a label that indicates how many quarters of data the workbook contains. As data workbook checks are continually being updated, especially in the beginning, it is also important to indicate which version of the workbook formulas the workbook contains.

Raw data is added to the new workbook in the "RAW_HR" tab of the QA/QC workbook, corresponding with each data logger, for the interval being checked. The data is added at the bottom of the rows. A "Date" field has been added to this tab due to a check's inability to decipher the "Date_Time" field from the raw data download. The "Date" field is updated for all rows when any new data is added to the workbook.

Depending on the type of check, the data may be scanned at an hourly or daily interval. The data is downloaded in hourly interval and transformed to daily interval using a PivotTable in the "RAW_DAY" tab of the QA/QC workbook. The "RAW_HR" tab and "RAW_DAY" tab should remain unmodified as this is the data which the other tabs use to perform the checks.

Downloading Climate Data

Weather data is included when new data is added to the workbook for the Range Check. Climate data should be added before updating any of the checks so all checks will function when data is refreshed. Each data logger is associated with the nearest airport weather station. Airport stations were chosen because they are most likely to have the weather data products desired for the program and be updated on a timely basis with fewer missing data records. Requests are received by the National Oceanic and Atmospheric Administration (NOAA) (www.ncdc.noaa.gov/cdo-web/search) and may take several hours to process. An email is returned once a data request has been processed and is available to download.

The following weather data is stored in the "NOAA" tab of the workbook by day of year according to station:

- Precipitation (PRCP)
- Air Temperature (TMAX)

NC NMVDP Phase 1 Weather Stations:

- GHCND:USW00093807 - WINSTON SALEM REYNOLDS AIRPORT, NC US
- GHCND:USW00013723 - GREENSBORO PIEDMONT TRIAD INTERNATIONAL AIRPORT, NC US
- GHCND:USW00013722 - RALEIGH DURHAM INTERNATIONAL AIRPORT, NC US

REQUESTED DATA REVIEW	
Dataset	Daily Summaries
Order Start Date	2015-06-01 00:00
Order End Date	2015-08-30 23:59
Output Format	Custom GHCN-Daily CSV
Data Types	PRCP, TMAX
Stations/Locations	RALEIGH DURHAM INTERNATIONAL AIRPORT, NC US (Station ID: GHCND:USW00013722) WINSTON SALEM REYNOLDS AIRPORT, NC US (Station ID: GHCND:USW00093807) GREENSBORO PIEDMONT TRIAD INTERNATIONAL AIRPORT, NC US (Station ID: GHCND:USW00013723)

Adding NOAA Data to the Workbook

When the data is ready for download an email with a download link will be sent to the email address you provide. Click the link and download the file (.csv).

Carefully check to ensure all rows contain data (no blank cells) and has data for every date in the quarter that data is being downloaded for. Please note that when there is no data for a date, the date does not appear as a row, so look at the dates to ensure they are all present. Substitute data from a trusted online weather source was provided for PRCP and TMAX for dates that were missing since there appeared to be some lag in availability of data – approximately 4-5 days for some stations.

The file will have the data for all stations in a single column. Copy and paste the appropriate data into the "NOAA" tab of the workbook, taking care to copy the appropriate "chunks" of data by station and date. Drag down the formulas for PRCP, TMAX, etc.

Drag down the rows with the date and days of the week that are to the right of the weather data until you reach the date at the end of the quarter for which the data is being checked.

Updating Workbook Tabs

PivotTables in the QA/QC workbook need to be refreshed to account for the new data in the workbook. Click on any PivotTable report, and use the "Refresh" button arrow, and then click "Refresh All" in the PivotTable tools. Note: If any changes to QA/QC formulas or tolerances need to be made prior to running the checks, it must be done before updating the workbook tabs. Next, drag down all cells with formulas in them in the "RANGE" tab until you reach the date at the end of the last day of the dataset.

Drag down all cells with formulas in each site tab (i.e., CHL_MLK, CRB_LCG) until reaching the date at the end of the quarter for which the data is being checked. If the last day's data is INVALID, you will need to copy the formula from a previous cell which is VALID and contains the correct formula. Cell formatting and column widths should be set to be preserved upon updating.

Appendix K. Phase 1 Continuous Count Station Overview and Data Summary

Data summaries of twelve Phase 1 CCSs are based on the count data, with days of missing data and data related to equipment errors removed. Based on the validation process, the corrected data are represented in tables and graphs within this appendix. Information given in the narrative for each station is based on interpretation of the data and cursory research on special events. Local agencies may have more information related to daily data outliers or trends.

To view the full Overview and Data Summary document for Phase 1 and published reports of scrubbed, corrected data from the NC NMVDP, please visit https://itre.ncsu.edu/focus/bike-ped/nc-nmvdp/.